MEMORANDUM

State of Alaska
Department of Transportation & Public Facilities

TO: Regional Directors and
All holders of the Roofing
Standards Manual

DATE: May 5, 1986

FILE NO:

TELEPHONE NO: 465-2951

FROM: John J. Simpson, Director
Engineering and Operations
Standards Division

SUBJECT: ROOFING STANDARDS MANUAL
TRANSMITTAL NO. 1-86

Upon receipt of this transmittal and the enclosed Roofing Standards Manual, you are instructed to implement, insofar as possible, the use of the Manual in the design, inspection and maintenance of all new and existing roof systems on buildings owned or operated by the State of Alaska.

The Manual consists of ten major subdivisions with applicability to nearly every aspect of roofing technology. The Manual is intended as a guide for the procedures and techniques to be used in the development and maintenance of roofing systems. Although primarily intended for use by private architects and/or engineers doing design work for the Department, the Manual is also appropriate for building managers and maintenance personnel. Aside from design considerations the Manual also covers maintenance requirements, roof investigation and testing procedures and construction inspection techniques.

Elements of Sections 3.9.3, Design Illustrations, and 5.5, Appendix - Master Specifications, are incomplete at this time. However, it is hoped that budgetary constraints will permit the completion of these items in the fall of 1986. In addition, this Manual will be periodically updated to reflect industry changes or necessary modifications. All Manual holders are encouraged to utilize the Comment Form located near the front of the publication to express their comments. Finalized copies of these sections will be distributed to all Manual holders as they become available.

Enclosure

TABLE OF CONTENTS

ROOFING STANDARDS MANUAL

DEPARTMENT OF TRANSPORTATION AND PUBLIC FACILITIES
STATE OF ALASKA

NOTE: An expanded Table of Contents appears at the beginning of each Section.

COMMENT FORM

for

ROOFING STANDARDS MANUAL
DEPARTMENT OF TRANSPORTATION AND PUBLIC FACILITIES
STATE OF ALASKA

RECOMMENDATION FROM:	MAIL TO:
NAME: ______________________	STATE OF ALASKA DOT/PF
FIRM: ______________________	ENGINEERING AND OPERATIONS STANDARDS DIVISION
MAILING ADDRESS: ______________________ ______________________	ATTN: ROD WILSON, ARCHITECT FOR BUILDING CRITERIA P.O. BOX Z (MS 2500) JUNEAU, AK 99811
PHONE:	PHONE: (907) 465-2960

RECOMMENDED CHANGE ______	REFERENCE:
RECOMMENDED ADDITION ______	SECTION ______________________
RECOMMENDED DELETION ______	PAGE ______________________

GIVE RECOMMENDATION AND REASONS WHY RECOMMENDATION IS VALID. PROVIDE PERTINENT INFORMATION TO SUPPORT RECOMMENDATION.

1. INTRODUCTION

1. INTRODUCTION

1.1 Purpose of the Roofing Standards Manual

Numerous roofing problems have been experienced on buildings owned by the State of Alaska. The monetary loss, inconvenience, and hazards presented to state employees and the public have been significant.

In an attempt to mitigate problems related to roofing in Alaska, this manual was prepared. It primarily focuses on **roof design**. However, it addresses issues related and useful to **DOT/PF Project Managers**, **Contractors**, **Roofers**, and **Building Maintenance**.

This manual distills the salient issues found in the vast array of roofing technology literature. It also presents the experience and expertise of many people that have practiced in the State of Alaska.

In the future, it is hoped that research can be conducted on issues that are somewhat unique to Alaska.

1.2 Roofing Problems

Roofing problems are not unique to Alaska. They are prevalent throughout the United States and Canada.

For decades roofing problems have been a major source of construction problems. A 1984 **GUIDELINES** document states "roofing amounts to 3% to 4% of construction costs and is the source of nearly half of the claims and lawsuits".

In numerous instances changes in practice or materials have historically resulted in problems. Unfortunately, the roofing industry (material manufacturers, designers, applicators, maintenance personnel) often has been unable to foresee the ramifications of the changes. For example:

- Decades ago, the introduction of steel decks led to problems because of their flexibility and lack of resistance to air flow. The 1953 General Motors fire in Livonia, Michigan, further illustrated problems with steel decks. That fire brought about further changes which, in turn, created new problems.

  By following recommended practices and Factory Mutual (FM) 1984 documents, steel decks may be used with confidence. However, this has taken decades.

- In the mid 1960's application of elasto/plastic ("single-ply") membranes began in the United States. Many of these failed prematurely. The roof systems did not gain widespread popularity until the 1980's.

- The Energy Crisis of the early 1970's brought dramatic changes. Rapid revisions occurred with insulation. Traditional roof insulation materials gave way to plastic foams and thermal resistance values increased by 100%. Asphalt quality also declined. Ultimately, the industry learned how to resolve these problems.

- In the 1980's the elasto/plastic membranes re-emerged with vigor. Unlike the 1960's, many manufacturer's now have a better understanding of the service conditions under which the membrane must perform and there is less likelihood of improper formulations. Also, designers and roofers are more knowledgeable of these membranes and now there is a significant amount of literature related to them.

  However, there are many relatively new elasto/plastic membranes and membrane manufacturers. Many of the products have not been proven over a long time in environments similar to Alaska. Also many designers and contractors have limited experience with these membranes.

  Perhaps the greatest concern regarding premature roof failure during the next several years relates to elasto/plastic membranes. Particular care must be exercised to mitigate problems.

In addition to problems created by changes, many problems are related to cost and design. Since the roof is often not in sight, it commonly suffers from an insufficient budget (both construction and maintenance). Designers often lack knowledge, and/or experience, or devote too little attention to roof design. Inadequate budget or design may result in premature failure.

1.2.1 Problems with Roofing in Alaska

Because of the state's vast size and great variety of climatic conditions, **the challenge of roofing in this state is great.**

While Alaska does not experience the hot temperatures of Southern California, it does enjoy some relatively hot weather in the Interior. And while Minnesota gets cold, it isn't subjected to the long, frigid winter seen at the North Slope. Boston's multiple freeze-thaw cycles are similarly experienced on the Aleutian Chain and in Southeast Alaska. And Adak's winds have few rivals.

Being familiar with weather conditions and responding accordingly (during application and service) is of great importance. Unfortunately, the state's size and variety of conditions makes this very difficult for designers and roofers.

Logistics is a significant factor for many projects. Limited or non-existent transport facilities and/or equipment precludes many roofing systems.

Remoteness is also a significant problem. The technical support received from manufacturer's representatives is limited.

The projects in the remote parts of the state generally receive only limited field time during design (i.e.: reroofing projects), and limited field quality control.

1.3 CHANGE

The roofing industry has been very dynamic in the past several years. This trend is expected to continue.

Hopefully, the state will issue periodic amendments to this manual so it remains current. However, it is still incumbent upon the users of this manual to stay abreast of changes in the industry (both within the State of Alaska, as well as the United States). An excellent way to stay current is to read the periodicals listed in Section 2, and attend seminars sponsored by the Roofing Industry Educational Institute, and read the RIEI **Information Letter**.

Although this manual is relatively up-to-date at the time of printing, it does not incorporate any new information that was presented at the Second International Symposium on Roofing Technology (September 1985). Also the 1982 Edition of the Uniform Building Code is referenced, however, the 1985 Edition will likely be adopted by the state in 1986.

Staying current in the field of roofing is a formidable task.

1.4 STANDARD OF CARE

Liability is generally based upon the "standard of care" principle. This principle relates to conduct that is reasonably and normally expected by someone working in this area under similar circumstances. "Reasonably and normally" means the degree of care and skill commonly exercised by others in this field of work.

The **ROOFING STANDARDS MANUAL** raises the expectation level of care and skill for roofing work in the State of Alaska. **It is incumbent upon designers and contractors to study and comply with the applicable portions of this manual.**

1.5 INTENT

It is the State of Alaska's intent to maximize the effectiveness of money spent on construction and maintenance of roofs on state buildings. Accordingly, this manual presents many recommendations and, to a limited extent, it presents mandatory requirements.

Within the context of this manual, "shall" is a mandatory requirement, while "should" is a recommendation.

Unique circumstances may invalidate a specific recommendation or requirement. The user of the manual is cautioned to use good judgement and document the basis for non-compliance.

Deviation from a mandatory requirement must be approved by the DOT/PF Project Manager in cooperation with the DOT/PF Engineering and Operations Standards Division's Architect for Building Criteria.

It is not the State's intent to limit the types of materials, system or detail design, application means and methods, or maintenance procedures. However, the State's intent regarding cost effectiveness (as noted above) remains paramount. The burden of proof in meeting this intent shall be presented for unproven materials, designs, applications, and maintenance. This is discussed in detail in Section 3.5.1.4.

Experimental roofs shall be utilized only under a carefully controlled research program.

1.6 ACKNOWLEDGEMENTS

This manual was written by Thomas Lee Smith, AIA, CSI, of Maynard and Partch, Anchorage, Alaska.

Appendix 1.7 lists reviewers of the manual.

Special acknowledgement is extended to Architect Donn Ketner, with DOT/PF. It is primarily through his vision and administrative effort that this manual came to be.

End of Section 1, INTRODUCTION

Appendix 1.7 Follows

APPENDIX 1.7.1

LIST OF REVIEWERS

Copies of portions of the manual were sent to a large number of organizations, companies, and individuals. Comments were received from the following:

Architects:

Phillip Usher & Associates
Anchorage, Alaska

Engineers:

Skilling Ward Rogers Barkshire, Inc.
Anchorage, Alaska
Bill Smith

Manufacturers/Representatives/Suppliers:

American Tar Company
Seattle, Washington
Bill Burnside II

Carlisle Syntec Systems
Carlisle, Pennsylvania
Wayne R. Asper

DOW Chemical USA
Granville, Ohio
Dave Roodvoets

Firestone Building Products Company
Indianapolis, Indianna
Leonard Grunstein, Legal Consultant

General Electric Company
Silicone Products Division
Waterford, New York
James R. Brown

W.R. Grace
Cambridge, Massachusettes
Thomas E. Murray

Malarkey
Bellevue, Washington
Peter Chance

Manville Building Materials Corporation
Denver, Colorado
T.W. Michelsen

Owens-Corning Fiberglas Corp.
Toledo, Ohio
David E. Richards

Protective Treatments, Inc.
Dayton, Ohio

Tramex Electronics, Inc.
Topanga, California
Michael Messore

URESCO Construction Materials, Inc.
Seattle, Washington
Doug Sobek

Watersaver Company, Inc.
Denver, Colorado
Bill Reetz

Organizations/Governmental Agencies

AGR Company
Charlotte, North Carolina
Charles R. Kellar

Army Construction Engineering Research Laboratory
Champaign, Illinois
Myer J. Rosenfield

Asphalt Roofing Manufacturers Association
Rockville, Maryland
Richard D. Snyder

Bureau of Reclamation
Denver, Colorado
Vernon Kuehn

Canadian Roofing Contractors' Association
Ottawa, Ontario
H.E. Saint-Amour

E.I. DuPont DeNemours & Company
Wilmington, Delaware
S.K. Rudys

Factory Mutual Research (FM)
Norwood, Massachusetts
E.A. Bamford

Products Research & Chemical Corp.
Glendale, California
Paul D. Lovik

Public Works Canada
Ottawa, Ontario
H. Dale - Harris

The Roofing Industry Educational Institute (RIEI)
Englewood, Colorado
Dick Fricklas

Underwriters Laboratories, Inc.
Northbrook, Illinois
Robert M. Berhinig

Roof Consultants

Alaska Test Lab
Anchorage, Alaska
Dick LaFond

Thermo-Scan Engineering, Inc.
Littleton, Colorado
Don Lewis

Roofing Contractors

Stark-Lewis Co.
Anchorage, Alaska
Earl Lewis

* * * * * *

2. RESOURCES AND LITERATURE

Note: Sections 2.4 and 2.5 contain limited information and will be expanded in the future.

2.1 ORGANIZATIONS

The RIEI Course Manuals list key organizations associated with roofing. The following are of particular interest:

- Canadian Roofing Contractors Association
  (CRCA)
  116 Albert Street, Suite 710
  Ottawa, Ontario K1P5G3
  (613) 232-6724

- Midwest Roofing Contractors Association
  (MRCA)
  1000 Power & Light Building
  106 W. 14th Street
  Kansas City, MO 64015
  (816) 474-8100

- National Roofing Contractors Association
  (NRCA)
  8600 Bryn Mawr Road
  Chicago, IL 60631
  (312) 693-0700

- The Roofing Industry Educational Institute
  (RIEI)
  6851 S. Holly Circle, Suite 100
  Englewood, CO 80112
  (303) 770-0613

- The Single Ply Roofing Institute
  (SPRI)
  1800 Pickwick Avenue
  Glenview, IL 60025
  (312) 724-7000

2.2 PUBLICATIONS FOR DESIGNERS

There are a large variety of publications available to designers (see NRCA and RIEI Publications for listings). The following books and manuals are the best general reference sources available (as of 1985):

- **Manual of Built-Up Roof Systems**, by C.W. Griffin, Second Edition, 1982.

- **Roofs**, by Maxwell C. Baker, 1980.

- **The NRCA Roofing and Waterproofing Manual**, Second Edition, 1985.

- The Roofing Industry Educational Institute's Course Manuals.

2.3 ROOFING PERIODICALS

2.3.1 Periodicals Primarily Related To Roofing:

- **EXTERIORS** (Formerly **"Roof Design"**)
  757 Third Avenue
  New York, New York 10017

  Published by RSI Magazine
  First published March 1983

- ROOFER MAGAZINE
  P.O. Box 06253
  Fort Myers, Florida 39906-9985

- ROOFING/SIDING/INSULATION
  P.O. Box 6039
  Duluth, Minnesota 55806

- ROOFING SPEC
  National Roofing Contractors Association
  8600 Bryn Mawr Avenue
  Chicago, Illinois 60631

- THE ROOFING INDUSTRY EDUCATIONAL INSTITUTE NEWSLETTER
  6851 S. Holly Circle, Suite 100
  Englewood, CO 80112

2.3.2 Periodicals that Occasionally Refer to Roofing:

- AIA JOURNAL
  1735 New York Ave., N.W.
  Washington, D.C. 20006

- ARCHITECTURAL RECORD
  P.O. Box 564
  Hightstown, New Jersey 08520

- BUILDING DESIGN & CONSTRUCTION
  P.O. Box 5731
  Denver, Colorado 80217

- BUILDING OPERATING MANAGEMENT
  P.O. Box 1983
  Clinton, Iowa 52735

- CANADIAN BUILDING DIGESTS
  National Research Council of Canada
  Ottawa, Ontario KIAOR6

- COMMERCIAL REMODELING
  c/o Orlock Co.
  Suite 900
  Union Carbide Bldg.
  230 No. Michigan Ave.
  Chicago, Illinois 60601

- METAL BUILDING REVIEW
  P.O. Box 17651
  Denver, CO 80217

- PROGRESSIVE ARCHITECTURE
  P.O. Box 95759
  Cleveland, Ohio 44101

- THE CONSTRUCTION SPECIFIER
  601 Madison St.
  Alexandria, Virginia 22314

- WESTERN BUILDING DESIGN
  McKellar Publications
  P.O. Box 2574
  Clinton, Iowa 52735

2.4 CODES AND STANDARDS

2.4.1 Listed by Organiation

2.4.1.1 ASTM Standards

ASTM A 361	Standard specification for steel sheet, zinc-coated (galvanized) by the hot-dip process for roofing and siding.
ASTM A 755	Standard specification for general requirements for steel sheet zinc-coated (galvanized) by the hot-dip process and coil-coated for roofing and siding.
ASTM C 222	Standard specification for asbestos - cement roofing shingles.
ASTM C 406	Standard specification for roofing slate.
ASTM C 578	Standard specification for preformed, cellular, polystyrene thermal insulation.
ASTM D 5	Standard test method for penetration of bituminous materials.
ASTM D 86	Standard method for distillation of petroleum products.

ASTM D 146	Standard methods of sampling and testing bitumen-saturated felts and woven fabrics for roofing and waterproofing.
ASTM D 173	Standard specification for bitumen-saturated cotton fabrics used in roofing and waterproofing.
ASTM D 224	Standard specification for smooth-surfaced asphalt roll roofing (organic felt). **Note: This is a base sheet.**
ASTM D 225	Standard specification for asphalt shingles (organic felt) surfaced with mineral granules.
ASTM D 226	Standard specification for asphalt-saturated organic felt used in roofing and waterproofing.
ASTM D 227	Standard specification for coal-tar-saturated organic felt used in roofing and waterproofing.
ASTM D 228	Standard methods of testing asphalt roll roofing, cap sheets, and shingles.
ASTM D 249	Standard specification for asphalt roll roofing (organic felt) surfaced with mineral granules. **Note: This is a mineral surfaced cap sheet.**
ASTM D 250	Standard specification for asphalt-saturated asbestos felt used in roofing and waterproofing.
ASTM D 312	Standard specification for asphalt used in roofing.
ASTM D 371	Standard specification for asphalt roll roofing (organic felt) surfaced with mineral granules; wide selvage. **Note: This is a mineral surfaced cap sheet, with surfacing on only ½ the sheet width**
ASTM D 449	Standard specification for asphalt used in dampproofing and waterproofing. **Note: This asphalt is used to saturate some felts and fabrics. It is not intended for field application. For field application use ASTM D 312.**
ASTM D 450	Standard specification for coal-tar bitumen used in roofing, dampproofing, and Waterproofing.
ASTM D 461	Standard method for testing felt.
ASTM D 529	Standard practice for accelerated weathering test of bituminous materials.

ASTM D 1227	Standard specification for emulsified asphalt used as a protective coating for roofing.
	Note: This is an emulsion coating.
ASTM D 1327	Standard Specification for bitumen - saturated woven burlap fabrics used in roofing and waterproofing.
ASTM D 1863	Standard specification for mineral aggregate used on built-up roofs.
ASTM D 2164	Standard methods of testing structural insulating roof deck.
ASTM D 2822	Standard Specification for asphalt roof cement.
	Note: This is "plastic cement".
ASTM D 2823	Standard Specification for asphalt roof coatings.
	Note: This is a cut back coating.
ASTM D 2824	Standard specification for aluminum-pigmented asphalt roof coatings.
	Note: This is an aluminum cut back coating.
ASTM D 2829	Standard recommended practice for sampling and analysis of built-up roofs.
ASTM D 3378	Standard specification for asphalt - saturated and coated asbestos felt base sheet used in roofing.
	Note: This is an "asbestos base sheet."
ASTM D 3462	Standard specification for asphalt shingles made from glass mat and surfaced with mineral granules.
ASTM D 3747	Standard specification for emulsified asphalt adhesive for adhering roof insulation.
	Note: This is an adhesive for use on steel decks.
ASTM D 3909	Standard Specification for asphalt rool roofing (glass mat) surfaced with mineral granules.
	Note: This is a mineral surfaced cap sheet.
ASTM E 72	Standard methods of conducting strength tests of panels for building construction.

ASTM E 108	Standard Methods of fire tests of roof coverings. **Note: There are three classes of exposure: Class A, Class B, Class C. Class A affords the greatest degree of protection.**
ASTM E 196	Standard practice for gravity load testing of floors and flat roofs. **Note: This practice is applicable to field testing.**

2.4.2 Listed by Subject

Built-Up Roofing

ASTM D 173	Standard specification for bitumen-saturated cotton fabrics used in roofing and waterproofing.
ASTM D 224	Standard specification for smooth-surfaced asphalt roll roofing (organic felt). **Note: This is a base sheet.**
ASTM D 226	Standard specification for asphalt-saturated organic felt used in roofing and waterproofing.
ASTM D 227	Standard specification for coal-tar-saturated organic felt used in roofing and waterproofing.
ASTM D 249	Standard specification for asphalt roll roofing (organic felt) surfaced with mineral granules. **Note: This is a mineral surfaced cap sheet.**
ASTM D 250	Standard specification for asphalt-saturated asbestos felt used in roofing and waterproofing.
ASTM D 312	Standard specification for asphalt used in roofing.
ASTM D 371	Standard specification for asphalt roll roofing (organic felt) surfaced with mineral granules; wide selvage. **Note: This is a mineral surfaced cap sheet, with surfacing on only $\frac{1}{2}$ the sheet width**
ASTM D 449	Standard specification for asphalt used in dampproofing and waterproofing. **Note: This asphalt is used to saturate some felts and fabrics. It is not intended for field application. For field application use ASTM D 312.**

ASTM D 450	Standard specification for coal-tar bitumen used in roofing, dampproofing, and Waterproofing.
ASTM D 1227	Standard specification for emulsified asphalt used as a protective coating for roofing. **Note: This is an emulsion coating.**
ASTM D 1327	Standard Specification for bitumen - saturated woven burlap fabrics used in roofing and waterproofing.
ASTM D 1863	Standard specification for mineral aggregate used on built-up roofs.
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ASTM D 2823	Standard Specification for asphalt roof coatings. **Note: This is a cut back coating.**
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ASTM D 3378	Standard specification for asphalt - saturated and coated asbestos felt base sheet used in roofing. **Note: This is an "asbestos base sheet."**
ASTM D 3747	Standard specification for emulsified asphalt adhesive for adhering roof insulation. **Note: This is an adhesive for use on steel decks.**
ASTM D 3909	Standard Specification for asphalt rool roofing (glass mat) surfaced with mineral granules. **Note: This is a mineral surfaced cap sheet.**

Built-Up Roofing, Bitumen

ASTM D 312	Standard specification for asphalt used in roofing.
ASTM D 449	Standard specification for asphalt used in dampproofing and waterproofing. **Note: This asphalt is used to saturate some felts and fabrics. It is not intended for field application. For field application use ASTM D 312.**

ASTM D 450	Standard specification for coal-tar bitumen used in roofing, dampproofing, and Waterproofing.
ASTM D 3747	Standard specification for emulsified asphalt adhesive for adhering roof insulation.
	Note: This is an adhesive for use on steel decks.

Built-Up Roofing, Coatings

ASTM D 1227	Standard specification for emulsified asphalt used as a protective coating for roofing.
	Note: This is an emulsion coating.
ASTM D 1863	Standard specification for mineral aggregate used on built-up roofs.
ASTM D 2823	Standard Specification for asphalt roof coatings.
	Note: This is a cut back coating.
ASTM D 2824	Standard specification for aluminum-pigmented asphalt roof coatings.
	Note: This is an aluminum cut back coating.

Built-Up Roofing, Fabrics

ASTM D 173	Standard specification for bitumen-saturated cotton fabrics used in roofing and waterproofing.
ASTM D 1327	Standard Specification for bitumen - saturated woven burlap fabrics used in roofing and waterproofing.

Built-Up Roofing, Felts

ASTM D 224	Standard specification for smooth-surfaced asphalt roll roofing (organic felt).
	Note: This is a base sheet.
ASTM D 226	Standard specification for asphalt-saturated organic felt used in roofing and waterproofing.
ASTM D 227	Standard specification for coal-tar-saturated organic felt used in roofing and waterproofing.
ASTM D 249	Standard specification for asphalt roll roofing (organic felt) surfaced with mineral granules.
	Note: This is a mineral surfaced cap sheet.

ASTM D 250	Standard specification for asphalt-saturated asbestos felt used in roofing and waterproofing.
ASTM D 371	Standard specification for asphalt roll roofing (organic felt) surfaced with mineral granules; wide selvage. **Note: This is a mineral surfaced cap sheet, with surfacing on only ½ the sheet width.**
ASTM D 3378	Standard specification for asphalt - saturated and coated asbestos felt base sheet used in roofing. **Note: This is an "asbestos base sheet."**
ASTM D 3909	Standard Specification for asphalt rool roofing (glass mat) surfaced with mineral granules. **Note: This is a mineral surfaced cap sheet.**

Laboratory Testing/Analysis

ASTM D 5	Standard test method for penetration of bituminous materials.
ASTM D 86	Standard method for distillation of petroleum products.
ASTM D 146	Standard methods of sampling and testing bitumen-saturated felts and woven fabrics for roofing and waterproofing.
ASTM D 228	Standard methods of testing asphalt roll roofing, cap sheets, and shingles.
ASTM D 461	Standard method for testing felt.
ASTM D 529	Standard practice for accelerated weathering test of bituminous materials.
ASTM D 2164	Standard methods of testing structural insulating roof deck.
ASTM D 2829	Standard recommended practice for sampling and analysis of built-up roofs.
ASTM E 72	Standard methods of conducting strength test of panels for building construction.
ASTM E 108	Standard Methods of fire tests of roof coverings. **Note: There are three classes of exposure: Class A, Class B, Class C. Class A affords the greatest degree of protection.**

ASTM E 196 — Standard practice for gravity load testing of floors and flat roofs.

Note: This practice is applicable to field testing.

Steep Roofing

ASTM A 361 — Standard specification for steel sheet, zinc-coated (galvanized) by the hot-dip process for roofing and siding.

ASTM A 755 — Standard specification for general requirements for steel sheet zinc-coated (galvanized) by the hot-dip process and coil-coated for roofing and siding.

ASTM C 222 — Standard specification for asbestos - cement roofing shingles.

ASTM C 406 — Standard specification for roofing slate.

ASTM D 225 — Standard specification for asphalt shingles (organic felt) surfaced with mineral granules.

ASTM D 3462 — Standard specification for asphalt shingles made from glass mat and surfaced with mineral granules.

2.5 REFERENCE LITERATURE

2.5.1 Listed By Organization

2.5.1.1 Canadian Building Digests
National Research Council of Canada
Division of Building Research
Ottawa, CANADA

NOTE:

1. Many of the Digests are elementary but should be beneficial to those with little roofing technology knowledge.

2. The Digests date back to 1960 -- **many are obsolete and contain information that is no longer valid.** Caution is therefore necessary. However, many of the Digests or portions thereof do contain credible information.

3. The following Digests may be of special interest, and are identified in the following list by two asteriks: 40, 65, 68, 73, 75, 83, 89, 117, 118, 151, 181, 193.

Canadian Building Digest - 1
Humidity in Canadian Buildings
Hutcheon, N. B.
January 1960, Corrected May 1968

Canadian Building Digest - 9
Vapour Barriers in Home Construction
Handegord, G. O.
September 1960

Canadian Building Digest - 18
Strength of Small Roofs
Schriever, W. R. & Thorburn, H. J.
June 1961

Canadian Building Digest - 23
Air Leakage in Buildings
Wilson, A. G.
November 1961

Canadian Building Digest - 24
Built-Up Roofing
Baker, M. C.
December 1961

Canadian Building Digest - 28
Wind on Buildings
Dalgliesh, W. A. & Boyd, D. W.
April 1962

Canadian Building Digests - 30
Water and Building Materials
Latta, J. K.
June 1962, Corrected May 1968

Canadian Building Digests - 34
Wind Pressures on Buildings
Dalgliesh, W. A. & Schriever, W. R.
October 1962, Corrected May 1963

Canadian Building Digests - 37
Snow Loads on Roofs
Peter, B. & Schriever, W. R.
January 1963, Corrected May 1968

Canadian Building Digests - 38
Bituminous Materials
Jones, P. M.
February 1963

Canadian Building Digests - 40
**Rain Penetration and Its Control
Garden, G. K.
April 1963

Canadian Building Digests - 42
Humidified Buildings
Hutcheon, N. B.
June 1963

Canadian Building Digests - 44
Thermal Bridges in Buildings
Brown, W. P. & Wilson, A. G.
August 1963

Canadian Building Digests - 47
Extreme Temperatures at the Outer Surfaces of Buildings
Stephenson, D. G.
November 1963

Canadian Building Digests - 49
New Roofing Systems
Baker, M. C.
January 1964, Corrected May 1968

Canadian Building Digests - 57
Vapour Diffusion and Condensation
Latta, J. K. & Beach, B. K.
September 1964, Corrected May 1968

Canadian Building Digests - 65
**Mineral Aggregate Roof Surfacing
Tibbetts, D. C. & Baker, M. C.
May 1965, Corrected May 1968

Canadian Building Digests - 67
Fundamentals of Roof Design
Garden, G. K.
July 1965

Canadian Building Digests - 68
**Wind Pressures and Suctions on Roofs
Dalgliesh, W. A. & Schriever, W. R.
August 1968

Canadian Building Digests - 69
Flashings for Membrane Roofing
Baker, M. C.
September 1965

Canadian Building Digests - 70
Thermal Considerations in Roof Design
Garden, G. K.
October 1965

Canadian Building Digests - 72
Control of Air Leakage is Important
Garden, G. K.
December 1965

Canadian Building Digests - 73
**Moisture Considerations in Roof Design
Handegord, G. O.
January 1965

Canadian Building Digests - 74
Properties of Bituminous Membranes
Jones, P. M. & Garden, G. K.
February 1966

Canadian Building Digests - 75
**Roof Terraces
Garden, G. K.
March 1966

Canadian Building Digests - 83
**Indoor Swimming Pools
Garden, G. K.
November 1966

Canadian Building Digests - 89
**Ice on Roofs
Baker, M. C.
May 1967

Canadian Building Digests - 95
Roofing Membrane Design
Baker, M. C.
November 1967, Corrected May 1968

Canadian Building Digests - 99
Application of Roof Design Principles
Handegord, G. O. & Baker, M. C.
March 1968

Canadian Building Digest - 112
Designing Wood Roofs to Prevent Decay
Baker, M. C.
April 1969

Canadian Building Digest - 115
Performance of Building Materials
Sereda, P. J.
July 1969

Canadian Building Digest - 117
**Weathering of Organic Building Materials
Ashton, H. E.
September 1969

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Ashton, H. E.
February 1970

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Flammability of Lining and Insulating Materials
Rose, A.
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Toxic Gases and Vapours Produced at Fires
Sumi, K. & Tsuchiya, Y.
January 1971

Canadian Building Digest - 149
Thermal Resistence of Building Insulation
Shirtliffe, C. J.
May 1979

Canadian Building Digest - 150
Protected-Membrane Roofs
Baker, M. C. & Hedlin, C. P.
June 1972

Canadian Building Digest - 151
**Drainage from Roofs
Baker, M. C.

Canadian Building Digest - 154
Plastics
Blaga, A.
October 1973

Canadian Building Digest - 158
Thermoplastics
Blaga, A.
1974

Canadian Building Digest - 166
Plastic Foams
Blaga, A.
1974

Canadian Building Digest - 167
Rigid Thermoplastic Foams
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Canadian Building Digest - 168
Rigid Thermosetting Plastic Foams
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Vapour Barriers: What Are They? Are They Effective?
Latta, J. K.
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May 1976

Canadian Building Digest - 179
Inspection and Maintenance of Flat Roofs
Hedlin, C. P.
July 1976

Canadian Building Digest - 181
**Shrinkage of Bituminous Roofing Membranes
Turenne, R. G.
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Canadian Building Digest - 193
Estimating Snow Loads on Roofs
Schriever, W. R.
February 1978

2.5.2 Listed By Subject

Note:

1. Abbreviations

   o CBD: Canadian Building Digest

2. Items of special interest are identified with two asteriks (**).

3. Index for Section 2.5.2:

o Built-up Roofing

o Built-up Roofing; Surfacings

- o Fire
- o Flashings/Sheet Metal
- o General Roofing Design
- o Heat Flow
- o Inspection/Maintenance
- o Inspection/Testing
- o Insulation
- o Non-Conventional Roofing Systems
- o Plaza Decks
- o Polymerics
- o Protected Membrane Roofs
- o Roof Drainage
- o Roof Failures
- o Snow/Ice
- o Special Occupancies
- o Structural
- o Vapor/Humidity/Moisture/Condensation
- o Wind

Built-Up Roofing

CBD 24, Built-Up Roofing, M. C. Baker, December 1961

CBD 38, Bituminous Materials, P. M. Jones, February 1963

CBD 65, Mineral Aggregate Roof Surfacing, M. C. Baker, May 1965, Corrected May 1968

CBD 74, Properties of Bituminous Membranes, G. K. Garden, P. M. Jones, February 1966

CBD 95, Roofing Membrane Design, M. C. Baker, November, 1967, Corrected May 1968

CBD 99, Application of Roof Design Principles, M. C. Baker, G. O. Handegord, March 1968

CBD 181, Shrinkage of Bituminous Roofing Membranes, R. G. Turenne, July 1976

Built-Up Roofing; Surfacings

CBD 65, Mineral Aggregate Roof Surfacing, M. C. Baker, D. C. Tibbetts, May 1965, Corrected May 1968

Fire

CBD 141, Flammability of Lining and Insulating Materials, A. Rose, September 1971

Flashings/Sheet Metal

CBD 40, Rain Penetration and Its Control, G. K. Garden, April 1963

CBD 69, Flashings for Membrane Roofing, M. C. Baker, September 1965

General Roofing Design

CBD 67, Fundamentals of Roof Desing, G. K. Garden, July 1965

CBD 150, Protected-Membrane Roofs, M. C. Baker, June 1972

Heat Flow

CBD 44, Thermal Bridges in Buildings, W. P. Brown, A. G. Wilson, August 1963

CBD 47, Extreme Temperatures at the Outer Surfaces of Buildings, D. G. Stephenson, November 1963

CBD 70, Thermal Considerations in Roof Design, G. K. Garden, October 1965

Inspection/Maintenance

CBD 179, Inspection and Maintenance of Flat Roofs, C. P. Hedlin, July 1976

Inspection/Testing

CBD 118, Accelerated Durability Tests for Organic Building Materials, H. E. Ashton, October 1969

Insulation

CBD 44, Thermal Bridges in Buildings, W. P. Brown, A. G. Wilson, August 1963

CBD 47, Extreme Temperatures at the Outer Surfaces of Buildings, D. G. Stephenson, November 1963

CBD 70, Thermal Considerations in Roof Design, G. K. Garden, October 1965

CBD 141, Flammability of Lining and Insulating Materials, A. Rose, September 1971

CBD 149, Thermal Resistence of Building C. J. Shirtliffe, May 1972

CBD 158, Thermoplastics, A. Blaga, -- 1974

CBD 159, Thermosetting Plastics, A. Blaga, -- 1974

CBD 166, Plastic Foams, A. Blaga, -- 1974

CBD 167, Rigid Thermoplastic Foams, A. Blaga, -- 1974

CBD 168, Rigid Thermosetting Plastic Foams, A. Blaga, -- 1974

Non-Conventional Roofing Systems

CBD 49, New Roofing Systems, M. C. Baker, January 1964, Corrected May 1968

CBD 158, Thermoplastics, A. Blaga, -- 1974

Plaza Decks

CBD 75, Roof Terraces, G. K. Garden, March 1966

Polymerics

CBD 144, Toxic Gases and Vapours Produced at Fires, K. Sumi, Y. Tsuchiya, December 1971

CBD 154, Plastics, A. Blaga, October 1973

CBD 158, Thermoplastics, A. Blaga, -- 1974

CBD 159, Thermosetting Plastics, A. Blaga, -- 1974

CBD 166, Plastic Foams, A. Blaga, -- 1974

CBD 167, Rigid Thermoplastic Foams, A. Blaga, -- 1974

CBD 168, Rigid Thermosetting Plastic Foams, A. Blaga, -- 1974

Protected Membrane Roofs

CBD 150, Protected-Membrane Roofs, C. P. Hedlin, June 1972

Roof Drainage

CBD 89, Ice on Roofs, M. C. Baker, May 1967

CBD 151, Drainage from Roofs, M. C. Baker

Roof Failures

CBD 115, Performance of Building Materials, P. J. Sereda, July 1969

CBD 117, Weathering of Organic Building Materials, H. E. Ashton, September 1969

CBD 118, Accelerated Durability Tests for Organic Building Materials, H. E. Ashton, October 1969

CBD 121, Irradiation Effects on Organic Materials, H. E. Ashton, January, 1970

CBD 122, Radiation and Other Weather Factors, H. E. Ashton, February 1970

CBD 124, Biological Attack on Organic Materials, H. E. Ashton, April 1970

CBD 181, Shrinkage of Bituminous Roofing Membranes, R. G. Turenne, July 1976

Snow/Ice

CBD 37, Snow Loads on Roofs, B. Peter, W. R. Schriever, January 1963, Corrected May 1968

CBD 89, Ice on Roofs, M. C. Baker, Snow/Ice, May 1967

CBD 193, Estimating Snow Loads on Roofs, W. R. Schriever, February 1978

Special Occupancies

CBD 75, Roof Terraces, G. K. Garden, March 1966

CBD 83, Indoor Swimming Pools, G. K. Garden, November 1966

Structural

CBD 18, Strength of Small Roofs, W. R. Schriever, H. J. Thorburn, June 1961

CBD 28, Wind on Buildings, D. W. Boyd, W. A. Dalgliesh, April 1962

CBD 34, Wind Pressures on Buildings, W. A. Dalgliesh, W. R. Schriever, October 1962, Corrected May 1963

CBD 37, Snow Loads on Roofs, B. Peter, W. R. Schriever, January 1963, Corrected May 1968

CBD 68, Wind Pressures and Suctions on Roofs, W. A. Dalgliesh, W. R. Schriever, August 1965

CBD 89, Ice on Roofs, M. C. Baker, May 1967

CBD 112, Designing Wood Roofs to Prevent Decay, M. C. Baker, April 1969

CBD 193, Estimating Snow Loads on Roofs, W. R. Schriever, February 1978

Vapor/Humidity/Moisture/Condensation

CBD 1, Humidity in Canadian Buildings, N. B. Hutcheon, January 1960, Corrected May 1968

CBD 9, Vapour Barriers in Home Construction, G. O. Handegord, September 1960

CBD 23, Air Leakage in Buildings, A. G. Wilson, November 1961

CBD 30, Water and Building Materials, J. K. Latta, June 1962, Corrected May 1968

CBD 42, Humidified Buildings, N. B. Hutcheon, June 1963

CBD 57, Vapour Diffusion and Condensation, B. K. Beach, J. K. Latta, September 1964, Corrected May 1968

CBD 72, Control of Air Leakage is Important, G. K. Garden, December 1965

CBD 73, Moisture Considerations in Roof Design, G. O. Handegord, January 1966

CBD 83, Indoor Swimming Pools, G. K. Garden, November 1966

CBD 99, Application of Roof Design Principles, M. C. Baker, G. O. Handegord, March 1968

CBD 112, Designing Wood Roofs to Prevent Decay, M. C. Baker, April 1969

CBD 175, Vapour Barriers: What Are They? Are They Effective?, J. K. Latta, March 1976

CBD 176, Venting of Flat Roofs, M. C. Baker, C. P. Hedlin, May 1976

Wind

CBD 28, Wind on Buildings, D. W. Boyd, W. A. Dalgliesh, April 1962

CBD 34, Wind Pressures on Buildings, W. A. Dalgliesh, W. R. Schriever, October 1962, Corrected May 1963

CBD 68, Wind Pressures and Suctions on Roofs, W. A. Dalgliesh, W. R. Schriever, August 1965

End of Section 2

RESOURCES AND LITERATURE

3. DESIGN CONSIDERATIONS AND CRITERIA

Note:

1. An expanded Table of Contents occurs on Pages 3.01 through 3.04.
2. Footnotes are referenced by a number within a bracket, ie. [1]. The footnotes occur in Appendix 3.9.2.
3. Appendix 3.9.3 will be issued in the future.

EXPANDED TABLE OF CONTENTS

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3. DESIGN CONSIDERATIONS AND CRITERIA

3.1 GENERAL

3.1.1 Roof Functions

- Carry Dead Loads.
- Carry induced live loads; such as wind, water, snow, seismic.
- Minimize fire spread from internal and external fire exposure.
- **Prevent entrance of water.**
- Prevent excessive condensation (under and within the roofing system).
- Reduce energy consumption.
- Visually respond in an appropriate manner to the building's aesthetics. Sloping roofs may be visually dominant and powerful. Flat roofs may be seen from above.

3.1.2 The Designer's Role

The Designer is a key element in achieving a "good roof". The selection of materials, their arrangement, and detailing is critical.

The current (1985) knowledge base of the roofing industry is extensive. In the past few years, roof design by knowledgeable designers has in reality been based upon roofing technology. **Unfortunately, many (if not most) roof designers possess very little roofing technology knowledge.**

This document presents all pertinent aspects of roofing. On some subjects it presents an overview. On others, it presents detailed information. References are presented to assist the designer in further exploration.

A discussion of what constitutes a "good roof", life expectancy, and costs occurs in **Section 3.5.4**.

3.1.3 Glossary

A full glossary (including terms pertaining to elastomeric and plastomeric materials) occurs in Section I "GLOSSARY". The following list of terms are frequently used and are included here for the reader's convenience. These terms are generally based upon the NRCA and RIEI glossaries.

Alligatoring: The cracking of the surfacing bitumen on a built-up roof, producing a pattern of cracks similar to an alligator's hide; the cracks may or may not extend through the surfacing bitumen.

Area Divider Joint: See "**Control Joint**"

Asphalt Flow: Down-slope movement of the flood or glaze coat on a built-up roof. Although this can occur with an aggregate surfaced roof, it is usually associated with a smooth surfaced roof.

Bitumen: The generic term for an amorphous, semi-solid mixture of complex hydrocarbons derived from any organic source. **Asphalt** and **coal tar** are the two bitumens used in the roofing industry.

In Alaska, asphalt is the commonly used bitumen.

Blister: An enclosed pocket of air mixed with water vapor, trapped between impermeable layers of felt, etc.

Blow-Off: The loss or partial loss of the roofing system, or components thereof, due to wind.

BUR: **Built-Up Roof** - 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 cap sheet.

BUR's are discussed in Section 3.5.3 and 3.5.8.

Control Joint: A joint through the roof membrane and insulation, but not through the deck. It is used to relieve thermal stresses in the membrane and to eliminate re-entrant corners. The joint should consist of a curb and coping.

Note:

1. See Section 3.9.3.
2. Expansion joints are similar to control joints, except the joint extends through the deck, and the joint cover must accommodate the joint movement.
3. Seismic joints are similar to expansion joints, except the amount of movement is generally larger and movement can occur in any direction.

Cricket: A superimposed construction placed in a roof area to assist drainage.

See the NRCA **Roofing and Waterproofing Manual**, Construction Detail **P**.

Cutback: Solvent-thinned bitumen used in cold process roofing adhesives, plastic cement, and roof coatings.

Cutoff: A detail designed to prevent lateral water movement into the insulation where the membrane terminates at the end of a day's work, or used to isolate sections of the roofing system. It is usually removed before the continuation of the work.

Dead Level Roof: Absolutely horizontal, or zero slope roof.

See **Flat Roof**.

Note: Slope is discussed in Section 3.3.1, 3.3.2, and 3.5.6.

Elastomeric: The term used to describe elastic, rubber-like properties in a material. Elastomerics return rapidly to their approximate initial dimensions and shape after subsequent release of stress.

Elastomeric materials are not influenced by heat and cold to the extent that plastomeric materials are.

Elasto/Plastic: A group on non-conventional roofing membrane materials, either sheet or liquid applied, either in single or multiple layers.

Elasto/Plastic includes:

- Modified Bitumen
- Polymeric
  - Thermoplastic: PVC
  - Elastomeric: EPDM and Neoprene
  - Semi-elastomers: Hypalon, chlorinated polyethylene (CPE)
- Spray-Applied Polyurethane Foam Roofing
- Liquid Applied Membranes

"**Single-Ply**" is also used to describe this group of materials. However, since many of these systems are liquid applied or applied in more than one layer, "**elasto/plastic**" is the preferred term.

EPDM:	Ethylene Propylene Diene Monomer - a common elasto/plastic polymeric (elastomeric) membrane.
EVT:	Equiviscous Temperature - The temperature range that bitumen should be applied at (at the point of application). The EVT for each different type of bitumen is noted on the "plug". See NRCA Bulletin 3.
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), asbestos fibers (asbestos felts), or glass fibers (glass fiber felts).
Fish Mouth:	A half cylindrical or half conical opening formed by an edge wrinkle or failure to embed a roofing felt.
Flat Roof:	A roof that is generally flat, but with some slope for drainage. Note: Slope is discussed in Section 3.3.1, 3.3.2, and 3.5.6.
Flood Coat:	The top layer of bitumen on a BUR. A flood coat is heavy. It is only used on an aggregate surfaced roof or Protected Membrane Roof. See **Glaze Coat.**
FM:	**Factory Mutual** - an organization which, among other things, classifies roof assemblies for their fire characteristics and wind-uplift resistance for insurance companies in the United States.

Fully Adhered Membrane:	Refers to an elasto/plastic sheet membrane that is completely bonded to the substrate.
Glaze Coat:	(1) The thin top layer of asphalt in a smooth surfaced built-up roof assembly. (2) A thin protective coating of bitumen applied to the lower plies or top of a built-up membrane, when application of additional felts, or the flood coat and aggregate surfacing are delayed. (3) A thin protective coating of bitumen over the top ply of a Protected Membrane Roof. This glaze coat is followed by a flood coat.
Holiday:	An area where a liquid applied material is missing.
"Hot Stuff" or "Hot":	A roofer's term for hot bitumen.
Interply:	Between two plies.
Loose-Laid:	Refers to an elasto/plastic sheet membrane that is not attached to the substrate. The membrane is held to the roof by ballast. If insulation occurs between the membrane and roof ballast, the system is referred to as a "loose-laid Protected Membrane Roof".
Membrane:	The roof covering materials whose primary function is the exclusion of water. Note: This document considers shingles, tile and metal panels as "membranes".
Mole Run:	A meandering ridge in a membrane not associated with insulation or deck joints.

Mop - and - Flop: An application procedure in which roofing elements (insulation boards, felts, cap sheets, etc.) are initially placed upside down adjacent to their ultimate locations, are coated with adhesive, and are then turned over and applied to the substrate.

Mopping: The application of hot bitumen with a mop or mechanical applicator to the substrate or to the plies of a built-up roof. There are four types of mopping:

Solid: a continuous coating.

Spot: bitumen is applied in roughly circular areas, generally about 18 in. in diameter, leaving a grid of unmopped, perpendicular area.

Strip: bitumen is applied in parallel bands, generally 8 in. wide and 12 in. apart.

Sprinkle: bitumen is shaken on the substrate from a broom or mop in a random pattern.

Mud Cracking: Surface cracking resembling a dried mud flat.

Nail One - Mop One: Refers to the installation procedure of multiple layers of insulation where the first layer is "nailed" (mechanically fastened) to the substrate. The next layer(s) is then fully adhered (usually with hot bitumen) to the layer below.

NDE: **Non-Destructive Evaluation** - the use of non-destructive techniques to find wet insulation.

See Section 8 "**ROOF INVESTIGATIONS AND TESTING**".

NRCA: National Roofing Contractor's Association.

See Section 2 "RESOURCES AND LITERATURE" for address and telephone number.

Partially Attached: Refers to an elasto/plastic sheet membrane that is intermittently secured to the substrate with bars or disks.

Phased Application: The installation of a roofing or waterproofing system during two or more separate time intervals; a roofing system not installed in a continuous operation.

Note: phased application should generally be avoided.

Picture Framing: A rectangular pattern of ridges in a membrane, occurring over insulation or deck joints.

See Ridging.

Pinhole: A tiny hole in a film (asphalt), foil, or laminate comparable in size to one made by a pin.

Plastic Cement: A trowelable mixture of cutback bitumen and mineral stabilizers, including asbestos or other inorganic fibers.

Note:

1. Due to governmental regulations, asbestos fibers may eventually be excluded from plastic cement.

2. NRCA and RIEI prefer the term **"flashing cement"**. However this document uses the term **"plastic cement"**.

Plastomeric: The term used to describe plastic-like properties in a material.

Plastomerics used for roof membranes are flexible and somewhat ductile. They are thermoplastic, hence they melt at high temperature and resolidify when cooled. At cold temperatures, plastomerics are relatively brittle.

Ply: A layer of felt in a built-up roofing membrane. A four ply membrane has at least four plies of felt at any vertical cross section cut through the membrane.

The dimension of the exposed surface (the "exposure") of any ply may be computed by dividing the felt width (minus 2 inches) by the number of plies; thus, the exposed surface of a 36 inch wide felt in a four-ply membrane should be 8-1/2 inches.

PMR: **Protected Membrane Roof** - This roofing system places insulation **above** the membrane. The insulation is covered with ballast for blow-off, fire, and UV protection.

PMR's are also known as "up-side down" roofs, and IRMA (Insulated Roof Membrane Assembly).

PMR's are discussed in Section 3.5.2.

Pond:	A surface which is incompletely drained. This results in water standing on the roof. Note: Ponds should be eliminated.
PUF:	**Spray-Applied Polyurethane Foam Roofing** - this roofing system consists of a field spray-applied polyurethane foam to a deck (either flat, sloping, or unusual shape). The foam is then coated with a thin elastomeric coating to provide fire, UV, and water protection. PUF's are discussed in Section 3.5.7.
R-Factor or R-Value:	See "**Thermal Resistance**".
Re-entrant Corner:	An inside corner of a surface, producing stress concentrations in adhered roofing or water-proofing membranes. Note: 1. Re-entrant corners should be eliminated in adhered systems. 2. See 3.9.3.
Roof Assembly:	See "**Roof System**".
Reroofing:	New roofing materials applied to an existing building. The existing roofing materials may or may not be torn off. Note: NRCA defines reroofing as the application of new materials **over** existing. However, this document uses the definition noted above.

Ridges: An upward, tenting displacement of a membrane, frequently over an insulation joint.

Note: Ridges are distinctly different from wrinkles.

Roof Failure: When a roof experiences or manifests some signs that may result in serious and costly consequences.

They are two different modes of failure - premature failure and aging failure. These are discussed in Section 9 **"REROOFING AND MAJOR ROOF REPAIR"**.

Roof System: An assembly of interacting components (including the roof deck) designed to weatherproof, and normally to insulate a building's top surface.

Note: RIEI and this document include the roof deck as part of the "system". However, NRCA excludes the deck from the "roof system" and uses the term "roof assembly" to include the deck.

Single Ply: See **Elasto/Plastic**.

Slippage: Relative lateral movement of adjacent components of a built-up membrane. It occurs mainly in roofing membranes on a slope, sometimes exposing the lower plies or even the base sheet to the weather.

Smooth Surfaced Roof: A built-up roof without aggregate surfacing.
Note: A BUR with a mineral surface cap sheet is considered a smooth surfaced roof.

Split: A membrane tear resulting from tensile stress.

Square: A roof area of 100 square feet, or enough material to cover 100 square feet of deck.

Steep Roof: A roof with a slope greater than 3 to 12.

Note: Slope is discussed in Section 3.3.1, 3.3.3, and 3.5.6.

Strawberry: A small bubble or blister in the flood coating of an aggregate surfaced membrane. The bubble of asphalt oozed up between the aggregate and is therefore visible.

Note: Strawberries are also referred to as blueberries and raspberrys.

Stripping or Strip Flashing: The technique of sealing a joint between metal and built-up membrane with one or two plies of felt or fabric and hot or cold applied bitumen.

Note: NRCA and RIEI also use this term to define the technique of taping joints between insulation boards or deck panels.

System: See "Roof System".

Tear-Off: The removal of a portion (or perhaps all) of a roofing system in preparation for reroofing.

Do not use the term "rip-off", since the Owner may envision a different definition than intended.

Thermal Resistance: An index of a material's resistance to heat flow, measured in terms of R per inch. For example, an insulation may have an R of 5. Therefore, a four inch thick piece of that particular insulation would have a total R of 20.

The R is the reciprocal of thermal conductivity (k), or the reciprocal of thermal conductance (C).

This is further discussed in Section 3.3.12.

Thermal Shock: The stress producing phenomenon resulting from sudden temperature drops in a roof membrane when, for example, a rain shower follows brilliant sunshine.

Thermal shock is discussed in Section 3.2.6.

UL: **Underwriter's Laboratories** - an organization which, among other things, classifies roof assemblies for their fire characteristics and wind-uplift resistance for insurance companies in the United States.

UV: Ultraviolet radiation: a component of solar radiation. UV can accelerate deterioration of materials by breaking primary molecular bonds.

UV is discussed in Section 3.2.7.

Vapor Retarder: A material designed to restrict the passage of water vapor through a wall or roof. For most roofs, the vapor retarder should have a perm rating of 0.5 or less.

Note:

1. The term "vapor barrier" is an outdated term for vapor retarder.

   There are very few **true** vapor barrier materials. Examples are glass and metal. These materials are rarely used for vapor control.

2. **The materials commonly used for vapor retarders do allow the migration of vapor.**

Wrinkling: Several small, closely spaced upward semicircular membrane displacements.

Note: wrinkles are distinctly different from **"ridges"**.

3.2 NATURAL ELEMENTS

3.2.1 **Weather: Impacts Upon Application and Design**

Rain (or snow), wind, and cold weather can have severe adverse effects on many roofing systems.

Generally, weather is only a critical factor during system application. Once a properly designed and constructed system is in place, weather is of little concern.

Although weather impacts application and the subsequent performance of the system, there is a direct correlation with **design**. For example, a designer should not specify a system that demands dry application conditions in an area that experiences nearly constant rain (built-up roofing is generally not appropriate for Adak).

The designer must anticipate the conditions under which a system will be installed and accordingly select an appropriate system. The contractor should take adequate measures to protect materials from the weather and to install the materials only under acceptable conditions. **However, the contractor should not be burdened with the installation of a system that is clearly not intended for, nor responsive to, the normal weather conditions at the building site.**

In Alaska, there are many areas where the "normal weather conditions" present severe obstacles to the proper application of many systems. This problem is one which should be solved primarily by the designer. With the correct design, the contractor then has a reasonable opportunity to successfully apply the roof.

3.2.1.1 Weather may also affect in-service performance of the roof:

- Snow and Ice

  Snow loads (particularly drifting) may overload the structure. Eave and valley icing may cause dams which may allow water to back up and infiltrate the building. Falling ice and snow may cause injury to building components or people.

  This is further discussed in Section 3.2.3 and 3.2.4.

- Wind

  High winds can be extremely detrimental to poorly designed, constructed, or maintained roofs. However, it is relatively easy to prevent problems associated with wind. This is further discussed in Section 3.2.2.

- Cold

Materials that are used should not be overly brittle. In particular, cold materials should not be subjected to dynamic loads (such as foot traffic to roof-top equipment). One solution to the foot traffic problem is the Protected Membrane Roof.

- Heat/Ultraviolet Radiation

Generally in Alaska, excessive solar heat and UV are of little concern. However, this is not true in many parts of the United States. Solutions include PMR, white colored membranes (or coatings), and asphalt aluminum roof coating. This is further discussed in Section 3.2.7.

All systems must be capable of accommodating the thermal movements that are induced by temperature changes. This is perhaps most critical with aluminum roof systems. This is further discussed in Section 3.5.6.

- Hail

Hailstones that fall within the State are usually soft and quite small.[1] No special considerations are deemed necessary.

In other parts of the United States, hailstones have caused extensive damage to roofs. Polyurethane foam roofs may be particularly vulnerable.

3.2.1.2 Primary Weather Considerations Related to Conditions at the Time of Application:

- Rain (or Snow)

Any rainfall (even misting) can be harmful to some systems, including built-up and spray-applied polyurethane foam roofing.

Metal roofing, shingles, and tile systems generally can be installed in fairly wet conditions if the insulation is protected from the rain or if it is not harmed by it. However, it is important for the contractor to use means and methods that minimize water infiltration and entrapment during application.

- Wind

  Metal roofing can be installed in fairly high winds, however caution must be exercised. A panel can easily become airborne, in which case it can be lethal.

  Polyurethane foam roofing has specific criteria regarding application during wind - this is discussed in Section 3.5.7.

  Sheet membranes (i.e. EPDM) can be difficult to install in moderate winds. They can also be dangerous - if a large sheet becomes airborne, it could easily take workers with it.

  Some of the tile and shingle systems (clay or concrete) can be installed in fairly high winds. Other tile and shingle systems (composition or wood) can be installed, but more effort is required to keep individual units from blowing away before they are applied.

- Cold Weather

  Cold weather has two potential impacts - it can adversely affect material properties and it **can adversely affect a worker's ability to do a good job**. Oftentimes this latter element is overlooked. For example, EPDM sheet, splice cleaner/primer, and splice adhesive materials may be capable of withstanding 10° F at the time of application. However a worker's hands may become numb, thereby making it impossible to roll seams with the required force, or the worker may simply do the work too fast in order to get out of the cold. Tedious difficult flashing details suffer the most from these conditions. This is unfortunate for they are usually the most likely to leak, even when installed under favorable conditions.

Built-up systems require the material to be within a specific temperature range during application. If this is not maintained bonding problems are likely.

Polyurethane foam roofing has fixed lower end temperature requirements.

Shingles and tiles generally are not impacted by cold weather application.

Metal systems generally are not impacted by cold weather application. However it is important for the installer to realize the metal is close to its fully contracted condition at the time of application.

Cold weather will increase the amount of time required for application - people don't work as fast in the cold. Also, for some systems (BUR) extra effort is required in cold weather (insulated pipes and mopping brackets). Materials generally do not lay as nicely when cold, and some materials are destroyed by the cold (asphalt emulsion).

A primary criterion for system design should be the effects of weather on the in-service roof and, most importantly, on roof application.

3.2.2 Wind (UL and FM)

3.2.2.1 General

The **Manual of Built-Up Roof Systems** by Griffin and **Roofs** by Baker are the basis of this discussion and should be consulted if further information is needed.

Since the mid 1950's, wind uplift failures (blow-offs) have been increasingly common. The 1953 General Motors fire at Livonia, Michigan dramatically illustrated the hazards of attaching insulation to metal decks with asphalt. Subsequently, the use of cold adhesives became common.

However, these adhesives oftentimes proved to be unsatisfactory. The other change that led to increased blow-offs was the increasing use of metal decks that were relatively flexible. Also, the methodology to calculate wind forces was perhaps not as accurate as believed.

Changes in ANSI and FM documents in 1982 and 1984 should result in significantly fewer blow-offs. ANSI (American National Standards Institute) **Building Code Requirements for Minimum Design Loads in Buildings and Other Structures** (ANSI A58.1 - 1982) underwent extensive revision from the 1972 version. This was subsequently incorporated into the 1982 edition of the Uniform Building Code and several FM documents.

The primary concern with wind is blow-off of the membrane (and perhaps the insulation and deck). When this occurs, significant water infiltration is possible. However, wind can cause other less severe problems - these are discussed at the end of this section.

Repair of major roof damage is discussed in Section 9 "**REROOFING AND MAJOR ROOF REPAIR**".

3.2.2.2 Wind Forces

Structural loads should be analyzed in terms of the UBC, FM 1-7, and the **DOT/PF Design Standards Manual - Buildings, Part II** (Section 3 "**STRUCTURAL CRITERIA**").

> **Note: The basic wind speed in FM 1-28 is for 100 year mean recurrence interval. The 1982 UBC and the DOT/PF Manual noted above are for 50 years. Therefore, the basic wind speeds in FM 1-28 are greater.**

Designers should be aware that local conditions and/or unique aspects of the building may not be fully accommodated by the Basic Wind Speed map. Wind tunnel analysis may be necessary for some Projects.

Wind usually lifts roofs by: suction, internal pressure or lifting/peeling.

- Suction: The upward deflection of wind when it strikes a wall and then passes over a nearly flat roof reduces the pressure above the roof. Higher pressure within the building pushes air through joints in the deck and insulation, resulting in an upward force on the underside of the covering.

- Internal pressure: Wind entering through doors, windows, and other openings creates high pressures within a building. The additional pressure caused by this infiltration adds to the pressure differential caused by the suction.

  This condition is particularly critical with overhangs/canopys and buildings with large door openings that may be left in the open position (warehouses, maintenance shops, etc.).

- Lifting and Peeling: When perimeter edge flashing assemblies are inadequately secured, wind can lift and remove the assembly, leaving the end of the roof covering unprotected. Peeling of the membrane, insulation, and perhaps lifting of the deck may then occur. As peeling progresses, a sail may be created, which in turn may lead to significant loss of material.

  According to FM data, about 60% of all blow-offs start with failure at the perimeter edge flashing assembly.[2]

Ballooning is a suction failure that occurs in the field of the roof. With ballooning, a poorly attached membrane (or membrane and insulation) billows in an undulating wave. Ballooning can quickly enlarge in area. Once a large area is unattached, blow-off can easily occur. Ballooning can occur with a loose-laid membrane dut to air leakage through the deck. This is further discussed in Section 3.5.2.

Partially attached elasto/plastic membranes are subject to ballooning. This is further discussed in Section 3.5.4.

Wind flutter is similar to ballooning, except the deflection amplitudes are much smaller. Flutter is usually associated with metal roofing systems. The fluttering (or vibration type movements) can fatigue the metal and work fasteners loose.

The greatest suction forces occur when the wind strikes the leading corner of the building on a 45 degree angle. Suction pressure coefficients on flat roofs are affected by parapets. High parapets (five feet or greater) may reduce the coefficient by a factor of 3.[3] Parapets approximately 18 inches high create maximum uplifts. Baker's book has several drawings which illustrate pressure coefficients of flat and sloping roofs, roofs with and without parapets, and roofs with and without overhangs. **It is important to realize that very large uplift forces can occur near the corners of the buildings.**

3.2.2.3 UL and FM

UL and FM have made significant contributions to the roofing industry in terms of fire and wind performance. **However, neither UL or FM test for water integrity of the roof!**

UL publishes a list of roof-deck assemblies rated **Class 30, 60 or 90,** depending upon their successful resistance to oscillating external pressure that relates to nominal wind velocities of 100, 142, or 174 miles per hour. The list of tested assemblies is published annually in **UL Building Materials Directory,** "Roof Deck Constructions". These assemblies are tested in accordance with UL 580.

FM tests metal deck assemblies for wind and fire. Cementitious decks are only tested for wind. There are two ratings - I-60 and I-90. To qualify for I-60 the roof-deck assembly must withstand 60 PSF of uplift. In general, where winds exceed 88 mph, I-90 is required. However, the pressure tables in FM 1-28 should be consulted. Assemblies meeting I-60 and I-90 are published annually in the FM **Approval Guide.**

In addition to the roof-deck assembly uplift tests, FM reviews and comments on other items. The **Approval Guide** lists a number of roofing system components. FM 1-7 **(Wind Forces on Buildings and Other Structures)** contains general information. FM 1-28 **(Insulated Steel Deck)** contains specific information regarding insulation attachment. FM 1-49 **(Perimeter Flashing)** contains specific information regarding metal thickness and fastener spacing.

FM 1-28, 1-49, and the Approval Guide are documents the Designer and Contractor should be familiar with.

3.2.2.4 Ballasted and Protected Membrane Roofs.

Wind-uplift mechanics on ballasted and protected membrane roofs are quite different than those of fully adhered systems. With adhered systems, an area of lost adhesion no longer contributes to the roof's uplift resistance. Due to low peeling shear strengths, the unadhered area can quickly enlarge. However with a ballasted system, an uplifted area simply shifts its ballast to an adjacent area, whose uplift resistance is therefore increased. (Note: with aggregate ballast, further resistance is provided by the use of a filter fabric between the membrane and aggregate.)

The mechanism for the lightweight mortar-faced PMR insulation (Dow Chemical LG [Lightguard]) is somewhat different than aggregate or paver ballast. With this system, the insulation boards are interlocked with one another. In addition, straps or pavers are also placed at high uplift areas. In essence, a raft is formed across the entire roof surface. As uplift begins to occur, the load is transferred to adjacent boards, which are in areas of reduced stress. With this system, ballast shift is not desired nor expected. Very few uplift failures have occurred with this system. Where problems have occurred, usually only a few boards in the high stress area have blown off. However in very high wind areas, loss of just a few boards could be serious, since wind could channel itself between the membrane and boards. If the resultant uplift force caused rotation at the tongue and groove joint, displacement of the boards could occur.

If a loose-laid membrane is used, preventing air pressure from developing between the membrane and substrate is absolutely critical with the mortar-faced system. Air pressure is less critical with aggregate and paver systems, but high wind areas may require additional ballast or paver strapping.

PMR's and wind is further discussed in Section 3.5.2.

3.2.2.5 Field Tests

FM 1-52 **(Field Uplift Tests)** presents criteria for two types of field tests. The Negative Pressure Test is nondestructive (unless the assembly fails). The Pull Test is destructive.

Both test procedures are generally only applicable to adhered systems. These tests may be helpful in evaluating roofs when there are questions regarding their uplift resistance. However, neither test is recommended as a routine procedure.

3.2.2.6 Other Wind Related Problems

Blow-offs are generally catastrophic events, and hence are the major concern regarding wind. However there are other problems related to wind scour, aggregate blow-off, wind driven water/snow, and accessories blow-off.

- Wind Scour: the removal of aggregate (either on a BUR or ballasted roof) by wind. This usually occurs at a corner, and the area is generally quite small. Often times, the scoured aggregate is piled nearby.

  In a BUR, scour can lead to accelerated weathering of the bitumen and felts. With a PMR, UV degradation or loss of the insulation boards below can occur. With a loose-laid ballasted system, ballooning can occur, which could cause over-stressing at seams or the parapet/edge flashing interface.

  Repair of wind scour is discussed under "Repair Work by Owner" in Section 7 "**MAINTENANCE**".

- Aggregate Blow-off: with aggregate blow-off, the aggregate leaves the roof (which may or may not happen with scour). With blow-off, the membrane may or may not be exposed.

If the membrane is exposed, the concerns are the same as those with scour. However, usually the primary concern is the potential damage to adjacent buildings, equipment (airplanes), and people. Blow-off can be mitigated by increasing the stone size, increasing the parapet height, using pavers in lieu of aggregate (on PMR or ballasted roofs), double surfacing (BUR), or omitting the aggregate entirely (BUR). Double surfacing and other BUR surface options are discussed in Section 3.5.3.

o Wind driven water/snow: Wind can force water up a vertical plane. Water infiltration can occur when flashing assemblies are too low and are not constructed for water immersion. A chart showing the relationship of wind speed to vertical water drive occurs in Section 3.9.3.

Wind driven snow can penetrate even complex baffles in ridge, eave, and gable vents and air intakes. This is an acute problem where the snow particles are very small (typical of the North Slope).

In areas such as Adak, horizontally driven rain can penetrate mechanical relief air vents and other similar items if the cap or hood does not extend down far enough over the penetration opening. Many standard components are only designed for vertical rainfall and hence are vulnerable to horizontal rain. This is further discussed in Section 3.3.14.

o Accessories Blow-Off: Various items (primarily mechanical) such as relief air hoods and roof-top mechanical equipment are vulnerable to blow-off. If blow-off occurs, the penetration is subject to water infiltration. Also, the piece of equipment could damage the roof as it tumbles away. This is further discussed in Section 3.3.15.

3.2.2.7 Air Foils and Other Devices of the Future

Although they will not become common place, air foils could be placed on buildings. Positive pressures or reduced negative pressures could thus be created where otherwise high negative pressures would occur. Of course the advent of foils would present connection detail problems and visual considerations.

In the future, considerable work and increase in knowledge can be expected in regards to wind and partially attached elasto/plastic, ballasted loose-laid, and PMR systems. In particular, considerable study regarding the lightweight mortar-faced insulation PMR system is anticipated. At the current time (1984) it is difficult to judge current practice - are we overly conservative and therefore needlessly spending too much money, or are we not conservative enough and therefore subjecting the building to an abnormally high blow-off risk?

3.2.3 Ice

The effects/concerns of ice on roofs is related to roof slope:

3.2.3.1 Flat Roofs

Although some people believe ice can cause membrane splitting or cracking, there is little to support this theory. The thermal coefficient of linear movement of ice is close enough to that of BUR components to generally avoid problems, especially since both ice and roofing will creep.[4] The strain induced in the ice by contraction is relatively small because the ice is weak in tension and it soon cracks to relieve it. The strain induced in the membrane will be less than that in ice, and is normally much less than the strain required to cause membrane failure.[5]

Since water increases 9% in volume when it turns to ice, ice formations in existing membrane defects could propagate the defective area. Small splits, fishmouths, and deep alligator cracks may be enlarged by the expansive ice force.

Baker reports cases of related ice-membrane splitting. These involve heavy layers of ice. It is believed that a sudden release of stress in the ice (due to splitting) is transferred to the membrane as an impact force. Another unusual phenomenon is related to **ice-thrust** forces. If there are parapets and deep water over an entire roof surface, large thrust forces may occur at the parapet during ice formation.

Ice dams can occur on flat roofs - these are usually located near a wall/roof intersection and are related to snow drifting. If an ice dam is formed and protected by drifted snow (which provides insulation), water may accumulate between the dam and the wall. The water may become sufficiently deep to subject base flashings to a head of water, which could lead to water infiltration. This is further discussed in Section 3.3.2 and 3.3.14.

Icing of overflow scuppers is usually of little concern, since it probably won't occur. However icing and resulting thrust forces and damage are of concern with active scuppers. See 3.3.2 as noted above.

It is important to not locate roof drains or drain lines in cold ceiling spaces (such as unheated canopies or overhangs), since freeze-up and breakage could occur.

The concerns of ice on flat roofs are greatly mitigated with proper slope for drainage. Protected Membrane Roofs also alleviate ice concerns.

3.2.3.2 Sloping Roofs

Icing on sloping roofs is of great concern due to potential problems related to:

- o Eave/valley ice dams and potential water infiltration.
- o Damage to eave due to weight of ice accumulation.
- o Falling ice.

Ice Formation: If snow can accumulate, **ice formation should be anticipated on all sloping roof eaves.** Irrespective of the thermal resistance of the roof and ventilation of the "attic" space (cold roof concept), icing will occur. Failure to recognize and respond to this fact may lead to one or all three of the above noted problems.

Icing should be expected in early and late winter. In early winter, the first snow fall to "stick" will often be followed by a day time warming trend, thus causing melting. At night, cooler temperatures will often cause freezing of the snow melt. In the spring, warm day time temperatures cause melting, followed by colder night time temperatures. Thus, ice formation occurs, whether or not the building is well insulated or built utilizing the cold roof concept. During the winter, icing is dependent upon warming trends, building heat loss, or solar radiation. Of course, snow accumulation on the roof is the key element. Sometimes, icing can be caused by "freezing rain". When this occurs, usually the entire roof structure is glazed with ice.

The amount of melting due to solar radiation is highly variable and depends on factors such as snow properties, depth of snow, wind, slope of roof, and building orientation. Transmission of radiation into deep snow can cause some melting, but transmission through shallow depths for absorption at the roof surface is usually the more significant factor. At Ottawa, Canada enough sunlight can be transmitted through a six inch snow cover on a clear winter day to cause melting at the roof surface, even when the outside temperature is as low as 10°F, with an attic temperature of only 25°F. [6]

3.2.3.2.2 Ice Dams: In addition to the ice formation at eaves, valleys are also capable of being dammed. When dams occur in either location, water may back-up behind the dam. If the roof is designed only for water-shedding, rather than waterproofing, water infiltration may occur. Special precautions should therefore be taken at eaves and valleys, as discussed in Section 3.3.3.

Snow guards placed too close to the eave may facilitate ice daming.

3.2.3.2.3 Ice Loading: **Significant loads can be placed on the eave by edge icing and icicle formation.** Both architectural and structural components of the eave assembly should be capable of withstanding these live loads.

3.2.3.2.4 Gutters: **Where icing conditions occur, gutters should not be used.** Other design means should be utilized to protect people and building components below from water run-off.

When used, gutters are subject to icing. Therefore, the gutter and gutter supports should be capable of taking the weight of ice within the gutter and icicles attached to it. Gutters are further discussed in Section 3.3.3.

3.2.3.2.5 Falling Ice: When the ambient temperature rises above freezing, the eave ice usually melts rapidly at its contact with the roof.

When this occurs, the ice mass may suddenly break loose, thus creating a hazard to people or building components below. **The design of the building must recognize this fact.** Main egress points should not occur under eaves - they should be placed at rakes or at flat roof areas. Due to reduced risk, **minor** egress points may be acceptable at eaves. Various landscape features (retaining walls, shrubs, etc.) should be utilized where people are likely to inadvertently walk under icicles.

Building components such as lower roofs below eaves are also vulnerable. Ice guards on lower sloping roofs may be required (see Section 3.3.3). If a lower roof is flat, adequate protection is probably afforded by a PMR with paver ballast. If sloped glazing occurs below an eave, design revisions are probably necessary.

3.2.3.3 Non-Solutions

The use of heat cables to prevent icing is considered a "non-solution".

They consume energy and their reliability is questionable. Manually cleaning ice and snow is also a "non-solution". This is expensive, risky to personnel, and may result in roof damage. As immediate temporary relief, either of these measures may be justifiable. However, they should not be considered as permanent solutions. If removal occurs, the roof should be closely inspected the following spring for damage. Specific observation should occur for at least two years, since it may be a while before the damage is apparent. Snow and ice removal is further discussed in Section 7.

3.2.3.4 Source

Roofs by Baker was the basis for the discussion on ice and should be consulted if further information is needed.

3.2.4 Snow

3.2.4.1 Structural Considerations

With snow, the primary concern is the amount and disposition of live load transmitted to the structure. **Catastrophic failure can result from snow accumulation.**

The basis for snow load requirements for flat and sloping roofs is ANSI (American National Standards Institute) **Building Code Requirements for Minimum Design Loads in Buildings and Other Structures** (ANSI A58.1 - 1982). This was incorporated into the 1982 edition of the Uniform Building Code. **The changes between the 1972 and 1982 versions of ANSI A 58.1 are significant.** Among other things, the following items are now taken into consideration in snow load analysis:

- Thermal resistance of the roof system.
- Importance Factor: critical facilities and facilities with high occupancy load are assigned a greater safety factor.

- Exposure Factor: takes into consideration the likelihood of snow removal by wind.

- Drifts are more fully accounted for and weight of the drift mass (in terms of per cubic foot) is given.

The DOT/PF Design Standards Manual - Buildings, Part II (Section 3 "STRUCTURAL CRITERIA") presents snow load criteria (based upon ANSI A58.1).

Structural analysis and design for snow loads shall be in accordance with and meet the minimal requirements of Section 3. A ground snow load map for the State occurs in Section 3. Cautions regarding its use are noted in that Section.

Section 3 of the Design Standards Manual discusses drifting due to adjacent buildings. If a new structure is built within twenty (20) feet of an existing structure, both shall be analyzed for drifting caused by the adjacent building. **Retro-fit of the existing building may be required.**

Snow drift modeling may be necessary on some Projects in order to more fully analyze drift patterns. Unusual terrain or complex/unusally shaped structures are likely candidates.

In addition to loading of the structure, snow presents other concerns:

- Sliding snow.

- Deflection considerations.

- Covering outside air intakes.

- Source of melt water.

- Snow removal.

3.2.4.2 Sliding Snow

Section 3 of the Design Standards Manual discusses snow slides from high to low roofs, and the resultant structural concerns. Sliding snow can also be hazardous to people or other building components below eaves. Sliding snow may also be detrimental to various roofing accessories. **Canadian Building Digest** 228 ("Sliding Snow on Sloping Roofs" by D.A. Taylor, November 1983) discusses the mechanics of sliding snow and presents methodology for determining the trajectory of a block of sliding snow and hence, the footprint of the impact zone.

Roof-top elements (plumbing vents, chimneys, corners, parapets, gutters, snow guards, etc.) may be damaged or even sheared off by snow slides. **Sliding forces must be determined and compared with the strength of the various roof-top elements.** Taylor presents criteria for analyzing these forces.

Snow guards (see Section 3.3.3) serve to keep snow from sliding, hence no snow load reduction should be taken. Section 3 of the Design Standards Manual takes this into account.

3.2.4.3 Deflection Considerations

Under full design live load, considerable structural deflection may occur, particularly with long-span steel members. Problems could occur at base and counterflashing assemblies. For example, if the base and counter-flashing is attached to a wall supported by a stiff beam (or if the wall is a bearing wall) and the adjacent roofing is supported by a beam with a large live load deflection, damage to the membrane or flashing assembly should be anticipated (see Section 3.9.3).

In addition to creating roofing problems, large structural deflections can affect interior mechanical, electrical and architectural components. Providing stiffer members may oftentimes be prudent.

3.2.4.4 Outside Air Intakes

Snow can block outside air intakes. Wall louvers should not be located where they can be covered by drifts, and they should be placed far enough above the roof surface to prevent blockage by the uniform snow depth. Intake devices in the field of the roof should be mounted on curbs that are high enough to prevent snow coverage.

Exhaust air outlets usually do not present problems, since the warm air generally melts the surrounding snow. However, ice formation and subsequent water immersion of counterflashing may occur (see Section 3.2.3).

3.2.4.5 Source of Melt Water

Snow is a source of melt water, which often leads to ice formation, which is discussed in Section 3.2.3.

3.2.4.6 Snow Removal

Snow removal by shoveling or snow blowers/ plows should not be necessary. This is expensive, risky to personnel, and may result in roof damage. As immediate temporary relief, removal may be justifiable. However, it should not be considered a permanent solution. If removal occurs, the roof should be closely inspected the following spring for damage.

Specific observation should occur for at least two years, since it may be a while before the damage is apparent.

Snow removal is further discussed in Section 7.

3.2.5 Vapor, Humidity, Moisture, and Condensation

3.2.5.1 General:

Physical processes responsible for material degradation are controlled by a complex set of variables usually involving oxygen, heat and sunlight. Water is required for most processes and it's presence, in conjunction with other variables, usually aggravates material degradation. It is often the medium that brings together the forces responsible for destructive chemical reactions.

Limiting the moisture content of materials is mandatory to ensure their longevity. The success of the roof (and other building components) depends, among other things, on how well the designer, contractor and owner are able to allow for **moisture control**.

"Vapor", "humidity", "moisture", and "condensation" are a family of terms that must be well understood:

- Water Vapor: The gaseous state of water.
- Humidity: Dampness.
- Moisture: Moderate degree of dampness; slight wetness.
- Condensation: The process through which vapor liquefies as the air temperature drops or atmospheric pressure rises. "Condensation" is also used in describing water in its liquid state.
- Dew Point: The temperature at which water condenses into liquid.

The **Manual of Built-Up Roof Systems** by Griffin and **Roofs** by Baker are the basis of this discussion and should be consulted if further information is needed.

3.2.5.2 Harmful Effects:

Excessive moisture can cause physical, chemical, and biological harm to materials.

- o Dimensional Changes: Some materials experience significant expansion/contraction, depending on moisture content. If installed wet, some materials may split as they dry. Or, dry materials over a damp substrate may split as the substrate shrinks. If in-service materials get wet, they may swell and buckle, thereby breaking bonds with adjacent materials.

- o Freeze-Thaw: As materials go through freeze-thaw cycles, they may be harmed by the expansive forces that occur as water is transformed into ice. Materials with a cellular or interstitial moisture saturation greater than 75 to 80 percent will likely be damaged.

- o Blistering: The presence of water may aggravate blister growth or delamination of materials due to the expansive forces created by the conversion of water into water vapor.

- o R-Factor Reduction: As the cells or interstices of insulation fill with moisture, the thermal resistance is decreased.

- o Corrosion: Metals are subject to corrosion processes that are largely electrolytic in nature. The electrolyte is provided by water. Corrosion may be very serious, since it can quickly disintegrate small structural components such as nails, screws, light gage clip angles, and metal decks.

- o Leaching and Staining: As water moves in a liquid state through the pores of a material, it may dissolve salts or other water soluble substances and carry them to a surface, where they are deposited. Efflorescence of masonry walls is a common example. This process is responsible for the unsightly stains that commonly occur on walls and ceilings from roof leaks.

- o Biological Deterioration: Organic materials can be quickly destroyed by fungi, bacteria, algae, insects, small rodents, and birds. Materials are attacked because they **are** a food source, because they are a barrier **to** a food source, or because they provide shelter or a place of attachment during the life of an organism.

  Wood "dry rot" is a common example. Even in Alaska, fungus growth can occur. With a moisture content of 25 - 30%, rotting should be expected. However, a content of 20% or below is necessary to ensure no fungi growth, unless the wood is pressure preservative treated. Once wood rotting has commenced, the fungi can produce the water it needs by the breakdown of cellulose. Although fungus goes dormant in the winter, complete loss of structural integrity of plywood sheets and 2 x framing members has been observed in Anchorage in less than five years.[7]

3.2.5.3 To overcome problems presented by excessive moisture, it is important to fully understand the family of terms previously presented:

- o **Vapor**

  Water in its gaseous state is not harmful - the problems occur when it condenses to its liquid state or freezes. However, **while it is in its gaseous state, it more freely moves through materials.** Vapor may easily pass through a material that is otherwise impervious to water. It is, therefore, easy to create **moisture traps**. Moisture traps are commonly created between vapor retarders and the roof membrane. Vapor penetrates the retarder by diffusion or air leakage. However, as it passes through the insulation towards the exterior skin of the building, it condenses when it reaches the dew point. Dew point is further discussed in Section 3.3.12. After it condenses, the water in its liquid state cannot penetrate back through the vapor retarder, hence build-up of moisture can occur within the insulation system.

Vapor migration is facilitated by a **vapor pressure differential**. In Alaska in the winter, there is a greater vapor pressure inside buildings than outside. This pressure depends on two variables - temperature and relative humidity. Of these two variables, temperature is the most important. Vapor pressure increases **exponentially** with increasing temperature, but only **linearly** with increasing relative humidity. Thus, there is low exterior vapor pressure in cold weather. In hot weather, the direction of vapor flow reverses - the drive is from the exterior to the interior. **Reversed conditions can also occur in the winter time with freezer buildings.** Griffin and Baker present methodology for determining direction of vapor flow. However, **in most of Alaska during the vast majority of the year, vapor will flow towards the exterior of the building.** The exceptions may be in temperate coastal portions of southeast Alaska. As noted, **freezer buildings should be carefully evaluated for primary direction of flow** (see 3.3.12.11).

Vapor migration occurs by **diffusion** and **air leakage**. Compared with heat transmission, diffusion corresponds roughly to conduction and air leakage corresponds precisely to convection. Diffusion can be explained by the kinetic theory of gases, which Griffin thoroughly covers. In essence, there is a movement of water molecules from a region of high to a region of low vapor pressure.

This movement (based upon differential vapor pressures) occurs regardless of the total atmospheric pressure. Hence, **it is possible to have inward air flow and outward vapor diffusion.**

Although diffusion is the mechanism generally thought of for migration, **air leakage is perhaps a greater concern.** Designer's should be thinking about **air retarders**, as discussed in 3.3.11, **since a tremendous quantity of water can be transferred by air movement.** Holes through vapor retarders at plumbing vents for example, can allow a large quantity of moist air to flow into an attic space where it can condense and turn to ice in winter time. Air leakage is promoted by differential pressures created by wind, by temperature differences between the interior and the exterior, interior pressurization by the building's mechanical system, and on tall buildings by "chimney effect". **The realities of construction provide many opportunities for air flow.** The designer's concept of the building plays an important role in this aspect, as well as proper execution of the work by the contractor. However, **a prudent designer will recognize that some air leakage is inevitable and will develop a design that will accommodate it.**

o **Humidity**

Even very cold air contains some moisture. **Relative humidity** is the ratio of the actual vapor pressure to a saturated (100% relative humidity) air-vapor mixture at a constant temperature and overall atmospheric pressure.

At a given temperature and air content of vapor, the vapor condenses to water (or ice) and goes from an unharmful state to a potentially harmful one. Griffin and Baker present information for determining what temperature and humidity combinations are possible without condensation occurring.

Realizing the harmful aspects of excessive moisture, and the potential risk of increasing the interior level of humidity, **artificial humidification should be avoided.** Where artificial humidification is necessary, the humidity level should be kept as low as possible (i.e., if 35% is acceptable, don't pump in 50%), and the roof design should accommodate this additional moisture burden.

Buildings are "naturally" humidified by the presence of people and by various activities such as cooking and laundering. Controlling/-accommodating natural and artificial moisture is discussed at the end of this section.

o **Moisture**

The problems of excessive moisture have previously been discussed, however, what is considered "excessive"? All "in-service" materials have an **equilibrium moisture content** (EMC). The EMC is the moisture content of a given material at a given temperature and relative humidity, expressed as a percentage of moisture by weight. **If a material is at its EMC, it will generally appear and feel "dry", even though it has a residual moisture level.** As long as materials are at their EMC, problems related to moisture should not be experienced. Materials have some "reserve capacity" to absorb additional moisture without the development of problems. Just what this reserve capacity is depends upon the specific material and in-service conditions (such as freeze-thaw cycling, temperature, etc.).

Some degree of dampness is often acceptable for a short time, if the source of the moisture gain is blocked. Subsequent drying trends (discussed at the end of this section) often allow the material to once again reach its EMC without permanent harm occurring to the material or the system of which it is a part. However, once a mechanism (such as a membrane puncture) for moisture gain develops, it usually isn't discovered and corrected until materials have become saturated and permanently damaged.

The difficult question that is usually faced when there are problems with moisture is "**is the material dry enough to remain in place?**" For a variety of reasons, it may be desirable to leave it, but as noted above, this could be a disastrous course of action. The successful answer requires judgement and experience and is dependent on a host of factors, as discussed in this section and in Section 7 **"MAINTENANCE"** and Section 9 **"REROOFING AND MAJOR ROOF REPAIR"**. Griffin's discussion of the self-drying roof system presents criteria and methodology that may be useful in answering this question. However, it is important to remember that much of that work was based upon laboratory studies that may not accurately reflect the in-service conditions of your problem.

- **Condensation**

  As previously noted, water vapor is not harmful until it condenses. In order for condensation to occur, the water molecules must hit a sub-dew point obstruction. Simply passing thorough sub-dew point air will not cause condensation. However, in buildings, obstructions are abundant. Condensation can occur on surfaces (underside of metal roof deck) or in the interstitial spaces of materials. **Interstitial condensation is perhaps the most insidious,** since moisture accumulation may continue over a long period of time and cause considerable damage before it is discovered.

  Surface condensation will often drip and be mistaken for a roof leak. Since the problem is from within, membrane replacement will not alleviate this condition. As noted in Section 7 and 8, problem identification is paramount prior to taking corrective action.

3.2.5.4 Moisture Control

It is important to be aware of the various sources for moisture gain. **The roofing system design must be capable of accommodating the moisture that cannot be eliminated by reasonable control techniques.** Sources of moisture are:

- The initial moisture content of fabricated materials (plywood, insulation, etc.) as they leave the factory. This content may be the EMC of the in-service material, but more likely it is less or greater.

- Moisture gain while materials are being transported to the construction site and while they are stored at the site. Since Alaska is so far from most material sources, **gain during transportation is very possible** - particularly the 2,000 mile stretch of ocean via barges.

Although specifications are usually adequate in their on-site storage requirements, how often do contractors take adequate measures? It is not uncommon to see plugs of asphalt uncovered, or pallets of perlite insulation protected only by their factory wrap, which is often torn. When materials are covered, usually they are covered by polyethylene sheets that are directly on the material. Hence, condensation (which is inevitable) will likely be transferred to the "protected" material.

o **During application of materials, considerable moisture gain may occur, and some pick-up is likely.** Although BUR application should not occur in mist or rain, it is likely the wood nailers at parapets, or the plywood substrate at base flashings were exposed to rain prior to application of the membrane and flashing. **Entrapment of this residual construction moisture is of significant concern.**

A further example to illustrate this problem is a building in a wet coastal area (i.e., Aleutian Chain) where rain is usually expected. The steeply sloped roof system is composed of T & G wood decking, covered with a vapor retarder. Over the retarder, a layer of insulation is placed, along with wood nailers. A second layer of insulation is placed, along with additional nailers perpendicular to those below. Directly over the insulation, plywood is fastened to the nailers. Building paper and composition shingles are then applied. Although this may be a good system, it involves a lot of components that take time to install. Unless the contractor is concerned about water entrapment and takes adequate measures to prevent it, a **considerable** amount of water could be trapped in this system. Unless the fasteners between the nailers and deck were corrosion resistant, they could soon loose integrity and blow-off could occur. Unless the nailers and plywood were preservative treated, dry rot could make them useless in a few years. Unless the insulation was extruded polystryene, R-value reduction (and perhaps degradation) would occur. Due to lack of ventilation and use of vapor retarder, **loss of this residual moisture may never occur.** In addition to these very serious structural considerations, interior drippage or staining could occur for some time after construction, as the water slowly migrates through the various system voids and then leaks through holes in the retarder.

The above example illustrates only one situation where significant moisture gain can occur during construction and then lead to very grave consequences. Other considerations during construction relate to creation of moisture within the building, which will generally flow towards the exterior. Unvented portable space heaters inject one gallon of water into the space for each gallon of fuel oil consumed, and propane heaters inject 30 gallons per 200 pound tank. Hydrating materials (plaster, concrete) also release a great quantity of material. A four inch thick slab releases approximately one ton of water per 1000 square feet of surface area. **Due to added cost, contractors seldom adequately ventilate and thus eliminate much of this moisture. Often specified ventilation requirements are not enforced.** The net effect is the roof (and wall) system may contend with interior humidity levels well above design conditions, or they may be subjected to high humidity prior to system completion. This latter condition commonly occurs with exterior walls where insulation is installed, **followed** by the vapor retarder. Thus, moisture from a space heater can flow unrestricted through the insulation until it reaches the dew point and then condenses. It then becomes trapped by the vapor retarder.

- After the building is completed, it is subjected to moisture gain from "natural" and perhaps artificial humidification.

- After the building is completed, it is subjected to potential moisture gain from rain, snow, and ice accumulation. Defects in design, materials, application, maintenance, or acts of nature can permit moisture entry through the roof, wall, or components (air intakes, vent baffles, etc.) thereof.

3.2.5.5 System Design

It is imperative the system's design is able to accommodate moisture gain. Likewise, moisture control measures are of extreme importance.

- Throughout most of Alaska, a vapor retarder should be used. See Section 3.3.11. The contractor should use caution in constructing it. The inspector should check it's integrity.

- If moisture traps cannot be prevented, an extremely efficient retarder should be specified.

- Spaces with very high artificial humidification (swimming pools, computer rooms, hospitals, etc.) should have a Protected Membrane Roof if a flat system is used, or it should be equipped with a very efficient vapor retarder. A significant ventilation space should be provided if a steep sloping system is used.

- The design should accommodate the application of an air retarder (which is probably also the vapor retarder). The Contract Documents should describe this and the Contractor should use caution in constructing it. The inspector should check it's integrity.

- **Ventilation is perhaps the key element. Where it can be provided (which in general includes all steep roofs), it should be considered.** See Section 3.3.2 and 3.3.3.

- Non-corrosive fasteners (preferably stainless steel) should be specified due to potential problems of residual construction moisture and the devastating consequence of fastener corrosion. This includes light gage framing connectors and clip angles, (however, galvanized steel is generally adequate).

- Preservative pressure treated wood should be specified where moisture entrapment is likely. The Code may require the use of fire retardant treated wood for some projects. Depending upon fire retardant chemicals used, preservative treatment may or may not be offered by the fire retardant chemicals. This may dictate other design solutions.

- o Materials that are not very susceptible to moisture gain should be considered (i.e., fiberglass instead of organic felt).

- o The HVAC system should provide the least acceptable building pressure.

- o Moisture sensitive materials should be protected while in shipment to the site. "Alaskan Wrap" should be specified where appropriate.

  Note: "Alaskan Wrap" refers to special packaging measures that are used in trans-ocean shipment of materials to Alaska.

- o Materials should be properly stored on site. Inspectors should enforce the specifications and manufacturer's recommendations.

- o Contractors should follow, and inspectors should enforce the specifications and manufacturer's recommendations regarding application and moisture.

- o HVAC and humidification equipment should be periodically checked to ensure it is operating as intended.

- o Semi-annual roof observations should occur as discussed in Section 7 **"MAINTENANCE"**.

3.2.5.5 Self-Drying Roof System

Griffin discusses a self-drying roof system and the results of a six year research program conducted by the National Bureau of Standards. Although this system is not applicable to most (if any) parts of Alaska, the research regarding it revealed some interesting data.

Buildings (roofs and walls) go through natural wetting and drying trends. During winter moisture migrates into the wall and roof system, while in summer moisture migrates out. If the drying equals or nearly equals the wetting, there will be little or no long term moisture gain. **Unfortunately, in most parts of the State, the number of weeks per year when drying takes place is limited. Therefore, moisture control measures previously identified are of great importance in Alaska.**

3.2.6 Thermal Shock

Thermal shock is the term for the stress producing phenomenon resulting from sudden temperature drops in a roof membrane. Brilliant sunshine followed by rain is a common example.

Thermal Shock Factor (TSF) is an **index** of a membrane's ability to withstand thermal stress. TSF is a **calculated** criterion, set at 100°F (for BUR membranes), for the temperature drop that must be theoretically resisted by a membrane test sample clamped at constant length. The formula for calculating TSF is presented by Griffin, along with extensive discussion.

Desirable membrane characteristics for good thermal shock resistance are:

- High tensile strength
- Low load/strain modulus
- Low coefficient of thermal contraction - expansion

The TSF concept offers a standard for comparing different membranes solely on their resistance to thermal stress. Essentially, it is an index of the membrane's reserve strength for resisting tensile stress from other sources - substrate movement, stress concentrations of one sort or another, etc. The higher a membrane's TSF, the greater its reserve strength to resist these other sources.

The majority of the past work regarding TSF is related to BUR. Most commercially marketed and well constructed BUR membranes easily satisfy TSF criteria when new. TSF for most elasto/ plastic membranes have not been established.

As BUR membranes age, they decline in TSF due to age-hardening and consequent rise in load/strain modulus and increase in thermal coefficient. Griffin reports a TSF reduction of up to 70%. However the TSF criterion established for BUR takes this reduction into consideration.

Protected Membrane Roofs alleviate the concerns of thermal shock (except for exposed base flashings).

3.2.7 Solar Radiation

3.2.7.1 General

This discussion is primarily based upon **Roofs** by Baker and the **Manual of Built-up Roof Systems** by Griffin. These should be consulted if further information is needed.

Solar radiation is short-wave electromagnetic energy. It is made up of:

- Ultraviolet (3%)
- Visible light (43%)
- Infrared (54%)

Solar radiation is one of the elements of the **weathering process** that, in combination with water and oxygen, can cause rapid degradation of some exposed materials. Fortunately, the two weather elements (water and radiation) do not usually occur simultaneously. However **standing water from poor drainage presents conditions for accelerated deterioration.** The weathering combination of oxygen and radiation is referred to as **photo-oxidation**. Griffin reports bitumen degration accelerates to a rate 200 times faster in sunlight and water than in the dark.

3.2.7.2 Ultraviolet Radiation (UV)

Many of the polymers used in organic building materials are composed of long-chained molecules with carbon-to-carbon backbones that can be disrupted by UV. Chemical deterioration from UV can take two forms:

- The UV energy starts a process (in some materials) which is the reverse of the polymerization reaction that originally produced the large molecules. The polymer may be broken in isolated locations (called chain scission) or it may completely revert to small molecules. This is referred to as "unzipping" the polymer, which only occurs slowly when radiation is the only factor.

- In the other form of chemical deterioration, the small molecules produced by chain scission or reactive sites on large molecules, react with other chains. This results in more crosslinking than was originally present, so the material becomes harder and more brittle.

UV must be absorbed for chemical deterioration to occur. Not all materials that are irradiated absorb radiation. Hence, this is the basis of some measures to reduce the effect of UV on materials, such as using polymers that do not absorb UV or adding materials that reflect or absorb the UV.

3.2.7.3 Infrared and Visible Radiation

The only chemical effect of infrared and visible radiation is to **heat** up the material and **speed up the rate of reactions** that may be occurring from other causes. However, these are important factors. Baker reports a doubling of the rate of material deterioration with every 18°F rise in temperature.

The temperature that roofing materials experience during their service life will have considerable influence on their performance. This is due to the chemical effect noted above and the thermal expansion and contraction movements associated with temperature changes. Thermal contraction of adhered membranes can create large stresses which must be transferred uniformly to a deck that is capable of resisting them. Poorly attached insulation or plys do not have uniform stress distribution. Hence splitting can occur. The most common problem associated with thermal movements is the bonding of metal flashings with the membrane. When two materials have different coefficients of expansion and are subjected to the same change in temperature they will be stressed. Often times, the stresses are large enough to cause damage to the assembly. Baker presents charts and graphs regarding this. Securely fastening the metal, or totally isolating the metal is generally necessary to prevent these problems.

Besides thermal movements, temperature increases soften some materials, which may cause slippage. Also, moisture entrapped in the roofing system can exert considerable pressure when heated.

Protected Membrane Roofs alleviate the concerns of solar radiation (except for exposed base flashings).

3.2.8 Fire (UL and FM)

3.2.8.1 General

The RIEI **Roofing Technology Course Manual** ("U/L, F/M, and Code Requirements", September 1980), the RIEI **Elasto/Plastic Sheet Applied Roofing Systems Course Manual** ("Performance Criteria and Testing for Wind and Fire Resistance", October 1981) and the **Manual of Built-Up Roof Systems** by Griffin are the basis for this discussion and should be consulted if further information is desired.

The roof system can be a major contributor to the spread of fire. This is in part due to the great amount of combustibles that make up most systems. This was dramatically illustrated by the General Motors Transmission Plant fire in Livonia, Michigan in 1953. The fire spread throughout the entire 30 acre (1,306,800 square feet) roof area and caused a 35 million dollar loss and total collapse of the structure.

The Livonia fire was the impetus for setting the standards for internal fire spread. In establishing requirements for roofing systems, three different conditions are considered.

- o External Fire Exposure
- o Internal Fire Spread
- o Internal Fire Resistance

3.2.8.2 External Fire Exposure

This exposure results from fires in roof-top equipment or burning brands from adjacent building or forest fires. The roof system should reduce the risk from this exposure by not spreading flame rapidly, by not producing flying brands, and by not permitting ignition of the roof deck.

UL has done most of the work regarding external exposure. Test method UL 790 (which is promulgated by ASTM as E108) defines the fire resistance performance for roof coverings. Three classifications are assigned:

- o Class A: Greatest resistance to fire
- o Class B: Moderate resistance to fire
- o Class C: Light resistance to fire

It should be realized that **even Class A coverings may allow flame spread.**

A number of factors affect the classification:

- o Slope
- o Surfacing material
- o Quantity of surfacing material
- o Composition of the membrane
- o Subsurface materials - as they affect surface burning.

It is important to correlate the design condition with the UL listed condition. For example, a material may have a Class B listing on low slope roofs and a Class C on steep slopes.

3.2.8.3 Internal Fire Spread

This situation is concerned with the **spread of fire by the roofing system**, which is initially ignited by the heat caused by a fire within a building.

The General Motors plant had a metal roof deck topped with a 2-ply vapor retarder which consisted of asphalt saturated felts mopped in place with asphalt. This was covered with one inch rigid insulation and a three ply BUR. During the initial stage of the fire, heat on the underside of the metal deck was quickly transferred to the vapor retarder. This liberated combustible gases in the asphalt. These pressurized gases were unable to escape up through the roof covering, so consequently they were forced down through the metal deck joints. The gases were then ignited by high heat or flame. **Thus the spread of fire was governed by the release and flow of gas from the roofing system.**

Subsequent testing showed that construction similar to the GM plant would allow fire to spread 100 feet in 10.5 minutes. Through a series of tests, it was determined that an acceptable level of performance for a slow self-propagating fire was 60 feet in 30 minutes. This was achievable by mechanically fastening non-combustible insulation directly to the deck, followed by the vapor retarder, additional insulation, and the BUR membrane.

FM and UL developed small scale test methods to evaluate fire spread performance of roof systems. FM and UL differ in their philosophy and techniques. This is described in detail in the resources previously referenced, as well as in UBC Standard 17-4.

Roof systems that have successfully passed UL fire spread criteria are described in the **UL Building Materials Directory** under "Roof Deck Constructions".

Roof systems that have successfully passed FM criteria are described in the FM **Approval Guide**. FM has two categories - systems that require sprinklers, and those that do not. Acceptable unsprinklered assemblies are:

- o Class I steel deck assemblies
- o Noncombustible decks (i.e. concrete)
- o Wood decks treated with fire retardant chemicals.

Acceptable sprinklered assemblies are:

- o Class II steel deck assemblies
- o Combustible decks (i.e. untreated wood).

The small scale test methods previously noted have proved to be reliable indicators of anticipated in-service performance. However some very small scale tests (ASTM D1692) failed to exhibit the hazards of plastic foam insulation when these products were first introduced into construction in the early 1970's. Fortunately the larger scale UL and FM tests did give the same results as experienced in actual fires, thus validating the larger scale tests. These tests showed that polyurethane insulation failed FM and UL criteria due to their burning characteristics and also because they melted and lost their ability to isolate the BUR membrane from the fire. Polyurethane was found to be acceptable when a suitable material (i.e. perlite or rigid fiberglass) was placed between the deck and the polyurethane. A more recent development is glass fiber reinforced polyisocyanurate and phenolic insulation (see Section 3.4.3 **"Roof Insulation Materials"**). Under fire load, this insulation chars and maintains enough integrity to satisfactorily isolate the BUR membrane from the fire.

In a related development, UL conducted a series of full scale fire tests on spray-applied polyurethane foam roofing applied to metal decks. Some systems, when properly constructed with specific deck, foam, and coatings, are "classified" for resistance to internal and external fire exposure.

3.2.8.4 Internal Fire Resistance

This situation is concerned with the resistance of containment performance of the roof-ceiling assembly to the upward passage of heat and flame and their resistance to collapse because of elevated temperatures due to an internal fire. The test method used to evaluate assemblies is described in ASTM E119, which is also promulgated as UL 263, NFPA 251, and ANSI A2.1. This test utilizes a time-temperature rating. Typically, roof-ceiling assemblies are non-rated, 1 hour, 1½ hours, or 2 hours.

Except with thermally massive decks (i.e. concrete), the increase in R-value that has come about since the mid-1970's raises questions regarding fire resistance. During a fire, the increased thermal efficiency of the roofing system results in an increased ceiling space temperature, which could accelerate structural problems.

Many of the assemblies that have been tested used a minimal amount of insulation. **Hence, increasing the insulation could affect the rating of the assembly.** This is an area where additional research and testing is needed to more fully understand the interaction of the thermal efficiency of the system and its time-temperature resistance. ASTM E 119 Assemblies tested and approved by FM are listed in their "Specification Tested Building Materials Guide".

Roof systems that have successfully passed UL fire resistance criteria are described in the **UL Fire Resistance Directory.** It is necessary for the designer and contractor to carefully follow the details in the **Directory** in order to obtain the desired resistance.

3.2.8.5 Codes and Standards

The following summarizes the applicable Codes and Standards:

3.2.8.5.1 UBC (1982)

- o Plastic foam insulation and vapor retarders are addressed in 1712, 1713, and 3204.

Note:

- 1712 (a) requires a thermal barrier between the interior of the building and plastic foam.

- 1712 (b) allows elimination of the thermal barrier when the plastic foam is part of Class A, B or C roof covering assembly, provided the entire assembly meets UBC Standard No. 17-4.

- 1712 (b) 5 allows any roof covering allowed by Code over plastic foam, when the foam is separated from the interior by plywood sheathing (or equivalent) with edge support. With this condition, the thermal barrier is not required.

- Fire resistive requirements are addressed in Table 17-A, 1806, and 1906.

- Roof coverings are addressed in 3202 (b) and 3203 (e) and (f).

- Table 43-C identifies various roof systems and their fire resistance.

3.2.8.5.2 UL

- UBC defines where Class A, B, and C roof coverings are required. UBC Standard No. 32-7 defines testing procedures for classification (32-7 is based on UL 790). The **UL Building Materials Directory** lists those materials that have been successfully tested in accordance with UL 790.

- UBC defines the required fire resistance of roof systems. UBC Standard 43-1 defines the testing procedures (43-1 is based on ASTM E119). ASTM E119 is equivalent to UL 263. The **UL Fire Resistance Directory** contains systems that have been successfully tested in accordance with UL 263.

Note: Assemblies in the **Fire Resistive Directory** are not tested for wind uplift resistance.

- The **UL Building Materials Directory** contains systems that have been successfully tested for spread of fire on the underside of the deck. Some of these systems are also tested for wind uplift resistance (in accordance with UL 580).

  Note: **The UBC does not reference or require testing for this fire spread**, except per 1712 (b) 5, which relates to plastic foam. 1712 (b) 5 references UBC Standard 17-4, which is based on UL and FM internal fire spread test methods.

3.2.8.5.3 FM

FM is primarily concerned with fire spread on the underside of the roof deck and with wind uplift and hail resistance. The primary documents of concern to the roof designer and contractor are **FM 1-28 (Insulated Steel Deck)**, **FM 1-47 (Roof Coverings)**, and the **FM Approval Guide**.

3.2.8.5.4 DOT/PF **Roofing Standards**

- **FM or UL shall be followed for internal fire spread.**

- UBC shall be followed for external fire exposure and internal fire resistance.

  Note: as previously noted, UBC does reference UL and FM for internal fire spread under given conditions. However the DOT/PF **Roofing Standards require** compliance with FM or UL for internal fire exposure.

3.2.8.6 **Testing, Marking, and Approval**

UL and FM tests various products to determine if they meet specific criteria. Both UL and FM have a follow-up program that serves to insure that products currently produced are still in compliance.

Products covered by the initial tests and subsequent follow-up program are allowed to bear a UL or FM mark. FM does "approve" products, however their label may or may not say "approved". UL does not "approve" products - it "lists" or "classifies" them. Hence, correct terminology is:

- o FM Approved
- o UL Listed or Classified.

Manufacturer's are not obligated to label all of their materials with the FM or UL mark. Products which do not bear the mark are not required to comply with FM or UL requirements. Accordingly, the appearance of a manufacturer's name in UL or FM literature does not assure that products will be or have been produced under FM or UL criteria. **It is therefore mandatory that materials at the job be marked. This should be specified and checked by the inspector.** Materials that are specified to be marked should not be incorporated into the Work if they are without marks.

3.2.8.7 Maintenance and Reroofing

Reroofing can adversely affect external an internal resistance as well as internal flame spread. For Example:

- o The application of some roof maintenance coatings can decrease the external resistance of the system, thereby potentially making the building in violation of the Code.

- o Additional insulation (as described in Section 9 **"REROOFING AND MAJOR ROOF REPAIR"**) may adversely affect the internal fire resistance.

Fire aspects must be considered.

3.2.8.8 Explosion, Smoke, and Heat Venting

See Section 3.3.8

3.3 BUILDING ELEMENTS

3.3.1 Slope

3.3.1.1 General

Slope is an element the designer usually has control of - the exception being some existing conditions. **SLOPE IS PERHAPS THE GREATEST SINGLE DESIGN ASPECT THAT CAN SIGNIFICANTLY AFFECT THE PERFORMANCE OF THE ROOFING SYSTEM.**

- **Dead level roofs shall be avoided.**

- **Flat roofs should not have any areas of standing water.**

  This is often difficult to achieve. For example, the low point of the roof may be a beam/column intersection, which prohibits the installation of the drain at the low point.

- **Unless designed as waterproofing rather than water-shedding elements, sloping roofs should be steep. All sloping roofs should be designed for glaciation at eaves and valleys.**

3.3.1.2. Providing slope serves three functions

- **With slope, a membrane defect may not present a problem.** For example, an EPDM seam failure may be of no consequence in a Protected Membrane Roof if the seam is properly shingled. Water would simply flow down hill across the defective seam. In a PMR system, there would be no concern regarding wind driven water entry, or propagation of seam/membrane failure due to wind.

- If infiltration occurs at a defect (such as a split), **the amount of infiltration will be greater if the defect is under water**, versus being only exposed to water run-off. With decreased infiltration, there will probably be decreased damage.

- Water in combination with sunlight is very detrimental to many materials (see Section 3.2.7). Eliminating ponding water will slow down the natural weathering process for these materials.

3.3.1.3 Developing Slope

Slope for flat roofs can be achieved by sloping the structure, by using a deck of varying thickness, by using tapered insulation, by using crickets, or a combination of any of these. Deflection should be taken into account when establishing slopes. **New roofs shall have a designed slope of approximately 1/4" per foot.**

With wood framing systems, it is difficult to eliminate ponding just with the structure itself. Steel and concrete systems allow the cutting and warping of members to the extent that all ponds may be eliminated by the structure. **Utilizing the structure to provide all (or partial) drainage should always at least be considered.**

Decks of varying thickness can also be successfully used to provide total drainage. However, of the several different materials presented in Section 3.4.1 **"Roof Deck Materials"**, usually reinforced concrete is the only deck of varying thickness encountered in Alaska.

Tapered insulation is theoretically effective however there are practical considerations that compromise this alternative.

- The type of insulation is an important consideration as discussed in Section 3.3.12 and 3.4.1.

- For adhered reroofing projects, field measurements are critical. Unfortunately, it is often impossible to obtain accurate information until tear-off occurs.

- In Alaska (as of 1984) only tapered expanded polystyrene (EPS, beadboard) is locally produced. Unfortunately EPS has many limitations (as discussed in Section 3.4.3.4). Hence, except for EPS, **obtaining tapered insulation for a small job or quickly obtaining tapered insulation after getting field measurements is either difficult, time consuming, or nearly impossible.**

Crickets are usually constructed out of tapered insulation or in some cases out of plywood. The cricket may be placed directly on the deck, or it may be placed on the insulation. **The transition from the cricket to the substrate is critical** for adhered systems. The membrane should be fully supported at the transition, which is often times very difficult.

- For many systems, perlite is a very good material for constructing crickets. It is fire resistant, can be well adhered with asphalt or plastic cement, and it can be easily field tapered and shaped. A weedwhacker is effective in shaping large areas. Debris from the shaved area should be broomed-up. The cut face should be primed with asphalt primer if a built-up membrane is applied over the perlite.

3.3.1.4 Quick Slopes

Very often, quick slopes occur on flat roofs. A quick slope is an area of the roof that has a radically different slope. For example, the majority of the roof may be sloped at 1/4" in 12", but one small area may quickly slope from a roof drain to an adjacent wall at 2" in 12". The designer is often unaware of the quick slopes. Problems can occur if the system is incapable of accommodating the abnormal condition. For example, Type II asphalt may be quite appropriate for all but the quick slope area. In this area, asphalt flow, wrinkling, or ply slippage could result.

It is important for the designer to evaluate the design for quick slope conditions. If these occur, the roof system must be designed to accommodate the slopes, or the slopes changed to suit the system.

3.3.2 Flat Roofs

3.3.2.1 General

A **flat roof** is a roof that is generally flat, but with some slope for drainage. **Dead level roofs** are absolutely horizontal. As noted in Section 3.3.1, **dead level roofs shall be avoided.**

3.3.2.2 Flat Roofs Versus Sloping Roofs

In recent years, many people have become very outspoken against flat roofs. Flat and steep roofs have their own advantages and disadvantages. **Both are viable systems**, and neither should be discarded on a whim. This is further discussed in Section 3.5.5.6).

3.3.2.3 Advantages of Flat Roofs

- There is little concern regarding sliding snow and falling ice.
- There is no concern regarding water run off at roof eaves. Hence, people entering or leaving the building are not diluged by water, nor is there any water erosion at grade (unless active scuppers are used).
- For buildings with large roof areas, large interior volumes are not required, as would be the case with sloping roofs.

3.3.2.4 Disadvantages of Flat Roofs

- Compared to steep roofs, many of the materials used for flat roofs have a shorter service life, require more maintenance, and must be installed in good weather.
- Large snow drift loads may occur. Except for the cost of the structure to support these loads, this may not be a problem if the drifts are properly accounted for (see Section 3.2.4).

- o The roof drainage and overflow system must be properly designed in order to prevent possible structural collapse of the roof system.

- o The membrane must be **waterproof**.

3.3.2.5 Roof Drainage

Controlled flow drains are rare in Alaska, and they **should be avoided.** Controlled flow drains limit the amount of water that can flow into the roof drain system. Some cities that experience large downpours require controlled flow drains in order to prevent overloading the municipal storm drainage system. With a controlled flow system, a roof can have a considerable amount of water on it for quite some time.

Water should not simply drain over the roof edge. Roof edges should be parapets or raised curbs in accordance with **NRCA Construction Details.**

Scuppers should generally not be used for the main roof drainage. For unheated roofs (such as canopies), roof drains are usually not practical due to freezing conditions. Hence, the use of scuppers may be the only viable solution. When scuppers are "active", consideration should be given to scupper glaciation, wetting of the wall below the scupper, and erosion at grade. To minimize the effects of icing, the scupper should be at least 18 to 24 inches wide. To simplify flashing, the scupper should be open at the top. The primary concern of wetting the wall is aesthetics - over time, discoloration should be expected.

Roof drains should be the primary drainage system for most flat roofs. They should be located at the actual low point of the roof - where beams do not permit this, crickets should be used to channel the water to the drain. If the drain is only 1/4" above the low point, utilizing a cricket is generally impractical and unwarranted. The insulation should be tapered to the drain to form a sump. However, with a Protected Membrane Roof, often there is very little insulation below the membrane, therefore, forming a sump may not be possible. Drains should be a minimum of three feet from parapets, edge flashings, or other penetrations in or order to allow adequate room for proper installation. **If drains are exposed they shall be a minimum of three inches in diameter. Exposed drains shall have metal domes** (although plastic domes are common, they are easily blown away when not properly set). In PMR systems, the drain shall be a minimum of two inches in diameter. See Section 5 "MASTER SPECIFICATIONS" for installation specifications. **The Architectural and Mechanical drawings and specifications require special coordination regarding roof drains** - these documents are often conflicting with one another.

Overflow drainage is required by UBC 3207 (1982). It can be provided by overflow drains or scuppers. However unless scuppers are justified due to unique conditions, **overflow drains should be used.** Overflow drains should have independent drain lines. They should also have independent dry wells, if drywells are used.

In addition to placing drains at low points, they should also be placed in areas that may have standing water due to ice dams (see Section 3.2.3).

Moisture gain and ventilation of flat roofs is discussed in Section 3.3.12.

3.3.3 Steep Roofs

3.3.3.1 General

A steep roof is defined as a roof with a slope greater than 3 to 12. However a **gently sloping roof with drainage over the edge has many of the same concerns as does a steep roof.** Steep roof "membranes" are water shedding rather than waterproofing. Roofs with a slope of less than 3 to 12 should have waterproof membranes. The steeper the roof, the less the concern regarding water back-up due to eave icing, however eave icing should always be assumed. Flat versus steep roofs is discussed in Section 3.3.2 and 3.5.5.6.

3.3.3.2 Advantages of Steep Roofs

o Except for eave icing conditions, the "membrane" only needs to be water shedding, rather than waterproofing.

- Many of the materials used for steep roofs have a very long service life.

- Many of the materials used for steep roofs require very little maintenance.

- Many of the materials used for steep roofs can be successfully installed during poor weather.

- Although with certain configurations snow drifting can occur, it generally is not a problem. See Section 3.2.4.

3.3.3.3 Disadvantages of Steep Roofs

- Falling ice can damage building components below the roof and it can harm people.

- Sliding snow can damage building components on and below the roof, and it can harm people.

- Soil erosion at the grade below eaves is possible, and nearby walls can be splattered and become quite dirty. **Significant snow or ice build-up or water run-off may occur, which in turn may present water infiltration problems at grade.**

- Very large interior volumes may be necessarily created.

3.3.3.4 Ice and Snow and Sloping Roofs (See Sections 3.2.3 and 3.2.4)

- The designer should determine if snow slides are acceptable - this is based upon possibility of damage to building components on or below the roof and possibility of harm to people. **Where conditions permit, the snow should be allowed to slide.**

Depending upon degree of slope and roof surface material, snow guards may be necessary if snow slides are to be prevented. **Guards shall be calculated.** Based upon snow weight, the strength and size of the guard, and the attachment to the roof, the quantity of guards can be determined. **Canadian Building Digest** 228 "Sliding Snow on Sloping Roofs" by D.A. Taylor (November 1983) contains pertinent related information.

The steeper the slope, the more difficult it is to retain snow (even with guards). **With most metal roofs, when the slope is greater than 3 in 12, retaining snow should be avoided.** Systems with greater surface friction (i.e., wood shakes), should be limited to 4 in 12 if snow is to be retained.

Snow guards should be at least two feet from the eave, otherwise the guard may promote eave icing.

- **Where an upper sloping roof occurs above a lower roof, falling ice must be considered.** If the lower roof is a PMR with pavers, there is probably little concern. However a PMR utilizing mortar faced insulation should have additional pavers placed at the impact area. Section 3.9.3 shows an ice guard for a metal roof.

- Eave and valley icing should always be anticipated and provisions made for backed up water. The actual provisions will depend upon the specific roofing system. With shingle and tile systems, eave and valley underlayment is required. However the provisions of UBC Chapter 32 may be inadequate - in terms of both materials and dimension. EPDM and self adhering modified bitumen sheets are good underlayments. Underlayment should also be placed under valleys of metal roofing systems. Eave underlayment may or may not be necessary with metal systems, depending upon the system used.

- A strip of metal along the eave edge of shingle and tile roofs may encourage snow to slide off and may also minimize eave icing.

However, this device is not routinely recommended, for other problems (thermal movements and through-fasteners) are then encountered.

- As previously noted, gutters are not recommended. However, if they are used, they deserve special consideration. They should be a minimum of 16 gage steel or equivalent in aluminum. They should be securely attached to the structure - the anchors should be designed to carry icicles as well as a gutter full of ice. The outer lip of the gutter should be a minimum of 1" below the roof lip, so that water or ice will flow over the gutter edge rather than back up the roof. Where possible, use open ended gutters and spill to grade rather than using downspouts. Where downspouts are used, they should be securely anchored. Assume the downspout will become completely frozen. Considerable oversizing of the gutter and downspout may help resolve the forces of the expanding ice.

- If there is an overhang, this portion of the roof should be warm if the remainder of the roof is warm, in order to minimize eave icing.

3.3.3.5 Ventilating Sloping Roofs

Ventilation should be considered for all sloping roofs. This is generally done for roofs with large unheated attics ("cold roofs"). However it is possible to ventilate roofs without attics. The ventilation space may be achieved by placing intermittent blocks under supporting clips, purlins, etc. The ventilating space may be quite small (1-½" high), hence the roof will probably be a "warm roof". However even this minor amount of ventilation offers advantages. It allows for the dissipation of moisture (either residual construction moisture, or moisture that has penetrated the vapor retarder). It also helps in minimizing eave icing by dissipating solar heat gain and building heat loss.

Depending upon degree of slope and plan dimensions, eave vents may be adequate, however the use of gable and/or ridge vents will often times be necessary. See Section 3.3.14 for further discussion on vents.

3.3.4 Structural Considerations

3.3.4.1 General

The RIEI **Roofing Technology** course manual contains a simplified chapter on "Architectural Elements and Structural Terminology".

3.3.4.2 Thermal Movements

It is important to be aware of thermal movements of the structure. The roofing system must be capable of accommodating all movements transferred to it.

With cold attics, the roof structure goes through a large thermal pendulum. Since the remainder of the structure probably doesn't see a great temperature swing, the connection between the roof structure and the remainder of the structure must be appropriately designed. For example, problems are presented by a steel roof structure transferring shear loads into the interior concrete wall. The wall is at a nearly consistent temperature, but the steel structure is experiencing large thermal movements. Overstressing of the concrete or the connectors between the steel and concrete may occur unless expansion joints are closely spaced. These joints would necessarily have to extend through the roofing system. See Section 3.3.5.

3.3.4.3 Deflections

When considering deflection, concerns are **differential deflection** and **total deflection**.

Differential deflection can result in large shear forces on the membrane. Differential deflection can be caused by having two equally stiff members adjacent to one another, but with different spans. This may occur for example in a building with precast concrete core slabs spanning from one bearing wall to another, but with some of the slabs also supported by an intermediate room divider wall. Differential deflection can also occur when adjacent, identical members have the same span, but are unequally loaded. **The concerns of differential deflection are greatly reduced when a loose-laid membrane is used.**

"Simple" deflection concerns are usually related to edge flashings/parapets at exterior walls, or base flashings at walls extending above the roof. However, deflection problems can also occur out in the field of the roof. Since deflection of simply supported members causes end rotation of the member at its support, it is possible to split an adhered membrane. For example, an 8" precast concrete core slab, simply supported and under a live load deflection of l/240, will rotate at the support and create a gap of approximately 1/4".

The most common deflection problem is related to wall conditions. If the base and counterflashing is attached to a wall or parapet supported by a stiff beam (or if the wall is a bearing wall) and the adjacent roofing is supported by a beam with a large live load deflection, damage to the membrane or flashing assembly should be anticipated. This is shown in Section 3.9.3, along with possible solutions to the problem.

It is important for the roofing designer to work closely with the structural designer. The roofing system and details must be able to accommodate the structural deflections, or the structure must be stiffened in order to reduce the amount of deflection. Roof members should be designed for a deflection of **l/240 or less. The roofing designer should be aware of the calculated total deflection under full design live loads.** See Section 3.2.4.

Lateral deflections of the structure due to wind or seismic loads can also affect the roofing system. This is normally manifested in the provision of seismic joints (see Section 3.3.5).

3.3.4.4 Decks

See Section 3.3.10 **"Roof Decks"** and 3.4.1 **"Roof Deck Materials"**. Decks shall be designed to accommodate the design dead and live load. They shall also be designed to accommodate a concentrated load of at least 300 pounds. Under these loads, deflection should be 1/240 or less.

It is mandatory the structural designer design the attachment of the deck and substrate in accordance with the pressure coefficients developed for membrane uplift (see Section 3.2.2). While blow-off failures are usually related to the flashings and membrane, occasionally the failure occurs between the deck and deck support. There have been cases where the failure occurred between the roof trusses and truss support, whereby the trusses and roof system were cleanly lifted from the building.

With adhered systems, where it is not possible to eliminate re-entrant corners in the membrane, the deck at the re-entrant area shall be securely fastened. See Section 5 **"MASTER SPECIFICATIONS"**.

3.3.4.5 Ponding

As discussed in Section 3.3.2, flat roofs should not pond water. However, if an existing roof with ponding is being evaluated, the RIEI **Basic Roofing Technology** course manual contains a monograph ("Estimating Weight of Ponded Roofing Water") that may be useful.

3.3.5 Control, Expansion, and Seismic Joints

3.3.5.1 General

A control joint is a joint through the roof membrane and insulation, but not through the deck. It is used to relieve thermal stresses **in the membrane** and **to eliminate re-entrant corners**. Control joints are also known as **area divider joints**.

An expansion joint is similar to a control joint, except the joint extends through the deck, and **the joint cover must accommodate the joint movement.** An expansion joint is used to relieve thermal stresses **in the structure**. It may also be used to relieve membrane stresses due to deflection (see 3.3.4.3).

A seismic joint is similar to an expansion joint, except the amount of movement is generally larger and movement can occur in **any** direction.

These various joints are shown in Section 3.9.3.

3.3.5.2 Control Joints

o Spacing and Location

Control joints should be used to eliminate re-entrant corners (see Section 3.3.6). They should be located so the base flashing maintains a straight line as it passes from the wall to the control joint curb.

They should also be placed approximately every **150** lineal feet to relieve membrane stress. The RIEI **Basic Roofing Technology** course manual ("Architectural Elements and Structural Terminology") recommends 150 to 200 feet, based on empirical methods. The thermal extremes (in terms of actual membrane temperature) is probably greater in many parts of the United States than in Alaska. The Interior part of the State has the greatest extremes, but how these compare with known empirical data is unknown.

Understandably, this is not a high research priority item. Also, there are few large exposed flat roofs in the State, and there has been no effort made in evaluating those that exist. **If the membrane is Protected, then there is no need to provide control joints for relieving thermal stress.**

For Protected Membrane Roofs, control joints shall be placed approximately every 150 to 200 lineal feet (maximum). However the purpose is not to control stress, rather it is **to isolate the roof into sections to facilitate future leak detection.** Finding a leak in a PMR can be extremely difficult, particularly with a loose-laid membrane (especially when it is over an existing BUR). By extending the control joint to the deck and constructing it to prevent lateral movement of water, the task of detection may be simplified.

Control joints **shall also be placed at deck discontinuities, such as a change in deck material or direction.** Control joints (or expansion, or seismic joints) shall be used to separate existing roofs from new roofs.

o Construction

Control joints **shall be placed on curbs**, similar to the details shown in Section 3.9.3. Pre-manufactured elastomeric "T" shaped control joints are available. The installed cost of these joints is much less than the illustrated raised curb joint. Also the "T" allows water to run over the joint, which the raised curb does not permit. However **the joint is a discontinuity in the membrane** and at base or edge flashings, it is difficult to effectively install and terminate the "T". If problems (i.e., fishmouths, ply separation, puncture) develop at the "T" and membrane interface, a considerable amount of water can enter the roofing system. Due to these inherent potential problems, curbs rather than "T" shall be used.

The top of the curb should align with the top of abutting edge flashings or parapets, to simplify construction of the base flashing and coping or edge flashing work.

Since the top of the control curb does not move laterally, it should be capped with a simple coping - see Section 3.3.14.

3.3.5.3 Expansion Joints

The joint should **totally separate the building into two buildings, with the only true connection between the two being the expansion joint cover.** Hence the base flashing, and edge flashing or coping cover must be severed by the expansion joint. Generally, expansion joints only assume cyclical movement in one direction.

o Spacing and Location

Since expansion joints relieve thermal stresses in the structure, their location is usually determined by the structural designer. However, involvement of the roofing designer is beneficial, for the expansion joint may also be located to solve problems normally taken care of by control joints. Also, by having the roof designer involved, the exact location of the joint may perhaps be located to eliminate a jog in the base flashing, if for example the joint terminates near a wall extending above the roof.

o Construction

Expansion joint covers shall be placed on a pair of raised curbs, similar to the details in Section 9.

The clear opening dimension between the curbs shall be the calculated contraction distance **plus one inch to allow for construction tolerances, or a minimum total designed clearance of two inches.** However, the cover need only accommodate the design movements plus one half inch for tolerance. The void space between the curbs shall be filled with mineral fiber batt insulation. The insulation shall be protected by a vapor retarder, which shall be draped to allow for expansion. **Special considerations may be necessary to accommodate required fire protection.**

The top of the joint should be covered with a metal coping as illustrated. It should align with the top of abutting edge flashings or parapets. These terminations are critical and often difficult to construct. **They shall be detailed (which may require isometric drawings).**

Premanufactured expansion joint covers using an elastomeric bellows and metal flanges are quite common. However, these are extremely difficult to successfully terminate. They are also somewhat vulnerable to mechanical damage, although termination problems are more prevalent.

3.3.5.4 Seismic Joints

As with expansion joints, the joint should totally separate the building. However, seismic joints assume cyclical movement in two directions plus there may be a small amount of differential vertical movement across the joint. **Due to this extreme freedom of movement, seismic joint covers can be very difficult to design and construct.**

o Spacing and Location

The discussion under "expansion joints" applies to seismic joints.

o Construction

Seismic joint covers shall be placed on a pair of curbs, similar to the details shown in Section 3.9.3. The clear opening dimension between the curbs shall be the calculated structural drift **plus two inches to allow for construction tolerances and insulation within the joint, or a minimum total designed clearance of three inches.** However the cover need only accommodate the design movements (both opening and closing) plus one half inch for tolerance.

Due to the complexities involved, unless significant money is spent (which is usually not justified) **a large seismic event may severely damage the joint covers.**

Although the roof should be observed after a major event, this is usually a low priority item and may not occur for some time. Therefore, **a secondary joint protection shall be placed under the top cover.** A draped elastomeric sheet (i.e. EPDM) is recommended.

The void space shall be filled as discussed under "expansion joints". **It is imperative that batts be used, in order to prevent pounding.**

The top of the joint should be covered with a metal coping similar to that discussed under "expansion joints" (except the seismic cover sees larger movements and movements in multiple directions).

3.3.6 Re-Entrant Corners

A re-entrant corner is an inside corner of a surface (see Section 3.9.3). In **adhered systems**, re-entrant corners produce stress concentrations in the roofing membrane. Sometimes these stresses exceed the membrane's strength and splits occur.

Re-entrant corners are often created by placing penthouses on the roof, or by the geometry of the building, such as an "L" shaped building. **If the roofing system is adhered, re-entrant corners should be eliminated.** This is often done with a **control joint**, as discussed in Section 3.3.5.

Sometimes it is very difficult or expensive to eliminate a re-entrant corner. If it is decided to accept this condition, it is important to **securely attach the deck** to the substructure (see Section 5) and **securely attach the insulation** to the deck. Also, **the maintenance staff should be requested to specifically observe the re-entrant corner during each semi-annual observation.**

If splitting occurs, the split should be repaired with plastic cement and glass fabric mesh, if the membrane is built-up. Repairs for other systems will depend upon the system at hand. It is important to realize the split may be somewhat active, hence **the repair should be able to accommodate some movement.**

3.3.7 Roof Access

In order to accommodate semi-annual roof observations, the roof shall be relatively accessible. Usually, due to security/safety concerns, fixed ladders from grade are not acceptable. Hence, internal ladders and roof hatches or portable ladders must be used. **However, with multiple roof levels, only internal ladders and roof hatches or fixed external ladders should be used** - portable ladders should not be depended upon.

Fixed ladders shall be wall supported, rather than supported by the roof structure. The wall brackets shall be located above the base flashing.

The ladder shall have a landing which cantilevers over the coping (or edge flashing and cant area).

Roof hatches shall be installed on raised curbs as specified in Section 5 "MASTER SPECIFICATIONS" and as illustrated in Section 3.9.3. A ladder extension is available from some hatch manufacturers. These shall be specified for internal ladders.

3.3.8 Explosion, Smoke, and Heat Venting

3.3.8.1 Code References

Uniform Building Code (1982):

910: Explosion Venting
3205: Smoke and Heat Venting
3901: Stage Roof Ventilators
3906: Platform Roof Ventilators

Uniform Fire Code (1982):

Article 76: Explosion Venting
Article 81: Venting of High-Piled Combustible Stock

National Fire Protection Association:

NFPA 204M: Guide for Smoke and Heat Venting

3.3.8.2 Explosion Venting

Explosion vents are located in walls or roofs. They are intended to relieve explosion pressures and thus minimize damage to the structure.

UBC 910 (a) 3. prohibits explosion vents on roofs where there are snow loads.

3.3.8.3 Smoke and Heat Venting

Smoke and heat vents are located in walls or roofs. They are intended to reduce dangerous heat, smoke, and toxic products of combustion that could have an explosive effect under certain conditions.

Vents are required in Group B and H occupancies per UBC 3206 and in Stages and Platforms per 3901 and 3906.

Venting serves to assist fire fighters. With vents, it usually is not necessary to cut holes in the roof. Thus the risk of fire fighting is somewhat reduced.

With sprinklered buildings, venting potentially conserves water and increases visibility within the building.

ITT Research recommends that when vents are provided for sprinklered buildings, they be provided in accordance with NFPA 204 for venting of unsprinklered buildings.

For further discussion on venting, see:

1. "Roof Vents and the Fire Fighter" by John Degenholb in the November 1981 issue of **Fire Service Today** (published by NFPA).

2. "Fire Vents and Automatic Sprinklers, A Report on an ITT Research Institute Study", by Tom Waterman in the January 1984 issue of **The Construction Specifier**.

3.3.9 Transporting Heavy Equipment Across a Roof

After the roofing system has been installed, severe membrane damage may be caused by transporting heavy equipment (i.e., roof-top HVAC unit) across the roof. This damage may not manifest itself until a few years after the occurrence.

Heavy equipment shall be transported by crane or helicopter if it is positioned after the roof is installed. Since this may be substantially more expensive than simply rolling it across the roof, this requirement shall be specified.

For new roofs, a heavy load is an item weighing over 1200 pounds (based upon interpretation of the Steel Deck Deflection Study - see Section 3.4.1.7). Such a load should only be transported on a cart with a minimum of four large pneumatic tires (similar to a roofer's cart) - rollers shall not be used. For existing roofs, the load transported by cart should be limited to approximately 600 pounds.

> Note: The above load limits assume an adhered roofing system. With a loose-laid system, greater loads may be permissible. The designer should evaluate specific circumstances prior to allowing greater loads.

3.3.10 Roof Decks

Decks serve two functions:

- Structurally, they support the live and dead loads placed upon them. Most decks also act as diaphragms by transmitting lateral (wind or seismic) forces to the remainder of the building's structural system.

- The deck is a part of the roof system; it is the base upon which the roof is built.

Usually the selection of the roof deck material is not governed by the roofing system. Other criteria have major impact on deck selection. Therefore, the roofing system selection generally begins with the deck being predetermined.

The roofing system must recognize the specific problems and attributes of the roof deck and the remainder of the building's structural system.

See Section 3.3.4 "Structural Considerations" and 3.4.1 "Roof Deck Materials".

Certain types of loose-laid membranes are very susceptible to blow-off due to air infiltration through the deck. See Section 3.3.14.1 and 3.5.2.

3.3.11 Vapor and Air Retarders

See Section 3.2.5 "Vapor, Humidity, Moisture, and Condensation" and Section 3.4.2 "Vapor Retarder Materials".

Normally the vapor retarder also acts as the air barrier. It is therefore important to realize the vapor retarder concept relates to the control of moisture by diffusion and air movement.

The term "vapor barrier" should not be used, since true vapor barriers seldom occur. Only in the 1980's has the term "vapor and air retarder" been used to any extent. This document incorporates the air barrier concept whenever it uses the term "vapor retarder".

Griffin gives methodology for calculating vapor flow by diffusion. However, due to the variables and the exclusion of vapor flow due to air movement, this calculation is rather theoretical. Generally it may be concluded that performing these calculations is of little value.

The decision to have or not to have a vapor retarder is a difficult one in many parts of the United States. Griffin suggests using one when the interior relative humidity exceeds 40% and the January temperature averages less than 35°F. UBC 3204 (1982) requires a vapor retarder where the average January temperature is below 45°F or where excessive moisture conditions are anticipated within the building. **In Alaska, a vapor retarder shall be used.**

To be considered as a vapor retarder material, the material's permeance rating should not exceed 0.1 perm. Griffin gives the perm rating of several common retarder materials.

To be effective, the retarder shall be sealed at penetrations, laps and at perimeters.

When vapor retarders are used, there is concern of a moisture trap being created. Assuming some permeance or discontinuity in the membrane, then it must be assumed that moisture can be transported into the insulation system. Built-up membranes (as well as many other types of membranes) are impermeable. Therefore the moisture is theoretically trapped between the retarder and the membrane. To compensate for this, the use of insulation moisture relief vents are recommended by some people. This is further discussed in Section 3.3.12 **"Thermal Insulation and Heat Flow"**. Water infiltrating from a roof leak can also be trapped by the retarder. If the water travels laterally along the surface of the retarder before eventually finding its way into the interior of the building, detecting the entry point at the membrane is made more difficult. Because of these concerns, it is logical to omit the retarder where climatic conditions permit. However, in Alaska the attributes of retarders exceed these negative aspects.

With Protected Membrane Roofs, the membrane may also be the vapor retarder, in which case the concerns of a moisture trap are eliminated. However, the dew point may occur in insulation below the membrane. In this case, a vapor retarder is required and a moisture trap is created. This is further discussed in Section 3.3.12 and 3.5.2.

Prior to FM's requirement to mechanically fasten insulation boards, the vapor retarder presented other problems with built-up roof systems. If the retarder was mopped directly to metal decks, a potential fire problem was created, as discussed in Section 3.2.8. If the retarder was attached with adhesives, blow-off became a concern, as discussed in Section 3.2.2. However, by mechanically fastening a thin insulation board, followed by a hot built-up retarder, followed by thicker insulation boards and a membrane as discussed in Section 3.5.3, it is possible to construct roofs with good vapor, fire and wind resistance.

As discussed in Section 3.5.6.3, sometimes it is appropriate to use a material that only retards air. When this is desired, spunbonded high density polyethylene ("Tyvek") should be considered.

3.3.12 Thermal Insulation and Heat Flow

3.3.12.1 General

The Manual of Built-up Roof Systems by Griffin, **Roofs** by Baker, the **NRCA Roofing and Waterproofing Manual** and the RIEI Basic Roof **Technology** course manual are the basis of this section and should be consulted if further information is needed.

See Section 3.4.3 "**Roof Insulation Materials**".

3.3.12.2 Purpose of Insulation

- o Provide a substrate for the roofing membrane.

  Insulation stabilizes deck components by reducing their temperature variations and consequent expansion and contraction.

  Insulation is used over decks that otherwise are unsuitable for membrane application (i.e. metal decks).

- o Insulation is often times an important element of condensation control, particularly in Alaska.

- o Insulation enhances occupant comfort (body heat loss via radiation to cold surfaces is reduced).

- o Insulation reduces the cost of energy consumption.

- o Tapered insulation can be used to provide roof slope (see Sections 3.3.1 and 3.4.3.11).

3.3.12.3 Types of Insulation

- o Rigid insulation boards. This is the most common roofing insulation (see Sections 3.4.3.1 - 3.4.3.10).
- o Cement wood fiber panels: Dual purpose deck/insulation (see Section 3.4.1.1).
- o Poured-in-place or blown-in insulating fills (see Sections 3.4.1.2, 3.4.1.8, and 3.4.3.12).
- o Spray-applied polyurethane foam (see Section 3.4.5.10).
- o Batt or blanket (see Section 3.4.3.12).

3.3.12.4 Historical Perspective

The energy crisis of the early 1970's had a profound impact on roofing.

Prior to that time, there was little concern regarding energy consumption. In South Central Alaska, the common roof insulation for built-up roofing was three inches (total thickness) of perlite (total R = 8.34).

Over a short time a factor that was not considered important became the predominate factor. This had two profound effects:

- o The traditional insulations (cellular glass, rigid fiberglass, perlite, and wood fiberboard) gave way to the newer plastic foams (polystyrene and polyurethane).

  While the foams had greatly increased insulative value, many of their other properties were highly inferior to the traditional insulations.

- o The thickness of insulation boards and the total thickness of insulation increased.

The thicker boards were far stiffer and, therefore, more difficult (or nearly impossible) to fully adhere.

Additional effects of the increased insulation are discussed in 3.3.12.7.

The rapid changes the industry went through soon resulted in numerous failures throughout the United States. This resulted in numerous studies and resultant recommendations. One of the first recommendations was NRCA's Bulletin #4 in 1978 regarding blistering over urethane insulation. Other important recommendations also emerged from the industry:

- **Use double layer application of insulation boards.**

- **Avoid use of very thick insulation boards.** Where high R-value is required, use thinner boards in multiple layers (see 3.3.12.7).

3.3.12.5 Heat Flow

- Calculations

  The **NRCA Roofing and Waterproofing Manual** presents methodology for performing several important calculations:

  - Overall coefficient of thermal transmission ("U value")

    Note: U = 1/R

  - Dew Point Temperature

  - Temperature of vapor retarder

  Since it is mandatory for the vapor retarder temperature to be above the dew point temperature, calculations are required unless it is abundantly obvious that this is the case (i.e. if all insulation is above the vapor retarder, calculations would normally not be necessary).

- Thermal Bridges

  Thermal bridges are "short circuits" through insulated elements (roofs, walls). Examples are:

  - Mechanical fasteners that penetrate the entire thickness of insulation.

    Note: If the insulation is applied in two layers and the fastener only penetrates one layer, a thermal bridge is not generally created.

  - Gaps in insulation: wide joints, broken corners.

  - Nailers between adjacent boards.

    Note: If insulation is applied in two layers and the nailer is covered by one layer of insulation, a thermal bridge is not generally created. However, if nailers also occur in the plane of the second layer of insulation, a bridge is created at the intersections of top and bottom nailers.

Thermal bridges have two primary impacts on building performance:

- Increased heat loss. This usually is not significant for mechanical fasteners or crossings of nailers but, it could be of significance if a large number of insulation boards had excessively wide joints.

- Condensation

  The greatest danger presented by thermal bridges is condensation below the vapor retarder. Condensation may occur on the interior tips of fasteners. Condensation may also occur below the vapor retarder at wide insulation joints or nailers.

  In the coldest portions of the State, the amount of condensation at thermal bridges may result in drippage. In milder areas, the condensation may be absorbed by adjacent materials or drippage may be absorbed by ceiling materials and go unnoticed and be of no consequence.

In the cold portions of the State, or in humidified buildings, thermal bridges may create significant problems.

o Temperature

It is important for the Designer to be aware of the temperature extremes that will be experienced by the roof. **The roof surface temperature range will far exceed the ambient temperature range due to radiation.** During winter nights in clear weather, the roof surface may be cooler than ambient temperature by 10°F or more (Griffin).

Solar radiation may increase the roof surface temperature by 75°F or more (Griffin).

> Note: Griffin's temperatures may not be applicable for Alaska. However, this is the only known data (as of 1985).

Designers should be aware of the thermal regimen experienced by the roof, at least in a general way. However, sometimes fairly precise data and calculations are necessary. For example, when designing aluminum roofing systems, thermal movement calculations must be performed.

3.3.12.6 Insulation Properties

The "ideal" roof insulation has the following properties:

- o Compatible with bitumen or adhesive.
- o Impact resistant.
- o Moisture resistant.
- o Unaffected by freeze-thaw.
- o Thermal Resistance: high and stable. (See discussion in Section 3.4.3.2 on RIC/TIMA).

- o Good attachment capability.
- o Dimensionally stable: temperature and moisture wise (see Griffin for discussion on warping - expansion).

Unfortunately, no insulation manufactured (as of 1985) meets all of the "ideal" properties. Many of the traditional insulations have many of the ideal properties, except for high thermal resistance.

The critical task for the Designer is to evaluate all aspects of the roof and determine which insulation is suitable for each specific job. The following must be considered:

- o Shipment of insulation to the site.
- o Site storage of the insulation.
- o Anticipated weather conditions during and after application.
- o Type of deck.
- o Type of membrane.
- o Anticipated impact loads during and after construction.
- o Effects of freeze-thaw if the insulation becomes wet.
- o Desired amount of thermal resistance.
- o Attachment capability suitable for anticipated wind loadings.
- o Dimension stability suitable for the selected system.

Section 3.4.3 "**Roof Insulation Materials**" gives information to assist the Designer in material selection.

3.3.12.7 Effects of Increased Insulation Thickness

As discussed in 3.3.12.4, the Energy Crisis resulted in thicker insulation, both in terms of total insulation thickness and the thickness of individual boards. 3.3.12.4 discussed attachment problems of the thicker boards. Unless properly attached, stress concentrations could lead to membrane splitting.

Increased thickness also has other ramifications:

- o Increased thickness results in reduced horizontal shear resistance to membrane contraction. Membrane splitting could result, especially in cold weather.

- Increased thickness results in more rapid thermal contraction which increases the splitting hazard.

- Increased thickness increases the frequency of cycles of thermal expansion and contraction in the membrane.

- Increased thickness increases the surface temperature which may accelerate the aging process.

  Note: The effect of thickness on temperature is far less than originally thought. Griffin reports the color of the roof has a far greater impact on surface temperature. Also, he states the first one-half inch of insulation has a greater impact on surface temperature than the next four inches.

Much of the foregoing discussion is only applicable to exposed built-up membranes. The use of Protected Membrane systems or the use of some elasto/plastic membranes in certain configurations eliminates all or most of the concerns noted.

- Increased thickness results in increased cost. Prior to designing a very high R-value, life-cycle costing should be considered. This costing will obviously consider energy and insulation costs. However, there are two other important considerations:

  - Impact upon roofing performance.
  - Potential dollar loss if failure occurs.

  These latter considerations may be of no significance if the appropriate roofing system is selected.

The November 1983 issue of **Tremco News** discusses the cost effectiveness of high R-values. It states that conservation of heat is not proportional to the increase in R-value. For example, it states that in the case of an R-40 roof, the first R-10 saves 84.2% of all heat energy, while the last R-30 conserves only 15.8%.

See Section 9, "Reroofing and Major Roof Repair" for discussion on thermal upgrade.

3.3.12.8 Moisture and Venting

3.3.12.8.1 Moisture

Moisture can have profound impacts on insulation performance:

- Absorption results in reduced thermal resistance, which increases energy consumption.

  With reduced R-value, the dew point may fall below the vapor retarder and result in condensation problems.

- If the insulation contains excessive moisture at the time of application, it may dry and shrink while it is in service. This could cause membrane splitting.

- Material degradation: Wood fiberboard can rot, perlite can loose its compressive strength and become mushy, the binder in rigid fiberglass can degrade over time, cellular glass cells are broken by freeze thaw cycles.

  Note: Although rigid fiberglass eventually breaks down, this process takes considerable time.

Particularly for Alaska, insulation is vulnerable while it is in shipment from the manufacturing site to the roofing site. It is also quite vulnerable while stored at the roofing site.

As discussed in Section 3.2.5 materials have an Equilibrium Moisture Content (EMC). The EMC for the various insulation products vary. The EMC is generally of no concern to the Designer, however, if tests are conducted on material taken from a roof, it is necessary to know what the EMC is, so that it can be compared to the actual moisture content of the sample.

3.3.12.8.2 Venting

Venting may be used to dissipate residual construction moisture and moisture that penetrates the vapor and air retarder. **Venting is not intended to dissipate water infiltration.**

If insulation in a built-up or adhered elasto/plastic system becomes saturated, rarely will it dry out, even with the installation of vents. If it is damp and the source of the dampness has been eliminated, it may dry out over time due to the building's natural drying trend. However, depending upon the length of time this takes and the type of insulation, the insulation may be harmed and it could require removal.

There are three primary ventilation methods:

- o Roof vents (also referred to as moisture relief vents). These are utilized in flat roofing.
- o Edge vents (eave and ridge vents if the roof is steeply sloped).
- o Underside vents

  Note: Underside vents are used for venting lightweight insulating concrete.

Although roof vents are recommended by many, Wayne Tobiasson's (CRREL) work has shown the ineffectiveness of these items. [8] These devices should not be used.

Eave and ridge vents for sleeply sloped roofs are very effective and should at least be considered.

Edge vents are used in flat roofing systems, in conjunction with insulation boards that are grooved to allow horizontal moisture migration to the roof edge. In lieu of grooved insulation, some base sheets are manufactured to allow horizontal moisture migration. The parapet wall is designed to allow moisture reaching the wall to migrate up along the wall and out underneath the coping. **However, horizontal moisture flow does not occur to any significant degree in flat roofing systems.**

Note: Lateral migration does occur when there is a difference in vertical elevation across the roof plane and a migration pathway is provided. However, this requires a steeply sloped roofing system. For further information see ASTM STP 779 **"Moisture Migration In Buildings"**, (in particular, page 29).

3.3.12.9 Anchoring Insulation

3.3.12.9.1 Adhered Systems (Built-up and Elasto/Plastic)

With adhered roofing systems it is vital to securely anchor the insulation boards to resist wind blow-off and to uniformly transfer membrane stress to the roof deck. Poorly attached boards often results in blow-offs or membrane splitting.

On metal decks, the first layer of all insulation boards shall be mechanically fastened in accordance with FM 1-28 "Insulated Steel Deck". The second layer shall be set in a full mopping of hot asphalt or full bed of adhesive. This is referred to as "nail one-mop one".

Note:

1. With an elasto/plastic system, it may not be economical to use asphalt to secure the second layer. Accordingly, the use of neoprene or butyl or similar type of adhesive may be appropriate. Verify the appropriateness of the system design and material selection with the adhesive and insulation manufacturers.

2. The layer of asphalt between the insulation boards will retard vapor flow to some degree. The Designer shall evaluate this potential and resultant impacts.

   Although the layer of asphalt retards vapor flow, this is insufficient to function as a vapor retarder.

3. In many instances, a vapor retarder can be effectively placed over the first layer of insulation. In this location, it is not penetrated by fasteners.

   Typically, the retarder will consist of a layer of felt set in asphalt. With higher humidities, a more effective vapor retarder should be constructed by using two layers of felt (each set in hot asphalt).

When the vapor retarder is sandwiched between insulation layers, the dew point must be above the vapor retarder.

In some instances, the use of mechanical fasteners through the entire insulation assembly may be appropriate but, in general, this should be avoided (see 3.3.12.5).

Other decks types have not presented the number of problems experienced with metal decks. Some other decks are suitable for either mechanical or fully adhered attachment. See Section 3.4.1 for recommendations regarding specific deck types.

Note: Sometimes a layer of rosin-sized sheathing paper and a layer of ply felt are mechanically attached to the deck and the insulation is set in hot asphalt.

3.3.12.9.2 Partially Attached Elasto/Plastic Systems

All insulation boards shall be attached with either mechanical fasteners or fully adhered.

Note: Depending upon spacing of the membrane fasteners, these fasteners alone may meet this requirement.

3.3.12.9.3 Loose-Laid Systems

Insulation below the membrane does not require attachment, unless it is used as an element for control of air infiltration through the deck (see Section 3.5.2).

If it is windy during application or if a delay in application of ballasting is anticipated, the Contractor may elect to install a minimum number of fasteners (i.e. one or two) per board in order to keeping the boards from walking.

3.3.12.10 Joints

- In general, insulation boards should be tightly a butted and joints should be staggered. The second layer of insulation should be offset from the layer below.

  These procedures reduce energy consumption and increase the structural integrity of the insulation system.

- **Joints should be filled or taped prior to covering with a fiberglass ply felt.** Otherwise, asphalt from the first interply mopping will run through the first felt and into the joint. When this happens, a felt-to-felt asphalt void is created.

  Hot asphalt can be used to fill the joint where there is no possibility of asphalt drippage or possibility of melting the insulation. Alternatively the joint could be taped with a 6" wide strip of organic felt set in hot asphalt.

  The top layer of rigid fiberglass insulation should always be taped (primarily due to it's low compressive strength). A special fiberglass tape should be used.

  With fully adhered systems it is important to avoid excessive adhesive in the joints otherwise, solvents may not flash-off and ridges may occur. This can be avoided by taping the joint, however, the tape must be capable of securely adhering to the insulation and the adhesive must be capable of securely adhering to the tape.

- Ridging

  Ridging commonly occurs with built-up systems applied over a single layer of insulation, particularly when the vapor retarder is insufficient.

Residual construction moisture, or vapor penetrating the vapor retarder can flow unimpeded to the underside of the membrane along the insulation joints, where it condenses. With cumulative moisture absorption, organic and asbestos felts swell and buckle, thus forming ridges directly above the insulation joint (Griffin).

Ridging can be avoided by using a double layer of insulation and filling/taping the joints as discussed above. Fiberglass ply felts should be used in lieu of organic or asbestos felts.

> Note: Some people suggest the use of a base sheet, however, as discussed in Section 3.4.4.2.5.2, base sheets are not recommended.

3.3.12.11 Buildings With Refrigerated Interiors

Buildings that have refrigerated (or freezer) interiors require special consideration. The recommended solution is to provide a refrigerated (or freezer) compartment within the building. Warm building air should surround the compartment.

Significant potential problems arise when the walls or roof of the compartment is the building's exterior walls or roof. See Griffin for further information.

3.3.13 Membranes

3.3.13.1 General

The term "membrane" refers to roof covering materials whose primary function is the exclusion of water.

Normally, the membrane is thought of as being a waterproofing element composed of built-up or elasto/plastic materials. However, this document also considers shingles, tiles, and metal panels as "membranes".

3.3.13.2 Built-up Membranes

In 1974 "Preliminary Performance Criteria for Bituminous Membrane Roofing" (Building Science Series 55, National Bureau of Standards), by R. G. Mathey and W. C. Cullen, was published.

This landmark document promulgated primary performance attributes required by built-up membranes:

- Tensile Strength
- Notch Tensile Strength
- Tensile Fatigue Strength
- Limited Creep
- Flexural Strength
- Flexural Fatigue Strength
- Pliability
- Shear Strength
- Impact Resistance
- Ply Adhesion
- Fire Resistance
- Fungus-attack Resistance

Form this list of required attributes a performance format of 10 criteria was developed. Each criteria had a stated requirement, criterion, test method, and commentary. A major goal of the preliminary performance criteria was to aid manufacturer's developing new built-up membranes with scientific means of evaluating the membrane's prospective performance during it's service life.

3.3.13.3 Other Membranes

Many of the performance attributes identified for built-up membranes are also applicable to other membranes, however, other types of membranes may require additional attributes.

With other membranes, criterion for a specific attribute will likely be different. The establishment of these criterion is greatly needed.

MRCA has issued two documents that may be of value, although they are somewhat simplified:

- Recommended Performance Criteria for Elastomeric Single Ply Roof Membrane Systems, Technical Document ME-20, November, 1982.

- Recommmended Performance Criteria for PVC Single Ply Roof Membrane Systems, Technical Document MP-10, November, 1981.

3.3.13.3 Membrane Materials

Built-up membrane materials are discussed in Section 3.4.4. Non-conventional roofing system materials are discussed in Section 3.4.5. Steep roofing materials are discussed in Section 3.4.6.

3.3.14 Roof Penetrations and Perimeters, Flashings, and Sealants

3.3.14.1 Roof Penetrations and Perimeters

3.3.14.1.1 General

- Roof-top equipment is discussed in Section 3.3.15.

- **Pitch pockets shall not be used with roofs on new buildings.** Pitch pockets shall not be used in reroofing projects, unless there are no other viable options. Where they are used, storm collars shall be provided. Also see "Tech Talk" in the December 1985 issue of the **Roofing Spec.**

- **Due to increased risk of leakage, the number of penetrations shall be minimized.** This is further discussed in Section 3.3.18. in the December 1985 issue of the **Roofing Spec.**

o The distance between penetrations shall be adequate (i.e. perhaps 2 - 3 feet) to allow room for the roofer to proprely flash the penetration. Likewise, there should be adequate room between penetrations and adjacent walls or parapet walls.

Detail V in the **NRCA Roofing and Waterproofing Manual** presents guidelines for minimum spacing between pipe (i.e. VTR) penetrations.

In reroofing projects, consideration shall be given to relocating poorly located penetrations. Although this may be costly, if existing conditions place the reroofing in jeopardy, relocation is prudent.

o In the colder portions of the State, metal (i.e. lead flashing at roof drains and VTR's, and edge flashings) should not be built into the membrane.

Note: Lead flashing at roof drains in Protected Membrane Systems is acceptable.

For VTR's, detail F in the **NRCA Manual** should be used in lieu of lead flashing.

The only viable solution for edge flashings is not use them. Instead, parapet walls with copings should be used.

o Penetrations shall accommodate deck deflections. If the penetration is supported by the deck and therefore deflects in unison with the deck, special considerations are not usually necessary. **However, if the penetration is not deck supported, the penetration must be detailed to accommodate the deflection differential.**

o Curbs

Roof accessories (i.e. roof hatch, skylight) and mechanical units (i.e. fans, hoods) shall be mounted on curbs, rather than placed directly on the plane of the membrane.

Curbs should be field fabricated of wood (plywood where appropriate) rather than factory fabricated of metal.

Curbs in Protected Membrane Roofs should be protected as discussed in Section 3.5.2.

See Section 3.9.3 for standard details.

- o Wood nailers are usually used for securing flashings. Nailers should be attached in accordance with Factory Mutual 1-49, "Perimeter Flashing".

  Where the Code permits, nailers shall be preservative treated. If fire retardant treated wood is required, exterior grade treatment should be used.

  Oil borne preservative treatment should not be used with bituminous materials, since the solvent may cause bitumen degradation and drippage.

- o Where penetrations block the flow of water, crickets shall be considered. Usually, penetrations with a dimension less than three feet will not require a cricket.

- o Air Leakage: See discussion in Section 3.3.14.2

3.3.14.2 Perimeters

- o Portions of the discussion in Section 3.3.14.1 are applicable to perimeters.

- o Perimeters should be in accordance with Factory Mutual 1-49.

- o Loose-laid Membranes

  Ballasted or protected loose-laid membranes may be susceptible to blow-off if air pressure develops below the membrane. Pressure may develop by air infiltrating through the roof deck or infiltrating at roof penetrations or perimeters.

Development of air pressure below loose-laid membranes ballasted by mortar-faced insulation boards are particularly vulnerable to blow-off.

The design and detailing of the roofing system and proper construction thereof is critical.

3.3.14.2 Flashings

This section discusses sheet metal flashings (i.e. copings, counter-flashings, reglets) that are used in conjunction with roofing. A full discussion on flashings is beyond the scope of this document, however, the critical aspects of sheet metal in relation to roofing are briefly discussed.

3.3.14.2.1 General

Sheet metal work should comply with applicable portions of:

- **Architectural Sheet Metal Manual,** by the Sheet Metal and Air Conditioning Contractors National Association (SMACNA).

- Factory Mutual (FM) 1-49 "**Perimeter Flashing**".

- The Aluminum Association, Inc. has a number of technical manuals that discuss the various alloy and temper properties, and it has information regarding various uses of aluminum architectural sheet metal.

All sheet metal work should be well above the membrane (i.e. eight inches). A common analogy is the bath tub concept: assume the roof is covered by eight inches of water - no sheet metal should be in water.

3.3.14.2.2 Materials

- Aluminum is the most common material used. Aluminum sheet metal should comply with ASTM B 209.

  Alloy and Temper:

  - Cleats should typically be 6061-T6.

  - Copings, counterflashings, and other general sheet metal work should typically be 3003-H14. For very windy areas (i.e. Aleutian Chain), 5052-H32 should be considered.

  Where possible, formed rather than extruded material should be utilized. This allows job-site fabrication and shop fabrication within the State, which usually is advantageous.

- Galvanized sheet metal should comply with ASTM A525 or A527 if it is lock-formed. Galvanizing should comply with G90 hot-dip galvanizing.

  If steel rather than aluminum is desired, in lieu of galvanized sheet metal, zinc/aluminum ("Zincalume") coated steel should be considered, especially in corrosive environments (i.e. coastal areas).

  Note: See discussion in Section 3.5.6.3.

- Other metals (i.e. copper, stainless steel) are suitable for sheet metal work but, due to cost, they are not routinely used.

3.3.14.2.3 Finishes

Unfinshed sheet metal (i.e. mill finish aluminum galvanized steel, or zinc/aluminum coated steel) is recommended. Successful (long lasting) field painting of aluminum or galvanized steel is possible but, unlikely and is not recommended. Shop applied fluoropolymer ("Kynar") is an excellent long lasting coating. However, as of 1985, there were no fluoropolymer coating shops in Alaska. Therefore, the use of these coatings greatly increases the Contractor's work. Fluoropolymer coatings are only recommended on "high profile" projects.

3.3.14.2.4 Copings and Counterflashings

For aluminum, 0.050 inch thick material is usually recommended. Thicker material is required on unusually wide profiles.

Copings and counterflashings shall be secured with continuous cleats. Where this is not possible, screws shall be used.

Joints shall be fully buttered with sealant as discussed in 3.3.14.3.1.

3.3.14.2.5 Cleats

Generally cleats should be thicker than the material it secures.

Cleat fasteners should be aluminum or stainless steel screw-shank or annular nails.

> Note: Aluminum nails should only be used with aluminum cleats. Aluminum nails should not be used in wood treated with interior grade fire retardant chemicals.

If the cleat fastener is loaded in tension rather than shear, stainless steel pan head screws should be used.

Cleats should be punched with horizontally slotted holes. Over-sized round holes should not be used, since these would allow undesired vertical movement. Cleat fasteners should be spaced in accordance with FM 1-49, if stainless steel fasteners are used. If aluminum nails are used, the FM 1-49 spacing should be decreased. **Fastener spacing shall be decreased by 50% for a distance of eight feet from corners.**

3.3.14.2.6 Welded Assemblies

Welded assemblies (i.e. coping corners and T's) are generally more reliable than lapped and sealed assemblies. Unfortunately these require careful field measurement and shop fabrication.

On many projects (i.e. remote or complex reroofing projects) welded assemblies are extremely difficult for the Contractor. The Designer should carefully evaluate where weld assemblies are appropriate and unappropriate.

3.3.14.2.7 Reglets

Surfaced mounted reglets shall only be used where there are no other viable options.

Where surface mounted reglets are used, consideration shall be given to flashing over the reglet with Uncured EPDM. The EPDM is adhered to the wall (note: a termination bar is required) and to the counterflashing.

3.3.14.3 Sealants

This section discusses sealants that are used in conjunction with sheet metal flashings and similar sealant work. Sealants used in conjunction with specific membranes (i.e. EPDM lap sealant) are not included in this section. A full discussion on sealants is beyond scope of this document, however, the critical aspects of sealants in relation to roofing are briefly discussed.

3.3.14.3.1 General

- The most common sealant problem is related to improper sealant application. Often times a high performance sealant (silicone or polyurethane) is specified. These sealants demand very clean substrates (which often require solvent cleaning). It is difficult to get sheet metal workers to do proper cleaning.

In most instances an easy solution to this problem is to use a sealant that does not have demanding substrate requirements (i.e. butyl or copolmerized polycarbonate).

o Proper ambient application temperature is also a common problem during much of the year in parts of Alaska. Many sealants require application temperatures of +40°F or greater. Typically the concern is with frost on the substrate or adequate temperature for sealant curing.

In terms of curing, the solution is to select materials that are suitable for cold weather application or to provide adequate heat.

If the concern is only related to surface moisture, it may be possible to remove the moisture by wiping the surface with methyl ethyl keytone (MEK), isopropyl alcohol, or acetone. The sealant must be applied as soon as the solvent evaporates in order to prevent reoccurrence of the moisture [8.1). It may also be possible to remove surface moisture with a hot air gun.

Either of these methods is very dependent upon workmanship and it is very difficult to check the work to see if it was properly executed.

Cold weather application shall be in compliance with the sealant manufacturer's instructions and recommendations.

o With lapped sheet metal joints, typically the entire contact surface should be fully buttered with sealant. Simply applying a bead or two of sealant is not recommended.

3.3.14.3.2 Sealant Materials

o Butyl

For typical sheet metal work, butyl sealant complying with Federal Specification TT-S-001657, Type I **has been an excellent choice.** This material is relatively inexpensive and does not require demanding substrate preparation.

Butyl has the ability to rejoin to itself if it is broken. At also has the ability to adhere to itself if additional sealant is applied over aged material. The ability to rejoin/adhere depends upon surface cleanliness and age of material.

Limitations

- This material should only be used at lapped joints, where it is not exposed to weather (except for the leading edge).

- This material cannot accommodate large joint movements.

  Note: Butyl is capable of withstanding movements encountered at joints of ten foot long sections of copings.

- Polyurethane

  For exposed sealant joints (i.e. sealing the top of a surface mounted reglet), or for joints with large movements, polyurethane sealant complying with Federal Specification TT-S-00230 C Type II (non-sag), Class A (low modulus) is recommended.
  Limitations

  - Substrate preparation is critical for this type of sealant (although it is not as demanding for polyurethane as it is for silicone).

- Silicone

  Silicone sealants are very popular and are excellent materials. **However, they are the most demanding in terms of substrate preparation**, and they are very expensive.

For virtually all roofing applications, other sealant materials are recommended.

o Copolmerized Polycarbonate

This product is relatively new in the U.S. (Mid 1980's). It originated in Europe. One proprietary product name is "Seal-One". Reportedly this material can bond to the substrate even if the substrate has standing water or a light oily film on it. **Accordingly, this material may be an excellent general purpose sheet metal sealant.**

Note: This sealant may be a good replacement for butyl.

This material reportedly bonds to bitumen and can be applied in cold weather provided the substrate is free of frost.

Limitations

- o This product is relatively new. The long term performance is uncertain. It should be further studied and considered.

o Ethylene Copolymer

This product was introduced in the early 1970's but, has not had widespread usage in Alaska (as of 1985). One proprietary product name is "Geocel Construction 2000".

Reportedly this material can bond to damp surfaces, however, standing water on the substrate is unacceptable.

This material can be applied in cold weather, provided the substrate is free of frost.

After curing, this sealant has the ability rejoin to iteself if it is broken. It also has the ability to adhere to itself if additional sealant is applied over cured material. The ability to rejoin/adhere depends upon surface cleanliness and age of material.

Limitations

- Alaskan experience with this product is limited. It should be further studied and considered.

- Sealant Tape

Sealant tape is distinctly different from sealant. Sealant tape is very useful in many instances. It comes in a variety of thickness and widths.

Sealant tapes are usually made from butyl polyisobutylene.

3.3.15 Roof-Top Equipment

Roof-top equipment includes mechanical equipment, solar collectors (although these are rare in Alaska), satellite dishes, antenna, signs, etc.

Section 3.3.9 discusses transporting heavy equipment across a roof. Section 3.3.14 discusses roof penetrations.

3.3.15.1 Mechanical Equipment

It is preferable to place mechanical equipment in penthouses. This eliminates roof penetrations and roof traffic for maintenance. Aesthetically, penthouses are usually preferred.

If the equipment is not in a penthouse, it should be either curb or stand mounted. Historically, stand mounted equipment was supported by stands that were too low. This presents severe difficulty in roof repair or replacement. The guideline presented by detail N-1 in the **NRCA Roofing and Waterproofing Manual** shall be followed for stand mounted equipment.

This guideline shall also be followed for non-continuous curb mounted equipment.

If the equipment is not in a penthouse, **consideration shall be given to inadvertent abuse of the membrane and flashings by maintenance personnel.** This problem can be overcome by using a protected membrane roof with protected base flashing details. If the roof is not a PMR, other solutions must be sought. **Exposed membranes are vulnerable to damage, particularly if equipment maintenance occurs in cold weather.**

3.3.15.2 Miscellaneous Items

Satellite dishes, antenna, signs, etc. should be located with care and their roof penetrations should be in accordance with Section 3.3.14. Where possible, wall mounts should be used, rather than roof mounts.

If several items occur in one area (i.e. antenna), consideration should be given to clustering and racking as discussed in Section 3.3.18.

Clearances between penetrations, and between penetrations and walls or parapets should be in compliance with detail V in the **NRCA Roofing and Waterproofing Manual**.

NRCA opposes pipes and conduits on roofs. However, where they are mandatory, detail S in their manual should be followed.

> Note: Roof-top piping and conduit present problems even when properly designed and constructed, for when the roof is eventually replaced, cost of their removal and replacement is incurred, or there is increased roofing cost due to the obstruction.

3.3.16 Work Over, or Adjacent to a New or Existing Roof

Construction work over (i.e. work on a tower above a large roofed base), or adjacent to a new or existing roof has the **very great potential for causing harm to the roof**. The construction work will likely involve trades other than roofing. Therefore respect for the roof is unlikely to occur, due to a lack of knowledge.

If construction work will occur over a new roof, the installation of a temporary roof shall be considered. Upon completion of other work the permanent roof would be installed. See Section 3.3.19 "**Temporary Roofing**".

Note:

1. If construction traffic and loading is light, a protected membrane roof may give adequate protection.

2. Paver ballast will provide the most protection.

3. The mortar faced insulation may be damaged. If it is utilized, it should be carefully inspected upon work completion.

4. Flashings are vulnerable, unless they are also protected.

When working adjacent to or over an existing roof, there are two options:

- Assume the roof will be harmed during construction and replaced afterwards.

- Protect the roof and **hope** it is unharmed.

When the roof is in good condition, it is logical to try to save it. Accordingly the following should occur:

- Perform non-destructive evaluation (see Section 8) just prior to construction. Infrared or capacitance are the preferred methods.

  Advise the Contractor NDE was performed prior to construction and will be performed afterwards. This may encourage the Contractor to properly conduct the work.

- Specify specific protection requirements. These will vary according to the type of existing roof and expected loading during construction.

Some examples are given in Section 5 "**Master Specifications**". Also see Section 3.3.9 "Transporting Heavy Equipment Across a Roof".

- Upon construction completion, perform another NDE. If new wet areas are found, they are likely the result of construction. Also, by performing NDE before and after construction it is easier to assess responsibility.

- An additional NDE should be performed one or two years after construction completion, since damage to the roof may not immediately manifest itself.

Unfortunately, saving an existing roof is very difficult due to the lack of roofing knowledge by most of the people on the construction site. Even with good clear protection specifications, the roof is in jeopardy. If damaged, the damage may not be apparent for several years, at which time it may be very difficult to prove it was the fault of the Contractor, even with NDE. **In some situations, it may be best to avoid NDE, protection costs and concerns, and simply replace the roof upon work completion.**

3.3.17 Historical Roofing Restoration

While Alaska has few historically significant buildings, occassionally, the opportunity to work on one may occur.

Problems with historical roofs, like most other roof problems, usually go unnoticed until leaks occur. And, as with other roofs, when this occurs, temporary patching, repair, or replacement is immediately desired. However, with historical roofs, special care and precautions are in order:

- Temporary patching methods should be carefully chosen and executed to prevent inadvertent damage to sound or historic roofing materials and related features.

- The decision to repair or replace should be carefully evaluated. From a purist viewpoint, repairing will probably be more desirable than replacement. However, the likelihood of a successful repair and its life expectancy must be considered.

- o In repairing or replacing, a decision is necessary regarding authenticity. From a purist viewpoint, authenticity is desirable. However, cost, time, or Code considerations may take precedence. Examples of striving for authenticity are:

- o Manufacturing new embossed tin shingles to match original shingles.

- o Obtaining new slate shingles from the quarry where the original shingles were quarried.

- o Obtaining birch bark for a new sod roof from the same forest the original bark came from.

If it is not possible to obtain this degree of authenticity, **salient visual features of the original roofing should be sought.** These would include items such as texture, form, and color.

- o As is typical with restoration work, it is imporatant to determine if the roof covering now in place is original. Often, original coverings have been removed or covered.

  Even if the original covering has been removed, often times there are clues as to what the original covering was.

- o If tiles, shingles, or other coverings are to be removed and reinstalled, it is important to photograph the installation prior to beginning work. Labeling the tiles as they are removed will help to ensure proper replacement location.

  These steps are especially important if there are noticeable variations with the units, such as mixture of slate tile colors.

For further information, see "Roofing Restoration: Historical Accuracy vs. Improved Technology" by Sarah M. Sweetser, **The Construction Specifier**, November 1978.

3.3.18 Aesthetics

Since sloping roofs may be visually dominant and powerful, designers generally give some (or perhaps a great deal) of consideration to aesthetics. However, flat roofs often seemingly escape visual consideration. Roof-top mechanical units, boiler stacks, antennae, microwave or satellite dishes, etc. are all too often placed without aesthetic concern. Many of these items are out of view as people approach the building. However, many times these are very visible from a distance or from adjacent higher buildings. And with multiple roof levels, it is not uncommon to have a window looking out on a piece of mechanical equipment.

Some items (satellite dishes, antennae) are beyond the designer's control. However, **it is not unreasonable to expect the designer to anticipate some of these elements and make provisions for them or try to positively influence the Owner regarding their placement.** For example on a police headquarters building, it should be assumed that many antennae will occur. By coordinating with the client, it is possible to design a system to accommodate present and future antennae that will allow an orderly arrangement which at the same time is not detrimental to the roofing system. However if left to the client, a vendor may install the items with no regard to visual order or respect for the roofing system.

The designer can also often positively influence the mechanical items that are visually troublesome on building after building. Several plumbing vents can sometimes be combined below the roof, resulting in only one VTR instead of three or four. Likewise relief or exhaust air ducts may be combined to minimize roof penetrations. Or, a vent or exhaust hood can be moved to a less objectionable location (i.e. from just in front of a window to around the corner, or from the main side of a sloped roof to the back side). While these adjustments may involve additional costs, the costs may be minimal and worthwhile. **As a minimum, this should at least be considered by the designer.**

Paradoxically, designers may select a system for its visual attributes, while giving little consideration to the likelihood of the system actually being beautifully installed, remaining beautiful, or its functional attributes. For example:

- Many elasto/plastic systems just don't look good - seams are often very noticeable, it's difficult to get the membrane and base flashing to lay flat, and there are usually patches where wrinkles have been cut out. On steep roofs, these features may be very visible and objectionable.

- Some materials look good when viewing a small sample in the office, but look remarkably different after a few months of exposure. White EPDM is probably going to look objectionable to many people after just one summer's exposure to the dust and light rains of Anchorage.

- Acrylic coatings for spray-applied polyurethane foam roofs are available in several striking colors. However acrylics don't have the longevity offered by other coating materials. **Is the initial beauty worth this trade-off? If so, the designer should make special effort in alerting the Owner** of the need to re-coat in a few years. Unless the system is properly maintained, not only will the roof not look good, it will become ineffective as a roofing system. This can occur in a relatively short time - perhaps in a little over five years.

In misguided efforts to make the building look good, designers frequently compromise functional aspects of the roof. Common examples are:

- Simply butting copings against intersecting walls, rather than providing flanges on the coping termination. A proper termination is shown in Section 3.9.3.

- Failure to place copings over the tops of parapets: in lieu of copings, the top of the parapet is left exposed and the base flashing is protected by a reglet and counterflashing assembly. This is sometimes done with concrete parapets. At joints in the concrete, sealant is the only line of defense against water entry. Spalling of the concrete due to freeze-thaw action is possible, along with sealant failure due to improper application or pecking by birds. **Parapets shall always be capped - preferably with metal copings.**

- **The greatest problem is perhaps the failure to extend the base flashing high enough above the membrane and failure to place edge flashings on raised curbs.** (See Section 3.3.14 "**Roof Penetrations, Flashings and Sealants**").

3.3.19 Temporary Roofing

A temporary roof is a roof that is installed for a short time period and is soon **replaced** with a permanent roof. Generally temporary roofs are used when poor weather conditions are expected to continue for several months, or when construction is expected to occur over the roof. For example, a large two storey base with a high rise tower is a likely temporary roofing situation. It may be desirable to complete the interior of the base, yet work on the tower could cause damage to the lower roof. By using a temporary roof, the base is protected, and after the tower is completed, the permanent roof is placed.

The temporary roof may or may not have a minimal amount of insulation. A vapor retarder may not be necessary, since the insulation may be removed prior to placing the permanent roof. **Considerable caution is necessary if the temporary roof is to remain. The new roof shall not be adhered to the temporary roof.**

Although there are many possibilities, one good durable temporary system is to mechanically fasten perlite insulation to the deck, followed by a two ply organic felt built-up membrane with an asphalt glaze coat. For final roofing, this can be covered with a thin layer of insulation, followed by a loose-laid Protected Membrane Roof as described in Section 3.5.2.

The temporary roof should meet the same fire properties as required of the permanent roof. If the temporary roof is to be demolished, it should be constructed to minimize these costs. If construction occurs over the temporary roof, it should be durable.

Since temporary roofing is expensive, if the designer believes temporary roofing will be needed, it shall be specified. The specification shall define how it is constructed, the requirements regarding demolition (if demolition occurs) and the attachment of the new system to the temporary roof or the temporary roof's substrate.

Unfortunately temporary roofing seldom occurs. Due to the cost, it is generally decided to gamble with the weather or the construction over the new roof. Taking this risk is in the Owner's interest, if the roof is not adversely affected. However, sometimes the new roof fails prematurely, resulting in a large monetary loss. **It is incumbent upon the designer to assess the project and recommend tempoarary roofing when temporary roofing is appropriate.**

3.4 Overview of Materials

This Section discusses the various materials currently (1985) available for use in roofing. For discussion regarding combining these materials into systems, see Section 3.5 "**Overview of Systems**". For further information, refer to **The NRCA Roofing & Waterproofing Manual** and current manufacturer's literature, which were the primary resources for this Section.

3.4.1 Roof Deck Materials

See Section 3.3.4 "**Structural Considerations**". Also, the RIEI **Basic Roofing Technology** course manual contains a series of articles that appeared in **The Roofing Spec** - these are presented in a reprint issued by NRCA titled "The Roof Deck". The RIEI manual also contains a chapter on "Roof Decks" (September 1980).

3.4.1.1 Cement Wood Fiber Panel

1) Commonly known proprietary name: "**Tectum**".

2) Composed of treated wood fibers bonded together with portland cement or other binder and compressed or molded into flat panels.

   Cement wood fiber panels are considered to be "**non-combustible, nailable**".

   These panels provide some acoustical and thermal insulation. The panels are relatively heavy. **Diaphragm action is difficult to develop.**

   This material should be protected from water during storage, and during and after application.

3) If there is high interior moisture in the building, specific moisture precautions are necessary.

4) Mechanical fasteners are used to attach the base ply or insulation.

5) **In Alaska, cement wood fiber panels should not be used for roof decks.**

3.4.1.2. Lightweight Insulating Concrete Fill

1) This material is designed to be applied over a structural deck composed of metal forms, bulb tee/formboard systems, or structural or precast concrete. Lightweight insulating concrete fills are considered to be "**non-combustible, nailable**".

2) This is a cementitious roof deck which provides insulation and a substrate for roofing. It is produced by combining lightweight insulating aggregates, such as perlite or vermiculite, with portland cement and water. It may also be produced by blending pre-generated foam with portland cement and water.

   This material is normally mixed, and is always placed and screeded, at the job site. Minimum thickness is 2".

Oven dry density is 20 to 40 pounds per cubic. Do not confuse lightweight insulating concrete fill with lightweight structural concrete (whose density may be as low as 85 pounds per cubic foot) - see Section 3.4.1.6 "**Reinforced Concrete (Cast-in-Place)**".

3) Special precautions are necessary to ensure adequate and proper moisture venting of the deck, in order to dissipate the excess water of the mix. Underside venting is usually required.

4) See RSTC (Roofing Systems Technical Committee) Bulletin for roofing over this type of deck. The Bulletin is available from ARMA or NRCA.

5) If there is high interior moisture in the building, specific moisture precautions are necessary.

6) **In Alaska, lightweight insulating concrete fill should not be used for roof decks.**

3.4.1.3 Poured Gypsum Concrete

1) This material consists of gypsum concrete that is mixed with either wood fibers or mineral aggregate and mixing water. This is poured on permanent formboards that are supported by steel sub-purlins. The mixture is reinforced with steel mesh. Minimum thickness of the gypsum concrete is 2".

Poured gypsum concrete decks are considered to be "**non-combustible nailable**".

2) Special precautions are necessary to ensure adequate and proper moisture venting of the deck, in order to dissipate the excess water of the mix.

3) If there is high interior moisture in the building, specific moisture precautions are necessary.

4) In Alaska, poured gypsum concrete should not be used for roof decks.

3.4.1.4 Precast Concrete

1) Precast concrete panels are manufactured in a variety of cross-sectional shapes: plain slabs, channel slabs, tongue-and-grove planks, simple or double tees.

   Precast concrete decks are considered to be **"non-combustible, non-nailable"**.

2) Perfect alignment between adjoining panels is rare. **Leveling fills or insulation boards should be used to compensate for these variances.** For adhered systems, a leveling fill is generally the preferred method - in Alaska, generally cast-in-place concrete is used.

3) See Item 2), 3) and 4) in Section 3.4.1.6 **"Reinforced Concrete (Cast-in-Place)"**.

4) If leveling fills are not used, care must be taken to avoid bitumen drippage at joints, as recommended by the NRCA Manual.

5) With built-up systems usually the base ply or insulation is adhered by a full mopping of bitumen.

3.4.1.5 Prestressed Concrete

1) This system is composed of concrete units (usually precast) that are prestressed with integral steel tendon reinforcement. The following shapes are common: tees, double tees, channel slabs, or hollow-core slabs.
   Prestressed concrete decks are considered to be **"non-combustible, non-nailable"**.

2) Perfect alignment between adjoining units is rare. **Leveling fills or insulation boards should be used to compensate for these variances.** For adhered systems, a leveling fill is generally the preferred method - in Alaska, generally cast-in-place concrete is the fill generally used.

3) See Items 3), 4), and 5) in Section 3.4.1.4.

3.4.1.6 Reinforced Concrete (Cast-in-Place)

1) Reinforced concrete (also referred to as **structural concrete** or cast-in-place concrete) may be applied over a steel deck or it may be self-supporting. Its density may range from 85 to 200 pounds per cubic foot, with 150 pcf being common.

Lightweight concrete (85 to 110 pcf) is available in parts of Alaska. It is produced by injecting air and a chemical compound into normal concrete, which results in air voids and hence the lighter weight. This lightweight concrete can be used as a fill over other decks (i.e. precast or prestressed concrete). Although this fill is heavier that **light weight insulating concrete** or **gypsum concrete** previously described, its advantage is that it contains less water and accordingly presents fewer problems. Normally, when used as a topping slab, it should be reinforced to control cracking.

Concrete decks are considered to be "**non-combustible, non-nailable**".

2) The deck should be dry prior to application of built-up membrane roofing. The following dryness test is an acceptable means for testing: [9]

1. Heat one pint of specified bitumen to its EVT.
2. Pour onto deck - **if the bitumen foams, the deck is not dry enough to roof.**
3. After the bitumen has cooled, attempt to strip it from the deck. **If it strips clean, the deck is not dry enough to roof.**

If an elasto/plastic membrane is used, there may be other specific dryness requirements.

3) If the deck is to be covered with an adhered system, surface irregularities require correction. Raised fins shall be removed and pockets or depressions shall be grouted level. The deck should be relatively smooth to ensure good adhesion of the roofing system.

Curing agents should not be used, due to bonding concerns.

4) Concrete shall be primed prior to the application of asphalt.

5) **Properly constructed reinforced concrete decks provide an excellent substrate for most roofing systems. They probably present fewer problems than any other deck system.**

- o Internal fire exposure is of little concern.
- o These decks are stiff - fluttering and concentrated loads (i.e. roof application loads) are generally not a problem.
- o A full uniform bearing surface presents an excellent substrate for adhering the roof.
- o Generally there is little (if any) air leakage from the interior of the building, hence the blow-off resistance is improved.

3.4.1.7 Steel (Metal)

1) This deck is made of cold-rolled steel sheets with ribs formed in each sheet to provide strength and rigidity. Steel decks are available in several depths and gages, with 1½" deep being the most common for roofing.

Steel decks are considered to be "**non-combustible, nailable**".

Note: If the steel deck is topped with reinforced concrete or other fill, also refer to those sections for deck discussion.

2. Steel decks are very common, but historically have presented several problems.

   o Many times, the greatest loads the deck sees during it's life occur during roofing application. Therefore, the gage of the deck must reflect these conditions.

     If a built-up or adhered elasto/plastic membrane is used, the deck shall be 18 gage minimum.

     If the membrane is partially attached or loose-laid, the deck shall be 22 gage minimum.

   o Attachment of insulation boards or vapor retarders to the deck is difficult since the bearing surface is not continuous. Also the bearing surface is sometimes concave, thereby further reducing contact area.

     FM's recent (1984) requirement to use mechanical fasteners for insulation attachment should result in a reduction of roofing problems associated with steel decks. However it is still incumbent upon the roofer to locate insulation board joints over the bearing surface (flange).

     By locating the vapor retarder over a thin layer of insulation, followed by another layer of insulation (as discussed in Section 3.3.12.9) the problems of attaching the retarder to the deck are eliminated.

   o Wind blow-off is a significant potential. This is partly due to attachment difficulties when using adhesives, but it is enhanced by the flexibility of steel decks and by positive pressure from within the building. **Steel decks are not very resistant to air leakage.**

By using gages previously noted, and by using mechanical fasteners as recommended by FM, wind blow-off problems should be rare.

3) Steel decks are available in painted or galvanized material. **Galvanized shall be used.**

Some manufacturers place sealant at the longitudinal joints, so the deck can be used as the vapor retarder. This is not recommended.

4) Standing water shall be removed from the ribs and the flanges shall be dry prior to roofing.

5) **Only decks in the FM Approval Guide shall be used.**

6) **FM 1-28 "Insulated Steel Deck" shall be followed.**

7) For further information, refer to "Steel Deck Deflection Study" sponsored by ARMA. This was published in RSI in the February and March 1976 issues. The study is also bound in the RIEI **Basic Roofing Technology** course manual.

3.4.1.8 Thermo-Setting Insulating Fill

1) Commonly known proprietary name: "All-weather Crete".

2) This is a non-structural material produced by mixing perlite or other mineral aggregate with a hot asphalt binder. The fill is compacted with a roller or hand tamper. It has a density of 18 to 22 pounds per cubic foot.

Thermo-setting insulating fills are considered to be **"non-combustible, non-nailable".**

This should be protected from weather during and after application.

3) Prior to the requirement for high R-values, this fill often provided the only roof insulation. Properly constructed, this is a good base for built-up systems.

4) Although this system was used in Alaska in the 1960's, due to R-value, cost and other factors, **it is no longer recommended in Alaska.**

3.4.1.9 Wood Planks or Plywood

1) Wood planks can either be solid or laminated. They are either tongue-and-groove, ship-lapped, or splined together.

   Plywood has largely replaced wood planks for roof decks, due to cost and due to the ease of developing diaphragm action with plywood.

   Wood planks and plywood decks are considered to be "**combustible**" (unless they are fire retardant treated) and "**nailable**".

2) FM recommends 2" minimum nominal thickness for planks and 3/4" for plywood. FM also recommends tongue-and-groove joints for plywood.

3) **If the building is not sprinklered, the deck** (and its support) **should be fire retardant treated.**

4) Plywood panels shall bear an American Plywood Association (APA) grade-trademark. **Plywood shall be made with exterior glue.**

   Generally, "C-D exterior glue" (CDX) will perform as well as "C-C exterior", but is less expensive. Where greater structural performance is required, structural grades are available.
   If a portion of the panel is permanently exposed to the weather (i.e., the underside of an overhang) the UBC requires an exterior type of plywood.

5) The APA grade-trademark contains a span rating (i.e., 32/16). The first number (32) indicates the maximum recommended center-to-center spacing of supports when the panel is used for roof decking (assuming the panels are continuous over two or more supports, and the long dimensions of the panel runs across the supports). The second number (16) indicates spacing if the panel is used for flooring.

   If the plywood deck supports an adhered membrane system, the span rating on the trademark may not be applicable. Some manufacturer's of roofing materials require a closer spacing of supports. Where this is the case, it is incumbent upon the roof designer to make the structural designer aware of the more stringent criteria.

6) All plywood panel edges require blocking or "H" shaped panel clips where tongue-and-grooves don't occur. If an adhered system is used, blocking rather than "H" clips should be used.

7) APA recommends ends of panels be separated by 1/16" and edges separated by 1/8" in order to avoid buckling problems due to change in moisture content. APA recommends doubling these dimensions if wet or humid conditions prevail. Rain during construction may be sufficient to require doubling the normal spacing.

8) If an elasto/plastic system is to be applied directly to a plywood deck, a special grade of plywood may be required. Check with the membrane manufacturer.

9) If the roof system has the capability of entrapping moisture, the use of preservative treated wood/plywood should be considered.

10) Protect wood planks and plywood from water during storage and after installation. Some moisture gain during application may be acceptable. However if an adhered system is placed over the deck, the deck shall be relatively dry prior to roofing application.

11) If a building is not heated until after roofing installation, the heat should be applied in gradual steps in order to minimize deck warp.

12) A rosin-sized sheathing paper (or similar material) should be nailed to the deck prior to the application of additional plies or insulation.

3.4.2 Vapor and Air Retarder Materials

See Section 3.3.11 **"Vapor and Air Retarders"**

3.4.2.1 Bituminoius Vapor Retarders

1) Combination of hot bitumen and one or more layers of felt. **For humid conditions, two plies should be used.**

2) As discussed in Section 3.2.8 **"Fire (UL and FM)"**, bituminous retarders should not be placed directly over some types of decks.

3.4.2.2 Non-Bituminous Vapor Retarders

1) Kraft paper and aluminum foil combinations, applied with adhesives or hot bitumen.

2) **If vapor retarders occur directly over metal decks, these retarders should be selected over bituminous retarders because of their improved fire properties. Also, adhesive rather than bitumen should be used.** However as noted in Section 3.5.3, the retarder will generally be placed over a thin layer of insulation, rather than directly to the deck.

3) Aluminum foil is supplied as a facer on some rigid insulation boards. Although aluminum foils are excellent retarders when of sufficient thickness, foil facers should not be considered to be the vapor retarder. If a retarder is required, an additional material other than the facer shall be used.

3.4.2.3 Plastic Sheet Vapor Retarders

1) Polyvinyl chloride (PVC) or polyethylene, and a compatible adhesive.

2) **These materials generally are not recommended for use as vapor retarders** for adhered flat roofing systems, due to attachment problems [10].

   Polyethylene is a common (and acceptable) retarder for wall systems, some loose-laid flat roofing systems and with some steep roofing systems, where the system design does not depend upon adhesives for blow-off resistance.

3.4.2.4 Liquid Applied Vapor Retarders

1) Liquid applied vapor retarders use chemical compounds that are spray, roller, or brush applied.

   Properly applied, a membrane with some vapor resistance is achievable.

2) In the early 1980's, vapor retardant paint began to be marketed. This paint is formulated to achieve a high vapor resistance.

   These paints may be effective on wall systems, however, aspects of roofing present obstacles for liquid applied vapor retarders.

   The substrate for the retarder (either the deck or insulation) is not a uniform surface, as are most interior walls. Bridging joints and other surface irregularities may be beyond the retarder's capacity.

   There may be unique instances where liquid applied retarders as the best retarder for a particular roof, but this will be rare. If they are considered, special consideration must be given to the manufacturer's recommendations and limitations of the product. Temperature and weather criteria, as well as required application skills must be reviewed to see if the requirements are achievable at the job site.

3) An example of a liquid applied vapor retarder that was unsuccessful consisted of a cement wood fiber deck over steel joists [11]. The deck served as the structural deck, the roof insulation, and substrate for a BUR. A liquid applied vapor retarder was sprayed to the underside of the deck after the decking was installed. Due to the highly irregular surface of the panels (which is common for this deck type), retarder continuity was not achieved. Also, the retarder was discontinuous at the joist bearing area (which amounted to a sizeable area). An analysis of this design prior to application should have revealed its likeliness for failure. The surface of cement wood fiber panels is not a good substrate for a liquid applied system. Also, there was not an effective way to seal the deck/joist interface.

4) **Liquid applied vapor retarders generally are not recommended for use as vapor retarders for roofing systems.**

3.4.2.5 Air Retarders

The materials discussed in Section 3.4.2.1 - 3.4.2.4 function as both vapor and air retarders.

As discussed in Section 3.5.6.3 sometimes a materials is desired that only retards air. DuPont "Tyvek" is an excellent material for this type of application. Tyvek is a sheet of spunbonded high-density polyethylene fibers.

3.4.3 Roof Insulation Materials

See Section 3.3.12 **"Thermal Insulation and Heat Flow".**

A very good table comparing various factors of various insulation boards occurs in the December 1964 issue of **Progressive Architecture** ("Insulation for Flat Roofs" by Werner Gumpertz). This article occurs in the course manual for the Seminar on Roofing Technology, presented at the University of Alaska in Anchorage in August 1977. Unfortunately due to its age, the table does not address many products currently available.

This section does not include insulation materials that were used decades ago, but are virtually no longer used (i.e., cork and straw board.) Nor does it include insulation materials that are not currently (1985) used for roofing, (i.e. urea-formaldehyde, epoxy foams, and silicone foams).

3.4.3.1 Cellular Glass

1) Composed of heat-fused, unconnected, closed glass cells. It is totally inorganic. As of 1985 there is only one manufacturer of this insulation in the United States. This product is produced in Missouri and Pennsylvania.

2) R-Value per inch:

   2.63 According to NRCA
   2.44 According to CRCA (Canadian Roofing Contractors Association)
   2.86 According to the manufacturer at 75°F, mean temperature
   3.03 According to the manufacturer at 50°F, mean temperature

3) Weight per square foot per inch thickness: approximately 0.71 pounds.

4) Compressive strength: 100 psi.

5) Thermal coefficient of expansion: 4.6×10^{-6}.

6) Specification Reference:

   - ASTM C 552
   - Fed. Spec. HH-1-551 E

Note: The Fed. Spec. may be cancelled, specify by ASTM.

7) **This is an excellent base for roofing.** It has good fire resistance, it is dimensionally stable, and is vapor impermeable. However it has a very low R per inch and is **relatively expensive in Alaska.**

With the presence of water, freeze-thaw action can quickly break down this material, leaving a water saturated gray-black dust.

Due to its cost, this material generally is not recommended for use as roof insulation in Alaska.

See Section 3.4.3.3, Item 2) regarding the use of cellular glass above the membrane in a Protected Membrane Roof System.

3.4.3.2 Composite Board

1) This is produced by factory-laminating a base layer of traditional roof insulation or other materials such as gypsum board or waferboard to polyurethane or polyisocyanurate insulation board. There are three general categories of this very common insulation:

- o Two-component perlite composite board: This consists of a thin layer (normally 3/4 inch) perlite board upon which a layer of either polyurethane or polyisocyanurate foam insulation is applied. A facer sheet is attached to the top of the foam.

  Other insulation materials may be used in lieu of perlite. However as of 1986, perlite is the most prevalent.

- o A variation of the above uses gypsum board or waferboard in lieu of perlite. There is no important advantage to gypsum board. The waferboard composites provide a nailable base. However their appropriateness from a system design standpoint is questionable.

- o Three-component perlite composite board: same as number one above, except a layer of perlite occurs on either side of the foam. A variation of this type uses other materials on either side, of the foam. **Three-component boards are not generally recommended.**

Polyurethane and polyisocyanurate foams bond to a variety of materials, hence from time to time a variety of substrates may be available.

2) A wide variety of facers have been available, but over time, perhaps only a few will be common. The facer accounts for a significant portion of the total insulation board cost. Understandably, some manufacturers may try to cut costs by cutting quality of the facer. Some facers are marketed with only limited field experience. Manufacturers may also suddenly change their facers. All of this presents difficulty for the roof designer, especially since there are few recognized standards for facers.

Common facers are:

- Aluminum foil, laminated with paper or fibrous glass mat. This **facer should not be used adjacent to a BUR or modified bituminous membranes.**

- Asphalt saturated organic or fiberglass felt. This facer is suitable for BUR and modified bitumen membranes. A separate divorcement sheet must be used between this and PVC membranes to avoid PVC attack. **In Alaska, the fiberglass felt is preferred over the organic felt** (due to potential moisture gain during shipment and job site storage).

- Asphalt emulsion-coated fiberglass mat: similar to the above.

- Coated, non-asphaltic fibrous glass paper. These are generally not compatible for use with BUR or modified bituminous membranes.

- o Uncoated, fibrous glass mat. These facers may be suitable for most systems. They are relatively new (1980's). **These may become the predominate facer in the market.**

  It is imperative the designer verifies the facer is compatible to the adjoining material. Further, if the system is adhered, the bonding characteristics of the facer are critical.

  For further information, See "Choosing the right roof insulation facer" by John McCorkle in **Roof Design**, September 1984. Development and changes in facers should be expected over the next several years.

3) The **potential for blister formation** exists when hot asphalt is applied directly to polyurethane or polyisocyanurate foam materials. Therefore when two - component composite boards are used, one of the following procedures should be used [12]:

   - o Over the foam side of the composite board, apply (in hot asphalt) a layer of wood fiberboard, perlite board, or rigid fiberglass board. Stagger joints from layer below.

   - o Over the foam side of the composite board, apply a venting type base to allow for venting.

   For a discussion on blister formation over polyurethane insulation, see the report prepared as a part of a joint NRCA - MRCA investigation, prepared by Southwest Research Institute, entitled "On the Development of Blisters During the Application of Hot Asphalt Over Urethane Insulation." A synopsis occurs in the September 1980 issue of **The Roofing Spec**.

4) **Many manufacturers promote composite boards for single-layer installation, however, a double-layer application should be used, with all joints offset [13]. Accordingly, three-component composite boards are generally not recommended.**

5) **Thermal Aging Factor:**

Polyurethane and polyisocynaurate insulations experience some loss of thermal resistance from the time they are manufactured until they are locked into the roofing system. This is due to loss of the freon blowing agent from the cells. Even after the boards are locked into the roofing system, loss of freon may continue until all the cell cavities are filled with air. Hence, the R-value of the boards after a few years may be substantially lower than the published "aged" value.

When considering the R-factor, use the "Aged" value. Specify the "RIC/TIMA (Roof Insulation Committee/Thermal Insulation Manufacturers Association) Thermal Conditioning Procedure Certification".

In the future, the "aged" value may be replaced with a value that accounts for total freon loss. The Industry struggled to get the RIC/TIMA Certification established. The next step (establishing actual in-place R-value after a few years of service) may not come about for quite some time.

6) Board Thickness:

As discussed in Section 3.3.12, it is generally **not recommend to use boards over approximately 2½" thick**, due to the potential for lack of attachment.

7) **Shaping the foam face of boards is extremely difficult** (i.e., at roof drain sumps, or shaving boards with vertical offsets due to deck irregularities). **Shaping requires removal of the facer. Bonding directly to the foam presents difficulties for most roofing systems.**

8) R-value per inch varies, depending upon the substrate the foam is applied to and the R of the foam. Other physical properties also vary, depending upon make-up of the composite board. See Section

3.4.3.7 "**Polyisocyanurate**" and 3.4.3.8 "**Polyurethane**" for specific discussion of the foams.

9) In the future, composite boards may be made with phenolic foam. See Section 3.4.3.10 "**Phenolic**".

3.4.3.3 Extruded Polystyrene

1) The raw material for this insulation, styrene, is made from coke and crude oil derivatives. Styrene is polymerized to form polystyrene and is then extruded. This is a thermoplastic material.

2) **This is the only insulation suitable for use above the membrane in a Protected Membrane Roof System [14].**

   Note: Cellular glass is also suitable for above membrane use, providing the insulation does not freeze. Hence cellular glass is not applicable for above membrane use in Alaska, as well as most of the U.S.

   This is not recommended for use below built-up membranes. It is appropriate for use under loose-laid or partially attached elasto/plastic membranes, if a thermal barrier is provided under the foam.

3) R-value per inch ("aged").

   5.0 at 75°F, mean temperature.
   5.4 at 40°F, mean temperature.

4) Weight per square foot per inch thickness: approximately 0.2 pounds.

5) Compressive strength: 40-45 psi (depending upon manufacturer).

6) Thermal coefficient of expansion:

35×10^{-6} for Dow Chemical products
24×10^{-6} for UC Industries products

7) Specification reference:

- o ASTM C 578
  - o Type IV: For DOW SM and TG, and Foamular 250.
  - o Type VI: For DOW RM and LG, and Foamular 404.

    Note:

    1. If LG (mortar facing) is desired, this must be specifically specified.
    2. Since C 578 is for extruded and expanded products, for clarity specify "**extruded polystyrene**" when this is the desired product.

- o Fed. Spec. HH-1-524 C Type IV

  Note: The Fed. Spec. has been cancelled, specify ASTM.

8) The only U.S. manufacturers of extruded polystyrene insulation for roofing applications (as of 1985) are the DOW Chemical Company and UC Industries.

Dow's insulation is blue in color. As of 1985, their roofing insulations are known as:

- o Styrofoam Lightguard (LG): formerly known as XFS-4249. LG is an RM board with a 3/8" thick factory applied latex mortar facing (weighing approximately 4.5 pounds per square foot). These boards are tongue-and-groove along the long edges. LG boards do not require ballasting or mechanical securement, except at roof perimeters and some roof penetrations.

  This product has been in use in Alaska since 1981.

- Styrofoam RM: These boards have water carrying channels along the bottom edges. These boards must be ballasted by aggregate, pavers, or LG boards.

UC Industries insulation is pink in color. As of 1985, their roofing insulation is known as:

- Foamular 404: This is similar to Styrofoam RM. This product was introduced in 1984.

If extruded polystyrene is used under elasto/plastic membranes, use Styrofoam SM or TG (tongue-and- groove) or Foamular 250 (square edge or tongue- and-groove). These products are slightly different and cheaper than the products intended for above-membrane use. **Tongue-and-groove boards are recommended for use over irregular surfaces (i.e. existing roofs).**

Styrofoam SM & TG and Foamular 250 have a minimum compressive strength of 25 psi.

Note: Lower compressive strength boards are available (15 psi).

9) There have been recent changes (during the early 1980's) that may impact extruded polystyrene products. Prior to the 1980's an extruded polystyrene manufacturing plant reportedly cost approximately 5-6 million dollars. However current (1985) technology has reduced the capital cost of a new plant to approximately $250,000 - $500,000 (lower 48 costs). This new technology will likely introduce new manufacturers into this market place.

Another significant development is the expiration of DOW's patent in November of 1985. This event coupled with minimal capital development costs for a new plant could have drastic impacts on the extruded polystyrene roofing market. Designers and roofers should be cognizant of these developments and watchful of what lies ahead.

10) See Section 3.5.2 "**Protected Membrane Roofs**".

3.4.3.4 Expanded Polystyrene

1) Also known as "EPS", molded polystyrene, and beadboard. EPS is white in color.

2) This insulation is made from the plastic polymer polystyrene, but it is not extruded. This is a thermoplastic material.

   Until the 1980's the capital investment for an EPS manufacturing plant was a fraction of the cost of an extrusion plant. Hence, EPS manufacturing facilities are more common.

   EPS is the only insulation manufactured in Alaska (as of 1985).

3) R-value per inch (based on one pound density):

   3.85 at 75°F, mean temperature.
   4.17 at 40°F, mean temperature.

   Note: EPS is available in several densities. The R-value increases with the density. For most roof applications, one pound density is used.

4) Weight per square foot per inch thickness (for one pound density): approximately 0.08 pounds.

5) Compressive strength.

   - One pound density: 10-14 psi
   - Two pound density: 25-33 psi

6) Thermal coefficient of expansion: 35×10^{-6}.

7) Specification reference:

- ASTM C 578
  - Type I : .9 pound density
  - Type VIII : 1.15 pound density
  - Type II : 1.35 pound density
  - Type IX : 1.8 pound density

  Note: Since C 578 if for both extruded and expanded products, for clarity, specify **"Expanded Polystyrene"** when this is the desired product.

- Fed. Spec. HH-1-524 C Type III

  Note: The Fed. Spec. has been cancelled. Specify ASTM.

8) This insulation can be used under loose-laid or partially attached elasto/plastic membranes, if a thermal barrier is provided under the foam. **However if rolling of field fabricated seams occurs, 1½ pound density (rather than one pound) should be used.**

If the substrate is irregular (i.e., existing roof), tongue-and-groove boards are recommended.

9) **This insulation is not suitable for use above membranes.**

10) **Attachment of EPS to the deck is difficult.** EPS is usually either attached to the deck with hot asphalt or mechanical fasteners. It can also be unattached under loose-laid membranes, without difficulty.

- Mechanical Attachment: Unless two layers of insulation occurs (with the fastener only penetrating the base layer), thermal bridges are created (see Section 3.3.12.5).

- Asphalt Attachment: Since EPS is destroyed by hot asphalt, the asphalt must cool prior to placing the board. This requires considerable skill, for if the asphalt is too cool prior to board application, there will be a poor bond. And if the asphalt is too hot, the foam melts, which results in very little bonding.

11) Achieving double layer application (i.e., laminating two EPS boards together on the roof) is difficult.

- Boards can be adhered with a compatible adhesive. Many compatible adhesives are stiff and do not lend themselves to application in a full uniform coating. Rather, these are more suitable for spot adhering. Unfortunately, spot adhering results in higher stresses.

  Some adhesives may be suitable for spray application, therefore allowing full embedment. Full adhesion is preferred over spot adhesion.

  As of 1985, tabulated values for the strength developed between adhered EPS boards are not readily available, hence the roof designer has difficulty in quantifying the blow-off resistance of this system.

- Mechanical fasteners can be used to secure both layers, but this results in thermal bridges (see Section 3.3.12.5).

- Due to melting potential, asphalt is not a suitable board-to-board adhesive.

12) If the membrane is built-up, the EPS must be covered with another material to prevent the asphalt from melting the foam. Usually a thin (3/8 or 1/2 inch) layer of wood fiberboard is used. This may be factory or field applied. When field applied, the wood fiberboards are "backmopped" with asphalt. After cooling, the boards are flopped onto the EPS and "walked-in".

Except possibly for very tight joints, **the wood fiberboard joints should be taped to prevent asphalt from flowing into the joint and melting the foam.**

Factory laminated boards may be manufactured with the wood fiberboard overhanging on two edges and inset on the other two, which serves to eliminate a through-joint between the deck and membrane. However, since the top layer is quite thin, this is not very effective thermally. Nor is it effective in terms of reducing possibilities of ridging. **This single ship-lapped composite board is not considered a "double layer application".**

13) If an exposed elasto/plastic membrane is placed over the EPS, the EPS should first be covered with a thin layer of insulation (i.e. wood fiberboard) in order to keep the EPS under its maximum recommended service temperature (167°F for "long-term", 180°F for intermittent exposure). In some parts of the U.S. this protective cover may have to be greater than 1/2" to keep within these temperatures. In many parts of Alaska, the protective cover will not be required.

14) **Because of the difficulty in obtaining adequate attachment, EPS is not recommended in high wind areas** (i.e., where FM I-90 is recommended) unless it is mechanically fastened in accordance with FM I-90 [15].

The mechanical fasteners must also secure the wood fiberboard, unless the wood fiber board is factory laminated. If laminated, the assembly must have a UL Class 90 or FM I-90 classification.

If EPS is used below a properly designed loose-laid system, it may be used in high wind areas (see Section 3.5.2).

15) EPS is a very common insulation in Alaska. It is readily available (it is manufactured in Anchorage), and is relatively inexpensive.
It is perhaps a very appropriate material for use in a temporary roof, a roof with a designed short service life, or underneath some

elasto/plastic membranes. **However, it is not recommended for built-up roofs with a designed long service life. This is due to its inherent attachment difficulties, difficulties in achieving double layer application,** and its high thermal coefficient of expansion.

- With a 120°F temperature swing (which is quite possible in Anchorage), a four foot long EPS board will move approximately 0.20 inches, while its wood fiber covering will move only approximately 0.02 inches (which is only 10% of the EPS movement).

EPS may be very appropriately used as a below-membrane component of a loose-laid protected membrane roof as discussed in Section 3.5.2.

16) For further information see "Report on Expended Polystyrene Roofing Systems", by Rene M. Dupuis and Jerome G. Dees sponsored by MRCA, NRCA, and The Society of the Plastics Industry, August 1984.

3.4.3.5 Rigid Fiberglass

1) Composed of fine glass fibers together with a binder and surfaced on one side with asphalt and Kraft paper. As of 1985, there is only one manufacturer of this insulation in the United States sponsored by MRCA, NRCA, and the Society of the Plastics Industry, August 1984. This product is produced at a number of locations, including the West Coast.

2) R-value per inch: 3.7

3) Weight per square foot per inch thickness: approximately __ pounds.

4) Compressive strength:

- Boards 7/8" thick or less: 15 psi.
- Boards 15/16" thick or greater: 11 psi.

5) Thermal coefficient of expansion: _____.

6) Specification Reference:

- o ASTM C 726

- o Fed. Spec. HH-1-526 C.
  Note: The Fed. Spec. has been cancelled. Specify ASTM.

7) **This is suitable for use as a fire barrier between steel decks and other roofing components.**

8) This product is not harmed by water, unless exposed to it for an extended length of time (in which case the binder may begin to deteriorate). However, while wet, there is a decrease in R-value.

It is theoretically possible to dry out saturated rigid fiberglass, but in practice this is often very difficult.

9) This material is somewhat difficult to shape.

10) **This material conforms to minor substrate irregularities** - perhaps better than any other insulation material.

11) In adhered systems, the joints in the top layer should be taped with fiberglass tape set in asphalt. This is primarily due to the low compressive strength of the boards.

12) **In general, this is a very good roofing insulation.** However, recent changes (1984) in the reference specifications resulted in a lessening of various performance criteria. In-service performance of insulation produced under the new specification may be less than that obtained with material produced under the old specification.

3.4.3.6 Perlite

1) Manufactured from expanded volcanic minerals combined with organic fibers and waterproofing binders. The top surface is generally treated to minimize bitumen absorption and improve bitumen bonding.

2) R-value per inch: 2.78.

3) Weight per square foot per inch thickness: 0.9 pounds.

4) Compressive strength: 35 psi.

5) Thermal coefficient of expansion:

6) Specification reference:

   - o ASTM C 728
   - o Fed. Spec. HH-1-529 b.

   Note: The Fed. Spec. has been cancelled. Specify ASTM.

7) **This is suitable for use as a fire barrier between steel decks and other roofing components.**

8) Perlite insulation has a laminar tensile strength (internal bond) of 4 psi, which is low. However this equals 576 PSF up-lift resistance. In a properly constructed and applied system, this low internal bond strength should not present a problem.

9) This insulation does not have good resistance to handling abuse. However, only reasonable precautions and efforts are required, extraordinary measures are not.

10) **This insulation is very easy to field shape** - perhaps easier than any other insulation material. For shaping larger areas (i.e., field fabrication of crickets), a weedwhacker is useful.

In adhered systems, debris from shaping should be completely removed to ensure good bonding.

In built-up systems, the shaped surfaces should be primed with asphalt primer before asphalt application.

11) When this material gets wet (i.e., near saturation), it begins to loose compressive strength. As the material deteriorates due to the presence of water, it looses its structural integrity and becomes mushy.

12) **Perlite cants and tapered edge strips** are available. These can be used with a variety of materials in various systems. These are preferred over plastic foam or wood fiberboard products.

13) **In general this is an excellent roofing insulation.**

3.4.3.7 Polyisocyanurate

1) This product resembles polyurethane insulation, but has slightly different physical properties and is made from a polyisocyanurate based chemical. It is sandwiched between facer sheets or boards (as discussed under Section 3.4.3.2 **"Composite Board"**).

Glass fiber reinforcement is used in most polyisocyanurate to achieve additional fire resistance and greater dimensional stability.

This is a thermosetting material.

Polyisocyanurate is also known as "isocyanurate".

2) R-value ("aged") per inch:

- 6.25 according to NRCA.

- o A review of eight manufacturers (in 1984) indicates aged R-values from 5.88 to 7.69.

- o At the 1985 convention, MRCA recommended using an R-value of 5.56. It is believed this more accurately represents the "in-service" value.

The disparity in R-value may in part be due to various assumptions made by the manufacturer. Some of these assumptions may be questionable. The R-value can also be varied as other properties of the board are varied. For example a roof insulation board sees greater loads than wall insulation boards. A good roofing board is manufacture to accommodate these loads, but this results in a board with a lower R-value, as compared to the wall board.

The roofing designer should assume that all quality polyisocyanurate roofing insulation boards have essentially the same R-value. R-values above 6.25 should be highly questioned.

The R-value for this insulation (in terms of thickness) is not linear. The R of a 4" board is not 4 times that of a 1" board.

For polyisocyanurate a specific manufacturer's product should be selected on its characteristics related to roofing, rather than the manufacturer's R-value claim.

3) Weight per square foot per inch thickness: approximately 0.21 pounds.

Note: The type of facer affects the weight - 0.21 assumes an asphalt fiberglass felt. Foil facers may be approximately 0.025 pounds lighter.

One manufacturer reports a weight of 0.36 pounds per square inch per foot. Most of the manufacturer's literature that was reviewed did not give the weight.

4) Compressive Strength: 25 psi.
Note: one manufacturer reports 20 psi.

5) Thermal coefficient of expansion: _____.

6) Specification Reference: Fed. Spec. HH-1-1972

Note: 1. This is a general specification that also covers polyurethane. The specifier should specify **"polyisocyanurate"** when this is the desired product. The specifier should also specify type of facers. If the board is to be placed directly on a metal deck, compliance with FM Class 1 shall also be specified.

2. This Spec. may eventually be cancelled and replaced by an ASTM Spec.

7) Refer to the discussion on Composite Boards for a discussion of facers, blister formation, thermal aging, board thickness, and field shaping.

8) These boards may be secured to decks with mechanical fasteners, asphalt, or adhesives. They can be secured to one another (i.e. double layer application) with asphalt or adhesives. When using asphalt or adhesives, proper facers are required.

9) Polyisocyanurate is expected to take over much of the market now enjoyed by polyurethane, according to **Roof Design** ("Plastic Foams: Roof Insulations of the Future", September 1984).

Because of the similarities, but improved characteristics of polyisocyanurate versus polyurethane, **polyisocyanurate is the preferred choice between these two insulations.**

In the future, phenolic may be preferred over polyisocyanurate. See Section 3.4.3.10.

10) The above referenced article briefly describes a "new generation" of polyisocyanurate which was introduced in 1984. Reportedly, the formulation meets the compressive strength and R-value of previous material, but at reduced densities. Hence, there is potentially lower cost.

Whereas previous manufacturing methods used ovens, the new process depends upon chemical reactions rather than ovens. This new process is known as "free rise".

3.4.3.8 Polyurethane

1). This product resembles polyisocyanurate insulation, but has slightly different physical properties and is made from a urethane chemical base. It is sandwiched between facer sheets or boards (as discussed in Section 3.4.3.2 "**Composite Board**").

This is a thermosetting material.

Polyurethane is also known as "urethane".

Spray-applied polyurethane is discussed in Section 3.4.5.10.

2) R-value ("aged") per inch: 6.25 according to NRCA.

- At the 1985 convention, MRCA recommended using an R-value of 5.56. It is believed this more accurately represents the "in-service" value.

3) Weight per square foot per inch thickness: approximately 0.21 pounds.

Note: The type of facer affects the weight - 0.21 assumes an asphalt fiberglass felt. Foil facers may be approximately 0.025 pounds lighter.

4) Compressive strength: 25 psi.

Note: one manufacturer reports 20 psi.

5) Thermal coefficient of expansion: ____.

6) Specification reference: Fed. Spec. HH-1-1972

Note: 1. This is general specification that also covers polyisocyanurate. The specifier should specify "polyurethane" when this is the desired product. The specifier should also specify type of facers.

2. This spec may eventually be cancelled and replaced by an ASTM Spec.

7) Refer to the discussion on Composite Boards for a discussion of facers, blister information, thermal aging, board thickness, and field shaping.

8) These boards may be secured to decks with mechanical fasteners, asphalt, or adhesives. They can be secured to one another (i.e. double layer application) with asphalt or adhesives. When using asphalt or adhesives, proper facers are required.

9) Polyisocyanurate is expected to take over much of the market now enjoyed by polyurethane, according to **Roof Design** ("Plastic Foams: Roof Insulations of the Future", September, 1984).

Because of the similarities, but improved characteristics of polyisocyanurate versus polyurethane, **polyisocyanurate is the preferred choice between these two insulations.**

In the future, phenolic may be preferred over polyisocyanurate. See Section 3.4.3.10.

3.4.3.9 Wood Fiberboard

1) Manufactured from wood or cane fibers and waterproofing binders. It may be coated or impregnated with asphalt.

2) R-value per inch: 2.77.

3) Weight per square foot per inch thickness: approximately 0.83 to 2.58 pounds. In Gumpertz's 1964 article, 1.33 pounds is reported.

4) Compressive strength: 350 psi (Gumpertz).

5) Thermal coefficient of expansion: approximately 3 x 10^{-6} (Gumpertz). Griffin reports 7 to 10 x 10^{-6}.

6) Specification reference:

   - o ASTM C 208
   - o Fed. Spec. LLL-1-535

   Note: The Fed. Spec. may be cancelled. Specify by ASTM.

7) This is a very traditional insulation that now (1985) finds little roofing use, due to a low R-factor and problems with dimensional stability.

   It is used as a thin covering (3/8" to 1/2" thick) over other products, such as EPS.

8) Tapered edge strips and cant strips are available. However, perlite is generally preferred due to various improved properties.

9) Torching should not occur adjacent to wood fiberboard, due to its flammability.

10) Wood fiberboard can deteriorate very quickly when exposed to excessive moisture.

3.4.3.10 Phenolic

1) This resembles polyisocyanurate and polyurethane insulation, but is made from a phenolic based chemical. It is sandwiched between facer sheets.

Phenolic plastics have been used for various consumer products for several years, however it was only in the 1980's when phenolic insulation boards became available. As of 1985, there is only one manufacturer of this insulation in the United States. This manufacturer produces a closed cell product. There is also a manufacturer in Canada, however this product is open celled.

This is a thermosetting material.

2) R-value per inch is 8.33 according to the U.S. manufacturer.

Note: This, along with other properties noted below, is for the closed cell product.

3) Weight per square foot per inch thickness: approximately 0.31 pounds.

Note: This assumes a foil facer. Other facer types may weigh more.

4) Compressive strength: 25 psi.

5) Thermal coefficient of expansion: 13×10^{-6}.

6) Specification reference:

As of 1985, there is no reference for phenolic insulation, however, the board now produced in the U.S. does meet HH-1-1972 (which is a general specification for polyisocyanurate and polyurethane). The specifier should specify "**phenolic**" when this is the desired product. The specifier should also specify type of facer.

Note: The Fed. Spec. may eventually be cancelled and replaced by an ASTM Spec.

7) Refer to the discussion on Composite Boards for a discussion of facers, blister formation, thermal aging, board thickness, and field shaping.

Prior to late 1984, the U.S. manufacturer only offered this product with corrugated foil facers. However fiberglass facers are the only available facer as of 1985. What is available can be expected to change.

Phenolics are not currently available as composite boards. However, it is technically possible to produce them. In the future they may be available.

Until there is sufficient data to indicate otherwise, **when phenolics are used in a BUR system, the precautions regarding blister formation (over polyisocyanurate/polyurethane) shall be followed.**

Since polyisocyanurate and polyurethane boards are freon soluble, they experience a reduction of thermal resistance. However according to the phenoic manufacturer in the U.S., their board is is not freon soluble. Therefore it doesn't experience a drop in thermal resistance after the time of manufacture. However the U.S. manufacturer does follow the RIC/TIMA conditioning procedure. Data has not been obtained regarding "aging" related to the open cell phenolics.

8) These boards may be secured to decks with mechanical fasteners, asphalt, or adhesives. They can be secured to one another (i.e., double layer application) with asphalt or adhesives. When using asphalt or adhesives, proper facers are required.

9) **Of all of the plastic foam insulations, phenolics have the best fire properties.**

10) Phenolics may eventually take over much of the market now enjoyed by polyisocyanurate and polyurethane, according to **Roof Design** ("Plastic Foams: Roof Insulations of the Future", September, 1984).

Because of the similarities, but improved characteristics of phenolics versus polyisocyanurate and polyurethane, phenolics may eventually be the preferred choice between these two insulations.

However, until phenolics have a longer record of proven experience in Alaska, their use is generally not recommended.

11) The above referenced article indicates some of the properties of phenolics are "the subject of controversy".

3.4.3.11 Tapered Insulation

Tapered insulation may be used to achieve roof slopes or to construct crickets for positive drainage, as discussed in Section 3.3.1 "**Slope**".

Materials:

1. Cellular glass
2. Extruded polystyrene
3. Expanded polystyrene (EPS)
4. Rigid fiberglass
5. Perlite
6. Polyisocyanurate

7. Polyurethane
8. Lightweight insulating concrete
9. Thermo-setting insulating fill

Items 1 - 7 were discussed in Section 3.4.3 "**Roof Insulation Materials**", while 8 and 9 were discussed in Section 3.4.1 "**Roof Deck Materials**". In the future, phenolic may be available in a tapered board.

Usually slopes of 1/8" or 1/4" per foot are available with cellular glass or perlite. The other materials offer numerous slope possibilities.

3.4.3.12 Below-Deck Insulation

The previously described insulation boards are generally used for above-deck installation, although some of them may be used for below-deck application.

The following materials may be used for below-deck (or wall) applications:

- Fiberglass batt
- Fiberglass blow-in
- Mineral wool
- Perlite loose fill
- Vermiculite loose fill

> Note: The Fed. Spec. that are referenced in this Section may be cancelled and replaced by ASTM.

- Cellulose fill

1) **Fiberglass Batt Insulation**

   - Fiberglass batts or blankets (the only difference being the length), are composed of fine glass fibers together with a binder. They may be surfaced on one side with a kraft paper or aluminum foil facer. Batts are generally four or eight feet long. Blankets are in rolls of lengths up to 39 to 70 feet, depending upon thickness.

Although the kraft paper or foil facers provide some vapor resistance, they should not be relied upon for the vapor retarder, due to discontinuity at the side laps. **If a vapor retarder is required, a separate retarder shall be used.** Accordingly, **it is generally recommended to use batts without factory facers, since this is less expensive.**

- Batt insulation is commonly available in the following nominal thickness and R-values:

3 1/2"	R 11
3 5/8"	R 13
6"	R 19
9 1/2"	R 30
12"	R 38

R-value, rather than thickness, should be specified.

- Specification reference: Fed Spec. HH-1-521 F.

  Note: This spec also covers mineral wool. The specifier should specify "fiberglass" when this is the desired product. Also, the Contractor should usually be given the opportunity to provide batts or blankets.

- In Alaska, **this is the most common, and preferred below-deck insulation.**

2) **Fiberglass Blow-in**

- o This is similar to fiberglass batts, except that it is blown into place with a machine.
- o Specification reference: Fed Spec. HH-1-1030 B.

3) **Mineral Wool**

- o Mineral wool is similar to fiberglass batts, except it is composed of mineral fibers and has greatly improved resistance to heat.

  Mineral wool is commonly used as fire-safing (i.e., curtain walls and fire walls or floor penetration sealing) and structural steel fireproofing.

  Mineral wool is available in rigid boards, blankets, and loose fill (for pour-in or blow-in application).

  This material is generally not used as below-deck roof insulation, but there may be situations where this is an appropriate material.

  This material should be used to fill seismic joints, as discussed in Section 3.3.5.

- o Specification reference:
  - o Blankets:
    - o Fed Spec. HH-1-521 F
    - o ASTM C 665

    Note: This Fed. Spec. also covers fiberglass insulation. The specifier should specify **"Mineral Wool"** when this is the desired product.

- o Blow-in: Fed. Spec. SS-S-111 B.

4) **Perlite Loose Fill**

- o Manufactured from expanded volcanic minerals which receive a water resistance treatment after expansion.

  Rigid perlite boards are also available, as described in Section 3.4.3.6 "**Perlite**".

- o This material is simply poured into place.

  Perlite fill is generally not recommended for below-deck application. Due to its granular structure, if the ceiling (or support element) is punctured, the perlite granules could easily spill onto the floor.

- o Specification reference:

  - o ASTM C 549
  - o Fed. Spec. HH-1-574 b

5) **Vermiculite Loose Fill**

- o Manufactured from expanded vermiculite (which is a type of mica).

- o This material is simply poured into place.

  Vermiculite fill is generally not recommended for below-deck application. Due to its granular structure, if the ceiling (or support element) is punctured, the vermiculite granules could easily spill onto the floor.

- o Specification reference:

- ASTM C 516
- Fed. Spec. HH-1-585 C

6) **Cellulose Fill**

- Composed of organic fibers (i.e., paper products) and a binder. This product may also be treated for mold and mildew, and/or fire resistance.

- This material may be poured or blown-in.

- **Generally, other materials (i.e., fiberglass batts) are preferred over cellulose.**

  If cellulose is used, it shall be fire retardant treated. FM has approved cellulose for various fire exposures and uses. The specifier shall determine the appropriate classification and require conformance therewith.

3.4.4 Built-up Membrane Materials

General

Conventional bituminous built-up roofing membranes have been used, in more or less their present form, since about 1840 [16]. These membranes consist of three elements:

- layers of waterproofing agent (bitumen): asphalt or coal tar.

- layers of reinforcing material (felts).

- a protective surfacing.

Asphalt: Historically the waterproofing quality of asphalt finds its earliest recorded use about 3800 B.C. Natural occurring asphalt deposits are still present today, but these are no longer used for roofing. The asphalt used is a by-product of petroleum refining (it is the heavy residue left behind after crude oil is refined). This residue is taken to an asphalt refinery for further processing.

Coal Tar: Vital to the manufacturing of steel and iron is the production of coke from coal. Crude coal tar is recovered during the coking process. The crude is distilled in a refinery into various coal tar products.

Both types of bitumen (asphalt and coal tar) are primarily hydrocarbon compounds that are highly complex in their chemical make-up. They have excellent resistance to water penetration and extremely low water absorptivity. They are durable under prolonged weather exposure. They have good internal cohesive strength and are excellent adhesives. Since bitumens are thermoplastic, they exhibit visco-elastic behavior. At warm temperatures, bitumens behave as viscous liquids, while at low temperature they behave as an elastic solid. This complexity makes it almost impossible to express values for some of the parameters of bitumens, as they vary so much with temperature and rate of testing. The linear coefficient of thermal expansion is an example - it is greatest when cold and not applicable when the material is liquid.

Deterioration (loss of desirable properties) normally takes the form of hardening. The net result is a decrease in adhesive and flow properties and an increase in the softening point and coefficient of thermal expansion. This hardening results in a reduction of its ability to accommodate deformations without cracking, while at the same time, the deforming forces are increasing. The weathering of bitumen is a complicated process involving evaporation, polymerization, and oxidation due to the effects of the sun, heat, and oxygen. The oxidation of asphalt is triggered by ultraviolet radiation, whereas coal tar weathers primarily by evaporation.

The application of gravel surfacing is primarily for the purpose of providing resistance to the effects of evaporation and oxidation due to the sun, heat, air, and water. However, perhaps the best protection now available is the Protected Membrane Roof System, as described in Section 3.5.2 "**Protected Membrane Roof**".

For further information, refer to "Roofing Grade Bitumens" in the RIEI **Basic Roofing Technology** course manual, **The NRCA Roofing and Waterproofing Manual**, **Roofs** by Baker, and the **Manual of Built-up Roof Systems** by Griffin.

3.4.4.1 Bitumen

3.4.4.1.1 General

Bitumen (asphalt and coal tar) is an excellent adhesive and waterproofing material when properly heated and applied:

- **Bitumen should not be heated above the actual Flash Point.**

- Bitumen should not be heated and held above the Finished Blowing Temperature for more than four hours.

- At the point of application, the bitumen temperature should be in the range referred to as Equiviscous Temperature (EVT). The EVT for each different type of bitumen should be noted on the asphalt container ("plug").

  The EVT was established in 1975 (See NRCA bulletin #2, December 15, 1977). It allows a tolerance range of plus or minus 25°F.

  The EVT concept is applicable to coal tar, but it has not been applied to it.

Asphalt and coal tar products should not be mixed. This applies to the bitumen, felts, and accessories such as plastic cement [17].

To determine if a bitumen is asphalt or coal tar, place a specimen (in solid form) in a jar of mineral spirits and shake. If the material begins to dissolve, it is asphalt.

Where to use what bitumen? The answer is not "asphalt vs. coal tar", but rather in answering the question "what are the parameters of the roof design, and how can these be achieved?" [18]. This is further discussed in Section 3.4.4.1.3

3.4.4.1.2 Asphalt (ASTM D 312)

There are four types of asphalt. The primary difference is the softening point temperature. The types are:

Type I Dead Level Asphalt
Type II Flat Asphalt
Type III Steep Asphalt
Type IV Special Steep Asphalt

In the past, asphalt roofing manufacturers had asphalts with constant physical characteristics. In general, they used asphalt fluxes which evolved from known petroleum sources which provided long-term weatherability.

However, crude oil began to come from foreign sources. In addition, domestic crude supplied to the refiners began to be transported through long pipelines, resulting from an intermingling of crude from various sources. The Industry experienced considerable problems in asphalt quality control in the 1970's.

In 1974, the Asphalt Roofing Manufacturers Association (ARMA) sponsored a research program to address the problem [19]. It had three phases:

- Determine a test to identify that a change in asphalt had occurred due to the crude source. This test has been developed and is now in use.

- o Develop a test to predict asphalt durability. Various test methods have been developed to assist manufacturers in ascertaining potential durability.

- o Determine ways of improving those asphalts that show poor durability in laboratory analysis.

In addition to Roofing Grade Asphalt (ASTM D312), asphalt complying with ASTM D 449 is used to factory saturate some felts and fabrics. It is also used for below grade dampproofing and waterproofing, but not for field application of roofing.

3.4.4.1.3 Coal Tar (ASTM D 450)

There are three types of coal tar:

Type I Coal Tar Pitch
Type II Waterproofing Pitch (for below grade and plaza decks)
Type III Coal Tar Bitumen

Type I is the traditional roofing grade coal tar. Type III is especially processed and manufactured to obtain a product which produces less fumes than Type I. Type I is no longer generally available.

Coal tar is more resistant to water than asphalt due to its chemical structure. It also has "cold flow" properties ("self-resealing"). Hence for a dead level roof, it general is preferable to asphalt.

> Note: As discussed in Section 3.3.1, dead level roofs shall be avoided. Also, in some instances, other membranes (i.e. EPDM) would be more appropriate for dead level situations than coal tar.

Coal tar is somewhat more brittle than asphalt at low temperatures.

As of 1985, the nearest coal tar manufacturer to Alaska is in Chicago. Therefore, coal tar may be more expensive than asphalt due to freight costs. Also, at the plant, coal tar is somewhat more expensive than asphalt.

3.4.4.2 Felts

3.4.4.1 General

Felts serve as the structural and reinforcing elements of the membrane. There are three material categories:

Organic (since about 1844).
Asbestos (since about 1858).
Fiberglass (since about 1945).

Polyester fabrics are discussed in Section 3.4.5.1.

Although not a true felt, **rosin-sized sheathing paper** somewhat resembles a felt, and is used in some BUR systems. It is a rosin coated building paper (ASTM D 549). This product is used to separate the bottom ply of a BUR from a wood or plywood deck. By using this material, the bottom felt will not adhere to the deck, which is important due to the potential shrinkage movement of the deck. By nailing the sheathing paper and the first felt to the deck, deck movements should not harm the membrane.

If rosin-sized sheathing paper is not available, a heavy felt kraft paper or reinforced sisal paper may be used.

3.4.4.2.2 Organic (Asphalt organic felt: ASTM D 226)

Organic felts are still used for membranes, although to a limited extent. Their major drawback is their **susceptibility to moisture gain** during shipment and storage. The moisture gain causes dimensional increases and deterioration of the felt. If a moist felt is installed, future shrinkage and membrane damage is likely. Moisture gain can also occur after membrane application, in which case swelling and resultant problems may occur. Organic felts are available "perforated" or "non-perforated". Perforated felts should be used for membrane construction, since the perforations facilitate the embedment of the felt. **If the felts are used for temporary protection (i.e., closing off the top of parapets), non-perforated should be used.**

Organic felts should not be used for water cut-offs in a fiberglass BUR.

Organic felts are used as facers for some insulation boards.

3.4.4.2.3 Asbestos (ASTM D 250)

Asbestos felts have been used for membranes and base flashings (for both organic, asbestos, and fiberglass membranes). They have good fire resistance, and they only have a small percentage of organic materials (hence their susceptibility to moisture gain is reduced).

However, apparently due to environmental factors related to manufacturing, as of 1984 asbestos felts are no longer produced in the U.S. The September 1984 issue of **Roof Design** reports that a firm in Canada still produces and markets asbestos felts in the U.S.

> Note: As of 1985, there is no known health concern related to asbestos containing felts, once the felts leave the manufacturer.

Due to limited availability, asbestos felts should not be specified.

3.4.4.2.4 Fiberglass (ASTM D 2178, Type IV)

In a 1981 report, fiberglass felts had 34% of the market and were expected to capture 73% of the felt market by 1985 [20]. This is partly due to the elimination of U.S. production of asbestos felts. However it is also due to the many attributes of fiberglass felts. Chief among these is its inorganic composition, which prohibits moisture gain.

> Note: Although the felt will not pick-up moisture, if exposed to rain, the surface of the felt may retain some moisture. Hence these felts should also be protected from moisture during shipment, storage and installation.

Because of their porous nature, embedment is relatively easy. However because of this property, two layers of felt should be used for temporary water cut-offs. Also, voids at the membrane substrate (i.e., insulation joints) may create problems. The first layer of asphalt may run into the joint, thus eliminating asphalt under the first ply. The second mopping may run through the first ply and on into the joint, thus allowing two plies to contact one another, which causes a point of weakness in the membrane. Therefore, **it is important to mop fiberglass membranes to tight substrates - filling in or taping joints is required unless the joints are relatively tight.**

Fiberglass base flashing material is available, however modified bitumen is recommended due to its improved properties (see Section 3.4.5.2 "**Modified Bitumen**").

Fiberglass felts are recommended for built-up membranes.

3.4.4.2.5 There are several types of felts:

- o Ply
- o Base
- o Mineral surfaced cap sheets

3.4.4.2.5.1 Ply Felts

These are thin felts saturated or impregnated with asphalt or coal tar.

Note: since fiberglass fibers do not absorb bitumen, the term "impregnated" is used.

3.4.4.2.5.2 Base Sheets

These are heavier tougher felts. In addition to being saturated (or impregnated), they have an extra layer of bitumen coating on each side, with a surfacing on at least one side consisting of a very fine mineral sand or other release agent to prevent adhesion while rolled.

A special type of base felt is the ventilating base sheet. These are discontinuously held to the substrate so that sub-membrane moisture may be vented to edge vents.
Base Sheets are not recommended, due to embedment difficulties [21].

Due to questionable effectiveness of ventilating base sheets (as discussed in Section 3.3.12.8.2) and lack of full attachment, **ventilating base sheets are not recommended.**

Specification reference:

- o ASTM D 224: organic (asphalt) base sheet

- o ASTM D 3378: asbestos (asphalt) base sheet

3.4.4.2.5.3 Mineral Surfaced Cap Sheets (Prepared Roofing Materials)

These saturated (or impregnated) and coated sheets are surfaced on one side with talc, mica, sand, or ceramic granules. **These sheets are intended to be the top ply.**

Application of this material requires the "mop and flop" technique. It is very difficult to fully embed these sheets. Moderate success can only be hoped for if ambient application temperatures are very hot (90°F +).

In Alaska, this material is recommended only for temporary or short life (i.e., five years) applications.

Specification reference:

- o ASTM D 249: organic (asphalt) cap sheet.
- o ASTM D 371: organic (asphalt) cap sheet, with surfacing on only 1/2 the sheet width.
- o ASTM D 3909: fiberglass (asphalt) cap sheet.

Do not confuse mineral surfaced cap sheets with modified bitumen membranes - sometimes these are very similar in appearance.

3.4.4.3 Surfacings

Surfacings help protect the membrane from flaming brands, degradations from the sun, they modify the effects of heat on the membrane, and they provide the membrane with a measure of protection from traffic, dropped tools, and other physical abuse. Perhaps the best "surfacing" is the Protected Membrane Roof as discussed in Section 3.5.2. Besides PMR's, there are three surfacing categories:

- o Aggregate (gravel)
- o Smooth
- o Mineral surfaced cap sheets

3.4.4.3.1 Aggregate

Aggregate is an excellent surfacing material.

Gravelling-in should not occur on the same day the last ply is applied (the membrane is too hot). Aggregate should not be windrowed on unfinished work. When gravelling-in, **the flood coat and gravel should be applied simultaneously.**

With a 60 pound flood coat, 250 to 300 pounds of aggregate per square should be secured in the bitumen. The remainder of the aggregate will be loose. Where loose aggregate is unacceptable (i.e. airports), a double surface may be obtained by: gravelling-in in a conventional manner, sweeping back loose aggregate, and adding a second flood coat and gravel-in the loose material.

Double surfacing should not occur on slopes of over ½" per foot, due to slippage concerns.

Specification reference: ASTM D 1863.

The 1980 and 1983 editions of D 1863 made several changes [22]. These changes affected gradation sizes, allowable dust content, and allowable water content. As a result of the revised specification, probably 500 pounds of aggregate per square (in lieu of the traditional 400 pounds) will be required to completely cover the bitumen [23].

Suggested field checks:

- Aggregate shall be free of ice and snow.
- A handful of aggregate shall not drip water.

See Section 3.2.2.6 for a discussion on wind and aggregates.

3.4.4.3.2 Smooth Surface

Smooth surface roofs require re-coating about every 5-7 years. Usually Owners do not have their roofs recoated and premature failure occurs. Because of this, and due to the limited protection offered, a **smooth surface is not recommended except for:**

- Temporary or short life (i.e., five years) applications.

- o Roofs with continual penetration changes. An example being a manufacturing plant, which may abandon or require new penetrations due to machinery changes.

  With a smooth surface, preparing new penetrations and repairing old ones is rather easy.

Organic membranes should not be smooth surfaced - only asbestos or fiberglass felts are suitable for this surface type.

3.4.4.3.2.1 A number of materials are available for smooth surface application:

1) Bitumen glaze coat

This is generally applied over the top ply on all smooth surface roofs. The glaze coat must be light in order to prevent alligatoring. **Bitumen should only be applied once in the membrane's life,** otherwise the build-up may result in alligatoring.

2) Cut Backs

Made of modestly blown asphalt and petroleum solvent. These are cold applied (do not require heating) by brush, roller, or spray. Cut backs are self priming on existing asphalt items, **they are not damaged by freezing,** and **they are vapor retarders (therefore the membrane must be free of moisture before applying).** The cut back family of coatings includes:

- o **Asphalt roof coating** (ASTM D 2823). This is a cut back with asbestos fibers.

- o **Asphalt aluminum roof coating** (ASTM D 2824, Type I). This is a cut back with aluminum pigment.

- **Fibrated asphalt aluminum roof coating** (ASTM D 2824, Type II). This is a cut back with aluminum pigment and asbestos fibers.

The cut back family also includes two other products, but these are not used as coatings:

- Asphalt primer (ASTM D 41). This is a cut back with additional solvent.

- Plastic cement (ASTM D 2822). This is a cut back with asbestos fibers and other fillers.

The aluminum coating and roof surface should be warm prior to application. Stir before use. **Prior to placing aluminum coatings on a new asphalt surface, the roof should go through one full summer and be 9-12 months old.** Otherwise, asphalt surface movement will crack the aluminum coating. **Aluminum coatings should not be applied where ponding occurs,** otherwise adhesion failure is likely.

Cut Back coatings have good water resistance but will flow under extreme heat, they **will support combustion**, and they are susceptible to blistering. See Section 3.2.8 "Fire". These coatings are persistently soft and are somewhat vulnerable to damage from roof-top traffic.

Some cut back products are available in winter grade or summer grade. The winter grades are formulated to facilitate application. Some wet surface products are also available. These are formulated to facilitate adhesion to wet surfaces. These are applicable to emergency patching situations, since wet surfaces are likely.

Apparently, due to environmental factors related to manufacturing, asbestos fibers may eventually be eliminated. When this occurs, **the replacement products may perform differently.** Particular care should then be given to semi-annual field observations in order to detect possible premature failures of the newly formulated materials.

Note: As of 1985, there is no known health concern related to asbestos containing cut backs, once the cut backs leave the manufacturer.

Cut Backs are also used in Cold Process roofing, as discussed in Section 3.5.3.

3) Emulsions

Consist of asphalt particles dispersed in water (ASTM D 1227, Type I). Emulsions may also contain mineral fibers (ASTM D 1227, Type II).

Unlike cut backs, these coatings breathe - they allow vapor to pass through them, but not water. These are cold applied by brush or spray. **Usually the surface should be primed with asphalt primer (ASTM D 41) prior to coating.**

Prior to application, emulsions may be damaged by freezing. If the material has been frozen, it should not be used.

After application, until the material "sets" it can be washed off the roof surface by rainfall. High humidity can also harm it (prior to setting). Set time depends on wind velocity, temperature, and humidity - it may take a few hours to a day or two.

Emulsions are not subject to alligatoring, **but they should not be applied over a new asphalt surface until the surface has gone through one full summer and is 9-12 months old.** Otherwise, asphalt surface movement will crack the coating.

Emulsion coatings are somewhat more durable than cut backs, and hence are generally preferred. But **special precautions are mandated due to their susceptibility to wash off and freezing.**

Emulsions are also used in Cold Process roofing, as discussed in Section 3.5.3

4) Latex Paints

These have poor freeze-thaw characteristics. They also readily flake away due to lack of adhesion.

These generally are not recommended for Alaska.

5) Coal Tar Coatings

Coatings are also available for coal tar roofs. These use a coal tar base, non-volatile oils, and asbestos fibers.

3.4.4.3.2.2 Recoating Smooth Surface Roofs

The following materials are used for recoating smooth surface roofs:

- o Cut backs
- o Emulsions
- o Latex paints
- o Coal tar coatings

Before Recoating, evaluate the roof condition as discussed in Section 9 "REROOFING AND MAJOR ROOF REPAIR". Does it have enough life expectancy to justify the cost of the recoating? Contrary to what some sales agents may say, **coatings will not:**

- o Correct serious roof problems
- o Substitute for re-roofing
- o Stop leaks alone

Many people refer to coatings as "resaturants". **There is little to suggest that any penetration will occur,** except perhaps with coal tar systems [24].

Think of these materials simply as coatings - coatings that have rather straight forward, non-mystical properties.

3.4.4.3.3 Mineral Surfaced Cap Sheets

This surfacing material was previously discussed in Section 3.4.4.2 "Felts".

3.4.5 Non-Conventional Roofing System Materials

General

Non-conventional systems include:

- o Protected Membrane Roofs
- o Cold-Process Roofs
- o Elasto/Plastic Membranes

Protected Membrane Roof Systems, utilize conventional materials previously discussed, as well as non-conventional materials.

Cold-Process Systems utilize conventional materials previously discussed, as well as polyester fabrics, which are discussed in Section 3.4.5.1.

The elasto/plastic membranes (also referred to as "single ply") include:

- o Modified Bituminous
- o Polymeric
    1) Elastomeric
        - o Butyl
        - o Polychloroprene ("Neoprene")
        - o EPDM
    2) Thermoplastic
        - o Polyvinyl Chloride (PVC)

3) Semi-Elastomer

   - Chlorosulfonated Polyethylene (CSPE, "Hypalon")
   - Chlorinated Polyethylene (CPE)
   - Polyisobutylene (PIB)

- Spray-Applied Polyurethane Foam Roofing
- Liquid Applied
- Blends

Prior to discussing the non-conventional materials, a brief discussion of elasto/plastics is in order:

In 1981, built-up roofing enjoyed 61% of the flat roofing market. By 1985 is was projected to decline 25%. The elasto/plastic products were virtually unknown in the United States until the later 1970's, but their use has dramatically increased.

These systems have taken the country by storm [25]. Performance standards are generally not yet available. Test procedures for these membranes are lacking. And many of these systems have not been in service long enough for the most critical evaluation of all - the test of time.

Despite this, more and more of these systems are being manufacturered, specified, and installed. There is a lot of curiosity and misunderstanding about these systems. The industry hasn't even decided what to call them. Some people use the term "single-ply". To others, these are "elasto/plastics".

The first elasto/plastic invasion in the U.S. occurred in the mid-1960's. Most of these failed. The majority of these failures were due to lack of understanding [26]. Manufacturers did not completely understand the needs and requirements these membranes had to meet. Some materials were improperly formulated or compounded.

The European market has been active with elasto/plastics for some time. In fact, most of the products on the U.S. market have their origins in Europe. The exception being EPDM, which originated in the U.S. However, the use of elasto/plastics in Europe is not as great as many people believe [27].

Polymerics

Prior to looking at the specific polymeric materials (Sections 3.4.5.3 through 3.4.5.9), a few comments about this group are in order. Polymerics are macromolecules. There are three classes of these materials:

- o Elastomers

  These are natural and synthetic rubbers and rubber-like materials. When these materials are stretched and released, they return to their original shape. Charles Goodyear found that by adding small amounts of sulphur to natural rubbers in the presence of heat, it would become non-plastic or thermosetting, and would have increased strength and elasticity. Examples are butyl, EPDM and polychloroprene ("Neoprene").

  The elastomers are very resistant to creep and are tougher than thermoplastics. It is difficult to bond the vulcanized materials together. In the factory, small sheets are seamed together under pressure prior to vulcanization.

  For further information, see "Recommended Performance Criteria for Elastomeric Single-Ply Roof Membrane Systems," Technical Document ME-20, November 1982 by MRCA.

- o Thermoplastics

  These melt when heated and resolidify when cooled. Polyethylene is a simple inexpensive thermoplastic. But it creeps and is just about impossible to bond to. Polyproylene is also equally as difficult to bond to, so it and polyethylene are prevented from being used as primary roofing materials.

Polyvinyl chloride (PVC) is stronger and more stable than polyethylene. It has good resistance to creep and can be solvent, adhesive, or heat welded. Thus this materials is practical for roofing. To make it flexible for this application, PVC is modified with plasticizers.

o Semi-elastomers

Some materials fall halfway between the thermoplastics and elastomerics. One of these is chlorosulfonated polyethylene (CSPE, "Hypalon"). By treating polyethylene with chlorine and sulfur, it is possible to make compounds which are thermoplastic and can be solvent welded in the field. Within months of sunlight exposure and normal weather, these sheets cure into a true thermosetting elastomer. Also included in this group is chlorinated polyethylene (CPE) and gum neoprene.

Changes

Changes in raw materials can have subtle but significant impact on many of the non-conventional materials [28]. Often, these changes may not be apparent to the manufacturer. There are no easy answers to these potential industry-wide problems.

This section was based upon the **NRCA Roofing & Waterproofing Manual**, "Non-Conventional Roofing Systems" in the RIEI **Basic Roofing Technology** Course Manual, the RIEI **Elasto/Plastic Sheet Applied Roofing Systems** Course Manual, and "Elastomeric Roofing", Part 1 - 4 in **Roofing/Siding/Insulation** in August - November 1979 by Water Rossiter, Jr. and Robert Mathey of the National Bureau of Standards. These documents should be consulted if further information is needed. Also, due to the rapid changing nature of elasto/plastics, the periodicals in Section 2 "**RESOURCES AND LITERATURE**" should be referred to.

3.4.5.1 Polyester Fabrics

- These materials have three basic uses:
  - As felts for Cold-Process roofing, as discussed in Section 3.5.3.
  - As reinforcements in modified bitumens.
  - As slip sheets under loose-laid membranes and for application between insulation and aggregate ballast in protected membrane roofs.
  - As felts for built-up roofing, as discussed in Section 3.5.3.

- These rather new products to the roofing industry may become very common [29].

- There are two types of fabrics for use in bituminous roofing: needle-punched and spunbonded. For further information, see "Non-Woven Fabrics in Roofing", **RSI**, February 1982.

- The fabrics used for built-up membranes have a fiberglass scrim bonded between two layers of polyester.

3.4.5.2 Modified Bitumen

- This elasto/plastic is also known as "Modified Asphalt", and "plasticized asphalt".

- Of the elasto/plastics, this is the only one that may be considered as being related to built-up systems. Modified bitumens are usually compatible with built-ups.

- Modified bitumen sheets are made from a variety of macromolecules blended with bitumen (usually asphalt) in various concentrations. Usually a reinforcing may be polyethylene film, polyester mat, glass fabric, or combinations thereof. In addition, a polyethylene sheet may be applied to the top and/or bottom to act as separators and reinforcements. Other surfacings include metal and ceramic granules.

- There are two groups of modifiers:

  - APP: Atatic Polypropylene

  - SBS: Styrene - Butadiene - Styrene

  SBS Modified Bitumen membranes have far superior cold weather properties and are generally recommended for Alaska.

  APP membranes present may obstacles to successful cold weather (i.e. below 40°F) application. They are also easily damaged when they are cold.

- These membranes are generally fully adhered. Attachment may be achieved by cold adhesives, hot bitumen, or torching. Usually a ply of conventional felt is placed underneath.

  Specific application techniques vary depending upon the manufacturer.

- **This product is a very good base flashing material for built-up systems. It is also very applicable to may unique retrofit or maintenance problems.**

3.4.5.3 Butyl

- This elastomeric is synthesized by copolymerizing isobutylene with a small amount of isoprene or butadiene.

- Originally available in sheet and two-component liquid applied systems.

- Poor resistance to petroleum oils and gasoline.

- Poor UV resistance.

- This was one of the first elastomeric but is seldom used today. Other products are available with improved properties at lower cost.

3.4.5.4 Polychloroprene ("Neoprene")

- This elastomeric, commonly know as "neoprene" is formulated of polymers and copolymers of chloroprene (2-chloro - 1, 3 - butadiene).

  This was the first commercially produced synthetic rubber (1932) [30]. It has been used in roofing for over 20 years, however it is rapidly giving way to EPDM.

- Available in sheets and liquid applied systems. Sheets are available in weathering and non-weathering grades. Weathering grade is black. Non-weathering grade is light colored and must be protected from sunlight - normally by a coating. Liquid applied neoprene is also coated. The coating usually used for sheet and liquid systems is chlorosulfonated polyethylene (CSPE, "Hypalon").

- Good resistance to sunlight, temperature extremes, weather, ozone and oil and grease

  Exposed neoprene should be coated with hypalon (CSPE) for improved weather resistance.

- A tentative ASTM standard has been prepared for liquid applied neoprene/CSPE roofing membranes - ASTM D-3468-75T.

- o Sheets may be adhered, partially attached or loose-laid.

- o Neoprenes have improved fire characteristics, compared with traditional EPDM. However fire resistant EPDM formulations are now available.

3.4.5.5 EPDM (Ethylene Proplyene Diene Monomer)

- o This elastomeric is synthesized from ethylene propylene and a small amount of diene monomer. This was developed in the early 1960's.

- o This is similar to butyl, but it has better resistance to weathering and ozone. It may be in contact with asphalt. It has very good cold weather properties.

- o It is not resistant to petroleum oils and gasoline.

- o Traditionally field splices were critical. However recent (1985) improvements in adhesives should result in fewer seam problems.

- o Traditionally uncured neoprene was used for flashing. However uncured EPDM has recently (1985) been introduced.

- o EPDM's have been on the market for some time. In Alaska there are several installations dating back to the early 1970's.

- o EPDM can be sand coated to increase fire resistance, however the coatings have a short life. Recently introduced (1985) fire resistive EPDM is available and should be used in lieu of sand coatings.

- o **EPDM is emerging as the predominate elasto/plastic membrane.**

- o For further information, see "Recommended Performance Criteria for Elastomeric Single-Ply Roof Membrane Systems," Technical Document ME-20, November 1982 by MRCA.

3.4.5.6 Polyvinyl Chloride (PVC)

- This thermoplastic is synthesized from vinyl chloride, with the addition of plasticizers.
- Little data is available regarding the permanency of the plasticizers. The loss of these may cause embrittlement and failure.
- Different manufactures use different plasticizers. PVC's from different manufacturers may behave quite differently.
- PVC's are harmed by bituminous products.
- Available in sheets (adhered or loose-laid) and liquid applied.
- PVC membranes can only be bonded to metal that has been factory coated with PVC.
- PVC membranes are not generally recommended for Alaska.
- Many manufacturers are entering the PVC roofing market. Several of these have had no prior roofing experience.

  If a PVC is used, it is recommended that it be obtained from a company that has been in the roofing market in the past.
- For further information see "Recommended Performance Criteria for PVC Systems," Technical Document MP-10, November 1981 by MRCA.

  The Germans have a PVC standard, but it is old:

  Deutsche Normen, Dachbahnen aus PVC Weich, Nicht Bitumenbestandig, din 16730, November 1973.

3.4.5.7 Chlorosulfonated Polyethylene (CSPE, "Hypalon")

- This semi-elastomer is a chlorinated polyethylene containing a small number of chlososulphonyl groups by the simultaneous chlorination and sulfonation of high molecular weight low density polyethylene.

- **After curing, CSPE has outstanding resistance to ozone, heat and weathering.** It also has good oxidation resistance.

- It has good color stability and may be formulated in a wide variety of colors.

- Available in sheet and liquid applied systems. The liquid applied material is suitable for use on spray-applied polyurethane frame insulation or other elastomeric membranes such as polychloroprene ("Neoprene").

3.4.5.8 Chlorinated Polyethylene (CPE)

- A theromplastic sheet composed of high molecular weight low density polyethylene that has been chlorinated to a given level. The cured material should be semi-elastomeric.

3.4.5.9 Polyisobutylene

- A synthetic rubber sheet composed of isoprene, highly-molecular isobutylene, carbon black and aging protectors. The cured material should be semi-elastomeric.

3.4.5.10 Spray-Applied Polyurethane Foam Roofing Systems (PUF)

- These systems were first used in the mid 1960's. They consist of spray-applied polyurethane foam on a deck, followed by an elastomeric coating. This system is suitable for structures of unusual shapes - such as hyperbolic paraboloids.

- Proper application of foam is critical. Once applied, it should be coated within 72 hours. It should not be subjected to moisture prior to coating.

There are a number of ways to make application errors [31]. The installer should be totally familiar with the system. Full time observation on behalf of the Owner by someone who is knowledgeable of this system is recommended.

- Two coating categories exist; there is controversy over which to use. The categories are permeable (0.5 perm rating or greater) and impermeable (less than 0.5 perm rating).

  1. Permeable coatings include: acrylics, silicones, and some urethanes. Most of these are applied by roller or spray.

     Acrylics are single component, water based. They must have sufficient time to cure to prevent washoff. These are generally cheaper than silicones or urethanes.

     Three different silicones are available - tow of these are single component (one of which was taken off of the market due to shelf stability problems) [32]. Silicones have a long history of good performance over PUF. Silicones may provide slightly better protection than acrylics.

     Two types of urethanes are available - single and two-component. Single component systems usually do not perform well unless top-coated. The two-components have excellent physical properties and may be the PUF coating of the future, particularly when top-coated with a two component aliphatic urethane [33].

  2. Impermeable coatings include: butyl and neoprene, hypalon, and some urethanes. Most of these are applied by roller or spray.

     Butyls are generally two-component and have the lowest perm.

They do not weather well unless top-coated with hypalon.

Neoprenes are usually low solid single-component. Because of their low solid content, multiple coatings are required. Like butyls, neoprenes should be top-coated with hypalon.

Hypalons may be single or two-component. They may be used as top coats only, or for the entire coating system.

The impermeable urethanes are available as single or two component systems. The single-components should usually be top-coated with hypalon.

- o A surfacing of mineral roofing granules is sometimes used. This provides some impact resistance.

- o Soft soled shoes should be worn when walking on PUF.

- o Birds sometimes peck at PUF.

- o Hail storms have damaged PUF.

- o PUF roofings have been installed in Alaska. **There are projects in which this will be the best system - but this will be rare.**

  PUF may perform satisfactorily when applied under ideal conditions with properly functioning equipment by fully qualified experienced applicators. **But ensuring that these parameters will be met is difficult - particularly in Alaska.**

- o PUF requires recoating about every 8 - 10 years.

3.4.5.1 Liquid Applied Coatings

- o Besides being used as the final skin on PUF, coatings may be used on other substrates - the most popular being concrete and plywood.

- Deck preparation is critical.

- There are two categories:

  1. Solvent borne:
     The solvent does not dissolve the elastomer, but swells the molecules to form a "paint". After the coating is applied, the solvent diffuses out and the elastomer vulcanizes in place.

     Early coatings used butyl, but this picked up a lot of dirt and presented unsatisfactory appearance.

     Hypalons weather well, but do not bond as well as neoprene and cost a lot more. As a result, the most popular systems became 2 or 3 coats of neoprene covered by 1 or 2 coats of hypalon.

     For the solvent to escape, thin multiple coatings are required.

  2. The other class of coatings consists of very low weight molecular compounds. These include polysulfides and urethanes. These are generally applied in one thick coat.

- Color variations are sometimes objectionable. Also, deck irregularities telegraph through the coating and become quite visible. Roofing granules may be added to help overcome these problems and provide some impact resistance

- For concerns regarding liquid applied coatings, refer to the previous discussion on PUF.

3.4.5.12 Epichlorohydrin

Epichlorhydrin ("Herclor") is a specialty membrane. It is resistant to hydrocarbons.

3.4.5.13 Blends

Blends are materials that don't fall precisely into other material categories. Most blends are likely to be minor variations from one of the other material groups.

Examples:

- Silicone impregnated fiberglass.
- Ethylenebutyl acrylate copolymer with bitumen (ECB)

3.4.6 Steep Roofing Materials

3.4.6.1 Composition Shingles

- Composition shingles are the most common residential roof covering. They are composed of an organic felt or fiberglass mat, a specially-formulated asphalt coating, and ceramic-coated mineral granules.
- A variety of weights are available, from 215 to 360 pounds per square.
- Shingles are available with a UL wind-resistant rating. **A wind-resistant rating should be specified for areas with a basic wind speed greater than 70 mph.**
- Self-tabbing ("self-sealing") shingles are available, however these generally are not effective in Alaska. **Hand tabbing shingles is recommended in areas with a basic wind speed greater than 70 mph.**
- For further information, see "Residential Asphalt Roofing Manual", by the Asphalt Roofing Manufacturers Association, 1984.

3.4.6.2 Wood Shingles And Shakes

- Shingles are sawed on both sides. Shakes are split on at least one surface. Shakes are available in 18 and 24 inch lengths. Shingles are available in 16, 18 and 24 inch lengths.

- The longer shingles and shakes result in greater "exposure", but are also more expensive.

- Cedar shingles are available in four grades: #1 Blue Label (the favored roofing grade), #2 Red Label (when used for roofing, a reduced weather exposure is recommended). Grades #3 and #4 are not generally used for roofing.

  Cedar shakes are generally #1 Certi-Split Label grade.

- Under certain conditions, preservative treatment should be considered: prolonged high heat and high humidity, low sloped roofs, and roofs beneath overhanging trees, etc.

- **Fire retardant treatment should always be considered, and normally specified.**

- For further information, contact the **Red Cedar Shingle and Handsplit Shake Bureau** in Bellevue, Washington.

3.4.6.3 Synthetic Tiles

A variety of tiles made of synthetic materials are available. One type of tile is similar in appearance to asbestos - cement shingles, while other types simulate other traditional tile materials.

The properties and characteristics of synthetic tiles depends upon their material composition.

3.4.6.3 Clay And Concrete Tiles

These are excellent roof coverings. They are available in a variety of textures and color. However, due to their great cost in Alaska, they are not commonly used.

3.4.6.5 Slate And Lead Shingles

These are excellent roof coverings. However, due to their great cost in Alaska, they are rarely used.

Specification reference for slate: ASTM C 406.

3.4.6.6 Asbestos - Cement Shingles

This product is generally no longer available and should not be specified.

If demolition or modification of an existing asbestos - cement shingle roof occurs, special precautions may be required. Dusting of fibers may occur if the shingles are broken.

3.4.6.7 Metal Panels

Traditional materials (i.e. copper) and methods (small field fabricated panels) have largely given way to preformed aluminum or steel. These systems are further discussed in Section 3.5.6.

Metal tiles are also available. These are generally fabricated to simulate other traditional materials.

3.4.6.8 Built-Up

The built-up materials discussed in Section 3.4.4 may be used in steep roofs, however, specific materials and precautions are necessary.

3.4.6.9 Elasto/Plastic

The elasto/plastic materials discussed in Section 3.4.5 may be used on steep roofs, however specific precautions may be necessary.

3.4.6.10 Spray-Applied Polyurethane Foam Roofing (PUF)

See Section 3.4.5.10.

3.4.6.11 Liquid Applied Membranes

See Section 3.4.5.11.

3.4.6.12 Glass

See Section 3.5.8.2.

3.4.6.13 Fabrics (For Air Supported Structures)

See Section 3.5.8.3.

3.5 OVERVIEW OF SYSTEMS

3.5.1 General

A roof system is defined as an assembly of interacting components (including the roof deck) designed to weatherproof, and normally to insulate a building's top surface.

The conceptual system design is of fundamental importance. The likelihood of achieving a good roof begins and is largely controlled at this stage. Conceptual system design focuses on:

- o Slope: Flat or steep?
- o If flat roof, is it a Protected Membrane Roof?

- o Drainage, sliding snow, falling ice.
- o Snow drifting.
- o Selection of deck type, type of vapor retarder and its location, insulation type(s) and thickness, and membrane type.

Roof decks, vapor retarders, insulation and membranes are discussed in Sections 3.3.10 through 3.3.13.

3.5.1.1 Weather

Weather is perhaps the primary determinent in system design. Knowledge and acknowledgement of weather at the building site (during application and service) is mandatory. Weather, wind, ice, and snow are discussed in Section 3.2.

3.5.1.2 Logistics

Getting materials and/or equipment to the building site must be considered. Logistical limitations may preclude some systems or impact system design. If there is sufficient justification, greater expenditure of money may overcome logistical problems.

Examples:

- o Lack of a crane may prohibit using large, heavy, rolls of EPDM.
- o Limited port facilities may prohibit very long metal roofing panels.
- o Lack of an asphalt kettle may necessitate utilizing a self-adhering or torch-down modified bitumen membrane.

3.5.1.3 Familiarity With System and Site

Before designing the roofing system, the Designer should be familiar with the Site's weather conditions and logistics.

The Designer should usually only consider systems and materials that

he/she is familiar with. New systems/materials or older systems/materials not previously used by the Designer should be avoided except under the following conditions:

- o Experimental roofs (designs or materials).

  As noted in Section 1.5, **experimental roofs shall be utilized only under a carefully controlled research program.**

- o Under a carefully controlled program, utilization of new or unfamiliar systems/ materials may be acceptable if the roof area is small (i.e. less than 5,000 square feet), the Designer thoroughly researches the system/design, and the Designer believes the applicator will be qualified to do the work.

  Note: In Public work, usually the Designer has little assurance a qualified applicator will be awarded the job.

Before designing a system, be sure there are roofers that are familiar with the system/materials and with the site.

Avoid the risk associated with a project wherein the designer or roofer is not familiar with the specified roofing system/materials or not familiar with the site's weather and logistics.

3.5.1.4 **A "Good Roof", Life Expectancy, and Costs**

3.5.1.4.1 A good roof is a roof that is satisfactory performing or is capable of performing the roof functions listed in Section 3.1.1, and ultimately will reach the life originally expected of it.

Accordingly it is possible to evaluate a roof during design, shortly after it is constructed, or after 15 years of service. Although such an evaluation will be based upon assumptions, it is possible to make a determination regarding whether or not a given roof is good at any time during it's life.

A **good roof** is founded upon **good design** (which includes good selection and arrangement of materials, good detailing, and good drawings and specifications), **good materials**, **good application** (including materials handling), and **good maintenance**.

Of course, a good roof can be adversely affected by extreme natural events such as earthquakes and wind.

3.5.1.4.2 **Life expectancy should always be anticipated and selected by the Designer.** Although the actual life may be significantly greater than the design life, it should always at least meet the design life.

To simplify choices, design life expectancy should be five, ten, or twenty years.

A five year life should only be used for buildings scheduled to have roof demolition or major roof change, within five years.

A ten year life should be used for buildings scheduled to have roof demolition or major roof change, within ten years.

A twenty year life should be used for most roofs.

Although it is possible to evaluate a roof to determine whether or not it is good, **it may be very difficult to accurately estimate the remaining life expectancy of an existing roof.** While difficult, this estimation is critical when contemplating reroofing or major roof repair. This is further discussed in Section 9 "REROOFING AND MAJOR ROOF REPAIR".

3.5.1.4.3 Cost

Although throwing money at a problem does not necessarily solve the problem, underfunding can adversely affect the likelihood of achieving a good roof.

Common problems are:

- Spending too little for design. The Owner sometimes underfunds the design budget. Sometimes the Designer elects to spend the design budget on other less critical aspects of the project.

- Spending too little for materials and systems. To reduce cost, often less expensive materials and systems (with inherently greater risks in terms of premature failure) are selected by either the Owner or Designer.

- Spending too little for application. Too often, unqualified or marginally qualified applicators perform the Work. Unfortunately in the Public sector, all too often these applicators are allowed the opportunity to perform, simply because of the difficulties that arise when they are not given the opportunity. This unfairly burdens the Public when failure occurs.

- Spending too little for maintenance. Maintenance is usually underfunded. However, many times the Maintenance Department has a roof that is too maintenance intensive (i.e.. demanding). **Considering budgetary and maintenance personnel uncertainties in the Public sector, the roof design should be one that demands very little maintenance.**

In conjunction with the Owner, the Designer should establish the desired design life expectancy of the roof. All subsequent decisions and work related to the roof should be conducted so as to achieve the design life. Obviously cost is an important element of the decisions and Work.

If a correct design life (i.e. 5, 10, or 20 years) is selected as discussed in Section 3.5.1.4.2, and it is achieved, the Owner wisely invested the money spent on roofing.

As the roof reaches the end of its life (either maturely or prematurely), it is important to monitor the roof and plan for its timely replacement. Substantial costs can be saved by replacing the roof before the insulation gets wet, or building components, finishes, or furnishings/equipment are damaged or destroyed. Unfortunately most roofs are not observed semi-annually, hence most problems go unnoticed until they become quite severe and costly.

3.5.1.5 Occupancy Considerations

Roof system design should always consider the type of building occupancy. The three primary concerns are humidity, roof-top equipment changes, and chemical attack.

Because of the high vapor pressure in many parts of the State, artificially humidified buildings need special attention. In addition to carefully designing and installing the vapor retarder, the insulation system must be adequately designed and installed to prevent condensation below the vapor retarder. See Section 3.2.5, 3.3.11, and 3.3.12.

Manufacturing facilities often have roof-top equipment changes that are necessitated due to revisions to manufacturing processes or equipment modifications. A roofing system that will easily accommodate new penetrations and lend it's self to being patched is therefore desirable.

Due to limited industrial and manufacturing work within the State, chemical attack is not common. Attack may be due to a corrosive interior environment (i.e. a sewage treatment plant or wood pulp mill). In this case, the entire underside of the roof may be subject to attack. However more likely the problem relates to exhausting harmful products out onto the roof. In either case, material selection is the key to preventing problems.

3.5.1.5.1 Swimming Pools

Of all humidified buildings, perhaps swimming pools present the greatest

challenge to successful moisture control. In addition to moisture control considerations, there is also concern regarding integrity of the structural frame and deck. Dry rot, corrosion, and chemical attack (hydrochloric acid from the chlorine) must be assessed and controlled.

The mechanical system is an important component of the moisture control issue. However due to uncertainties during initial system start-up and future equipment failures, misadjustments, or lack of maintenance, **the mechanical system should not be relied upon. Successful moisture control should be designed and built into the roofing system.**

Key Considerations

- Structural: Structural components (including the deck) should be resistant to moisture and chemical attack. For example:

  1) Wood components should be preservative treated (note: verify Code provisions do not require fire retardant treatment - although some fire retardant treatment processes offer some preservative characteristics, they may be inadequate).

  2) Steel:

     Due to moisture, steel decks should be galvanized. Depending upon several variables, galvanizing of the joists, beams, and columns should at least be considered.

     Since the galvanized coating can be attacked by hydrochloric acid, the galvanized steel should be painted with a suitable coating. If the coating is factory applied, careful field touch-up is required. If it is field painted, care should be taken to spray into concealed areas (i.e. congested connections, deck end and side laps).

  3) Concrete is least susceptible to moisture and chemical attack

problems. Also with a concrete deck, moisture migration by air flow (as discussed in Section 3.2.5) is minimized.

o Roofing

1) If the roof is flat, a protected membrane system should be used and the dew point should occur above the membrane.

   At least two layers of three inch thick insulation should occur above the membrane. In the colder parts of the State, three layers of insulation should be used (at least two of the layers should be three inches thick; the third layer should be at least two inches thick).

2) If the roof is sloping, it should have a ventilation space between the top of the insulation and underside of the roofing.

3.5.1.6 Flat Versus Steep Roofs

In recent years, many people have become very outspoken against flat roofs. Flat and steep roofs have their own advantages and disadvantages. Both are viable systems under certain circumstances. The following items should be considered:

1) Weather conditions during application may suggest a steep roof, since many steep roof systems may be successfully installed in poor weather.

2) Steep roofing systems often have lower construction and maintenance costs and longer lives than comparable flat roofs.

3) Falling ice should always be anticipated with steep roofs. If people cannot be protected from this potential hazard, flat roof systems should be used.

Note:

1. Infrequent passage below eaves (i.e. minor emergency egress) may be acceptable.

2. Steep roofs may be successfully used in conjunction with flat roofs at main egress points.

3. It is not realistic to totally prevent someone from walking underneath an eave. Reasonable care is the design goal. For example, a school play yard should not be adjacent to a building eave.

Icing is further discussed in 3.2.3

4) Sliding snow should always be considered with steep roofs. However depending upon the slope, texture of the roof surface, and snow guards, snow slides may not occur. If slides can occur and people cannot be protected from this potential hazard, flat roof systems should be used.

Snow is further discussed in 3.2.4.

5) With steep roofs, soil erosion at grade may occur below eaves. Also, nearby walls can become quite dirty. These problems are generally easy to solve, but this may be relatively expensive in some instances. With steep roofs, infiltration at grade may occur if there is a great amount of water run-off or glaciation. For a new building, this problem can be overcome by careful attention to wall detailing and sloping the grade. However this may be a formidable problem with and existing building. **If an existing flat roof is converted to a sloping roof, this potential problem should be studied during design.**

6) Depending upon the size and shape of the roof plan, very large interior volumes may be created by a steep roofing system. This may be prohibitively expensive.

7) Complex shaped plans may not lend themselves to steep roofing.

8) Snow drifting may occur on flat or steep roofs, although it is generally a greater problem with flat roofs. Drifting should not present a problem, provided the design accounts for it.

9) Drainage from flat roofs must be properly designed in order to prevent structural collapse of the roof system.

In summary, steep roofing will likely be the preferred system in terms of application, cost, and life expectancy. However for many buildings, various disadvantages of steep roofs will dictate a flat roof system.

Slope, flat roofs, and steep roofs are further discussed in 3.3.1, 3.3.2, and 3.3.3.

3.5.1.7 Plaza Decks

A plaza deck is similar to a Protected Membrane Roof. However plaza decks demand special consideration.

3.5.1.7.1 Dead and Live Loads

The dead and/or live loads may be greater for plaza decks than for Protected Membrane Roofs. Normally the membrane should be capable of accommodating this greater load. However if the load is significantly greater than what is normally encountered with a PMR, verify the proposed membrane is suitable.

With most plaza decks, some insulation will be placed above the membrane. As with PMR's, extruded polystyrene shall be used. If the loads are light, Styrofoam RM or Foamular 404 should be suitable. For heavier loads, Styrofoam PD is required (note: as of 1985, Foamular does not produce a board equivalent to PD). In all cases, verify the proposed insulation (both above and below the membrane) have sufficient compressive strength.

3.5.1.7.2 Frost Heaving

With PMR's, there is no concern regarding frost heaving. **However with plaza decks this is of great concern.** Heaving of the wearing surface can create tripping hazards and be very unsightly. To overcome this problem there are two critical considerations:

- The primary water drainage from the wearing surface should be accomplished by sloping the surface to divert the water away from the plaza deck.

  The goal is to eliminate or at least minimize the amount of water that reaches the membrane below the plaza deck.

  Attention to the sealant joints in the wearing surface is important. The joint design shall comply with recommended practice. Normally a one-component polyurethane sealant complying with Federal Specification TT-S-00230-C Type 1 or II, Class A or B, with a shore hardness of 45 or greater should be used. Since sealant joints are often poorly constructed, field observation of sealant application is recommended.

- Air voids shall occur between the membrane and the wearing surface. This should allow the water to freeze and expand without jacking the wearing surface.

  The void can be created by placing the wearing surface paver blocks on pedestals or it can be achieved by placing pea gravel between the insulation and wearing surface. The size of the void should be a function of the quantity of water that is expected to enter the void space. The pea gravel layer should be one inch thick, as a minimum.

  > Note: **Always anticipate that water will penetrate the wearing surface.** Even if all water is designed to run off of the surface, sealant joint failures or cracking of the wearing surface will likely occur.

If pea gravel is used, a filter fabric shall be placed over the insulation prior to placing the gravel.

If the wearing surface is cast-in-place concrete, a filter fabric shall also be placed between the gravel and the concrete. A stiff concrete mix may be advantageous to placing operations.

3.5.1.7.3 Particular Attention to Good Roofing Practices

Because of the great difficulty and expense that can be incurred with a plaza deck failure, particular attention to good roofing practices is mandatory. This applies to work by the designer, contractor, and field observer.

Conservative design and workmanship is required.

3.5.2 Protected Membrane Roofs (PMR's)

3.5.2.1 General

This roofing system places insulation above the membrane. The insulation is covered with ballast for blow-off, fire, and UV protection.

Ballast options include aggregate, pavers, and mortar-faced insulation.

As of 1985, extruded polystyrene (see Section 3.4.3.3) is the only insulation suitable for above-membrane application.

PMR's are also know as "up-side down" roofs and IRMA (insulated roof membrane assembly). They offer significant attributes:

- o Protection from mechanical damage due to foot traffic, dropped tools, wind blown debris and hail.

- o Protection from the harmful weathering effects of solar radiation.

- Protection from thermal shock.

- Reduces the membrane's thermal variation.

  Note: A ballasted roof (a roof without insulation above the membrane) provides some degree of protection, however the addition of at least one inch of insulation above the membrane greatly increases the degree of protection.

All new flat roofs with a long design life (i.e. twenty years) shall be Protected Membrane Roofs. All flat reroofing projects that can accommodate the dead load of a PMR shall also be Protected Membrane Roofs.

3.5.2.2 Thickness of Insulation Above Membrane

Traditionally, virtually all of the thermal insulation in PMR's has been placed above the membrane. **However, consideration shall be given to placing the majority of the insulation below the membrane.** This variation on the traditional concept allows the use of less expensive insulation (for below-membrane) while maintaining the majority of the attributes of the traditional system.

With this variation, the dew point likely falls below the membrane, hence a vapor retarder will be required.

With high humidities (i.e. fifty percent or greater), the traditional system which places virtually all of the insulation above membrane shall be utilized.

3.5.2.3 Where possible, base flashings at parapets, walls, and penetrations shall be protected. Typical details are illustrated in Section 3.9.3.

3.5.2.5 Air Below the Membrane

If a loose-laid membrane is used, preventing air pressure from developing between the membrane and substrate is absolutely critical with the mortar-faced system.

Air leakage through the deck may cause ballooning of the membrane. This in turn could cause rotation of the tongue-and-groove insulation joints and loss of ballast integrity.

Normally, cast-in-place concrete decks are very resistant to air infiltration. Likewise, an existing built-up membrane that is left in place is normally quite resistant. **Most other deck systems are susceptible to air infiltration to some degree.** Depending upon the Basic Wind Speed and other factors (i.e. roof overhangs and exterior wall openings), **an air retarder may be required.** In many instances, DuPont "Tyvek" as discussed in Section 3.4.2.5 will be an appropriate air retarder material. The retarder must be designed, detailed, and constructed in a manner that allows it to function as intended.

Under severe conditions, an air retarder may also be appropriate for aggregate and paver systems.

3.5.3 Flat Roofs, Built-up and Cold-Process Membranes

3.5.3.1 Weather Limitations

o System shall not be installed when it is raining or misting.

    Note: In locations where it is likely to be raining during construction, this system should not be specified.

o System can be successfully installed in moderately windy conditions.

o Cold weather application of built-up membranes can be successful, provided the EVT is maintained.

- Cold-process materials should be applied at ambient temperatures of 55°F or greater. If the materials are preheated, application during subfreezing temperatures may be possible. Polyester fabrics should be used for cold weather application.

3.5.3.2 BUR Component Materials

- Decks: See Section 3.4.1

- Vapor Retarder: Bituminous, see Section 3.4.2.1

- Insulation: See Section 3.4.3

- Bitumen: Because of the reasons discussed in Section 3.4.4.1, asphalt is typically used in Alaska.

- Felts: Typically fiberglass ply felts should be used. See Section 3.4.4.2.

  Note:

  1. Due to moisture gain susceptibility (prior to or during application), organic felts should only be used for temporary or short life (i.e. five years) roofs.

  2. Generally avoid base sheets, as noted in Section 3.4.4.2.5.2.

  3. Use of polyester fabrics may eventually be recommended for built-up membranes. However since they are new (1984), they should not be used until additional experience and data is generated.

- Surfacing: Protected membrane as discussed in Section 3.5.2, or aggregate as discussed in 3.4.4.3.1. Other surfacings are discussed in Section 3.4.4.3, however, these are generally not as preferable.

- Base Flashings: Modified bitumen as discussed in Section 3.4.5.2.

3.5.3.3 BUR Component Arrangement

- Unless a PMR system is used, the insulation should be installed in two layers.

  Note: For extremely high R-values, three layers will be required. However, because of labor cost and slippage concerns, utilization of a PMR system should be considered in lieu of three layers in a conventional system.

- Each layer of insulation should be no more than 2½ inches thick, otherwise it is difficult to conform the board to the substrate and achieve full adhesion.

  Note: With a PMR system, thicker boards below the membrane may be acceptable. See discussion in Section 3.5.2.2.

- For nailable decks, the first layer of insulation shall be mechanically fastened in accordance with FM and the second layer mopped-in ("nail one, mop one").

- For non-nailable decks, the insulation shall be set in a solid mopping.

- To minimize mechanical fastener penetrations through the vapor retarder, the retarder should be placed over the first layer of insulation.

  Note: The second layer shall be thick enough to cause the dew point to occur above the vapor retarder.

3.5.3.4 Slippage

- Select type of asphalt based upon roof slope. Be cautious of areas with quick slopes (see Section 3.3.1.4).

- o Backnailing (using nails in addition to bitumen to secure felts) may be required on slopes over 1½ inches per foot. See Griffin for further discussion.

- o Double surfacing (as discussed in Section 3.4.4.3.1) should not occur on slopes over 1/2 inch per foot.

3.5.3.5 Cold-Process

3.5.3.5.1 General

Cold-Process bituminous roof membranes differ from traditional hot-applied BUR primarily in only one aspect. The interply adhesive and top coating is field applied at ambient temperature.

Cold-Process has typically been used in the past for BUR repair work and recoating smooth surfaced BUR. However introduction of polyester fabrics (Section 3.4.5.1) in the early 1980's has led to increased use of cold-process roofing for new construction.

For a more detailed discussion, see Griffin and "Cold Roofing: Options in New Construction", **RSI**, December 1984.

3.5.3.5.2 System Description

- o Substrate construction is similar to that for BUR.

- o Asphalt cut back (see 3.4.4.3.2.1) is used for interply adhesive and surfacing. Asphalt-based emulsion (see 3.4.4.3.2.1) may also be used for interply adhesive and surfacing, although this material takes greater application skill and must be used with a specific type of polyester fabric. **Cut backs should not be used in conjunction with emulsions.**

- o Plys can either be coated felts (see 3.4.4.2) or polyester fabrics (see 3.4.5.1). Coated fabrics are preferred over saturated felts because they fuse better with the cold adhesive.

  Polyester fabrics are relatively new, however they appear very promising.

- o Surfacing can be smooth (cut back or emulsion) or aggregate-surfaced. In addition to normal aggregate, No. 11 mineral granules (as used on asphalt shingles) may be used.

3.5.3.5.3 Advantages of Cold-Process

- o Cold-Process may be somewhat less expensive than BUR.
- o Not as equipment intensive as BUR.
- o Reduced hazards to workers, compared with BUR.
- o Reduction of air pollution, compared with BUR.

Many of the advantages are in comparison with BUR. However when compared with other elasto/plastics, cold-process may not compare as favorably.

3.5.3.5.4 Disadvantages of Cold-Process

- o Due to the persistent softness of the cut back, cold-process membranes are more vulnerable to damage from roof-top traffic.
- o During application, point loading may cause the soft interply adhesive to flow, thus creating a felt-to-felt defect in the membrane.

3.5.3.5.5 Recommendations

Due to limited cold weather experience, cold-process is not generally recommended for Alaska. This system should not be used unless thoroughly researched and justification is apparent.

Cold-Process may not be suitable in a Protected Membrane Roof System, due to potential cut back flow as discussed in 3.5.3.5.4.

3.5.4 Flat Roofs, Elasto/Plastic Membrane

These systems include:

- Modified Bitumen
- Butyl
- Neoprene
- EPDM
- PVC
- CSPE
- CPE
- PIB
- Epichlorohydrin
- Blends

In most roofing projects in Alaska, the elasto/plastic membrane which will normally be used will be modified bitumen or EPDM:

- Butyl roofing membranes are essentially no longer available.

- Neoprene is very similar to EPDM, however, EPDM has better cold weather properties and is less expensive. In exposed configurations, neoprene was often specified due to its superior fire resistance properties. However, fire resistive EPDM formulations are now available.

- PVC, CSPE, CPE, and PIB either lack the performance of EPDM or are more expensive. These membranes should only be used in lieu of EPDM where justification for doing so is clear.

An example would be a roof with contaminants harmful to EPDM. In this case, utilizing CSPE, epichlorohydrin, or other suitable materials will be required. If the contaminated area is limited in size (i.e. from an exhaust air discharge), it may be most economical to use EPDM for the roof, except in the discharge area. In the discharge area, a more expensive contaminant resistant membrane could be used.

- Epichlorohydrin ("Herclor") is a specialty membrane. It is resistant to hydrocarbons.

- Blends are materials that don't fall precisely into other material categories. Most blends are likely to be minor variations from one of the other material groups. In the future new formulations may lead to new membrane categories.

When evaluating other membranes in comparison to EPDM, the following items shall be considered:

- Are large sheets available?
- Is loose-laid configuration (ballasted or protected) possible?
- Material Properties

  The following properties are critical:

  - Brittleness temperature at -50°C (-58°F); test method ASTM D 746.
  - Resistance to water change in weight after immersion; test method ASTM D 471.
  - Heat aging; test method ASTM D 573

  The following properties are less critical:

  - Specific gravity; test method ASTM D 297
  - Tensile Strength; test method ASTM D 412

- o Elongation; ASTM D 412
- o Tear Resistance; ASTM D 624
- o Shore A Durometer; test method ASTM D 2240
- o Ozone Resistance; test method ASTM D 1149

Tests should be performed on materials that are identical to those used in the job (i.e. if a reinforced membrane is being considered, material property tests should be on reinforced rather than unreinforced material).

Although test methods are identified, minimum performance levels are not. Minimum performance of other membranes should be evaluated in comparison to EPDM and the specific roof under consideration.

3.5.4.1 Modified Bitumen (MB)

Modified bitumen is very similar to built-up. See Section 3.5.3.

Modified bitumen is available in factory fabricated sheets. Typically these use polyethylene, polyester or fiberglass sheets (or both) as reinforcers or carriers. MB extruded sheets without reinforcement are entering the market (1985).

Modified asphalt is also available for field application with traditional felts or polyester fabrics. In this application, the membrane construction is virtually identical to BUR, except for use of modified asphalt.

As noted in Section 3.4.5.2, MB is available with APP or SBS modifiers. **In Alaska, SBS should be used.**

If the membrane is exposed, granular surfacing should be used. If it is protected or ballasted, surfacing is not required, except for exposed portions (i.e. base flashings). If it is protected, a slip sheet may be required (depending upon membrane surface) to prevent the insulation from bonding to the membrane.

There is insufficient long term experience (as of 1985) to make recommendations regarding:

- o Type of reinforcing.
- o The use of extruded sheets.
- o The use of factory fabricated sheets compared with full field membrane fabrication.
- o Use of self-adhering MB versus hot or torch-applied MB.

Of these issues, the use of polyethylene or polyester in lieu of fiberglass is probably preferable in Alaska.

Modified bitumen is a viable system. New developments and resolution of the issues noted above should be expected in the years ahead.

3.5.4.2 EPDM

EPDM can be arranged as follows:

- o Fully adhered, exposed.
- o Partially attached, exposed.
- o Ballasted.
- o Protected.

Adhered and partially attached systems should use fire resistive formulations.

> Note: Until recently (1985), EPDM had to be field coated with sand and hypalon to achieve fire resistance. However, these coatings weather away.

Adhered and partially attached membranes are somewhat vulnerable to mechanical damage (i.e. dropped tools). **Although generally more expensive, ballasted or protected systems are recommended.**

3.5.4.2.1 Weather Limitations

- **Adhesive application (i.e. seams, bonding to parapet or deck) must not occur while it is raining, misting or snowing.** The membrane must also be free of frost and dew.

- Moderate and high winds present problems:

  - Freshly applied adhesive may be contaminated by wind blown dust or debris.

  - Difficult to get membrane to relax and to lay in the proper position during adhesive application and solvent flash-off.

  - Field seams may be over-stressed prior to gaining their design value.

    Note: This may be overcome by proper positioning of temporary ballast.

  - Large sheets can be hazardous to workers if the sheet becomes airborne while workers are on it.

    Note: Many of the problems noted above can be overcome by minimizing field seams and careful planning. Successful jobs are possible in very windy areas.

- Cold weather is a greater detriment to workers than to materials. Tasks that require careful hand work (field seams, parapet walls, details) should not occur in weather colder than +20°F (actual or wind chill).

3.5.4.2.2 Fully Adhered

This system is very light weight. It is more expensive than partially attached, due to the adhesive.

The membrane is set in a full bed of adhesive. The solvents in the adhesive must flash-off before applying the membrane, which can take 30 minutes or longer (depending upon temperature and humidity). Therefore, this system is very vulnerable to rainfall. Generally, it should not be used in very wet areas (i.e. Aleutian Chain).

Only certain types of insulation are suitable substrates for the adhesive. Check with the EDPM manufacturer.

3.5.4.2.3 Partially Attached

This system is very lightweight. This is usually the least expensive EPDM system. With small busy roofs, or unusual shapes, the cost efficiency decreases.

A number of failures have been reported. These have been related to the attachment components or design of the attachment system. As more experience is gained, this type of failure should become rare.
Systems that use plates bonded to the underside of the membrane should be avoided, due to potential blind match-up problems. Also these systems have low peel resistance, which is critical since wind accentuates peel loads at each attachment point.

Only systems with mechanical attachment should be used. The non-penetrating systems (Carlisle "NP" or Firestone's "Fastrac") which were introduced around 1984 appear to be promising, although they have limited field experience.

Special Considerations for Partially Attached Systems:

- With concrete decks, fastener installation cost is great. Some other deck types are also expensive to attach to. Steel and wood or plywood decks are the most suitable.

- o All insulation below the membrane must be mechanically attached to prevent the boards from walking during high winds.

- o Thermal bridges are presented by fasteners. **In the colder parts of the State, condensation on the tip of fasteners may present problems.**

- o There is no definitive information (as of 1985) on long-term effects of wind flutter on seams or at fastening points. Accordingly, **partially attached systems are not recommended in areas that experience constant winds or frequent very high winds** (i.e. Aleutian Chain and much of Coastal Alaska).

For further information on partially attached systems see:

- o "The Partially Attached Single-Ply System", **1983 Handbook of Single-Ply Roofing Systems, RSI.**

- o "Non-Penetrating Systems: How will they perform in high winds?", **Roof Design**, March/April 1985.

3.5.5 Steep Roofs, Shingles and Tiles

3.5.5.1 Weather Limitations

- o Application during rain is generally acceptable, provided an underlayment is in place to prevent water from being entrapped within the insulation or deck system. Depending upon specific system being installed, some wet weather limitations may be applicable.

- o System can be successfully installed in moderately windy conditions. The heavier systems can be installed during very high winds.

- o Cold weather application is generally acceptable, and requires little if any extra precautions.

3.5.5.2 General

See Section 3.3.3 "**Steep Roofs**" and Sections 3.4.6.1 through 3.4.6.6 for discussions on shingle and tile materials.

Historically there have been very few problems with shingle or tile roofs. Accordingly this Section will be brief.

Shingle and tiles represent a very broad range of costs. Composition shingles are very inexpensive while slate and some clay tiles are extremely expensive.

The life expectancy of some shingle/tile systems is measured in centuries rather than decades.

3.5.5.3 Special Considerations

o The shingle/tile shall have a fire resistance at least equivalent U.L. Class C. Class A is recommended.

o Many shingles/tiles are brittle. Where falling ice can land on a roof, damage potential must be addressed during design. See Section 3.3.3.

o Valleys and eaves can present problems due to water backing up behind ice dams. If daming of valleys is anticipated, widen the valley width. Eighteen to 36 inches wide valleys are often appropriate.

  A waterproof membrane should be placed underneath the shingles/tiles along the eave and underneath valley flashings. Self-adhering modified bitumen or EPDM are usually excellent materials for this application. See the Uniform Building Code, Chapter 32 for eave and valley requirements. However those requirements are minimum and inadequate in many instances.

- An underlayment sheet should generally be used for shingle/tile roofs. See 3.5.6.3.

- While many shingle/tile systems are very resistant to wind blow-off, some systems are susceptible to water infiltration via wind driven rain. In very windy/rainy areas (i.e. Aleutian Chain), the problem of wind driven water must be addressed through materials selection and design or selection of a different type of roofing system.

- Composition shingles have experienced wind blow-off problems (Anchorage suffered many losses in two storms in the early 1980's and one storm in 1985). The problems were associated with a number of poor practices:

  - insufficient shingle weight
  - insufficient number of staples
  - relying upon self-tabbing adhesive

  In high wind areas, use heavier weight shingles (the cost difference between the lightest and heaviest shingle is not great).

  Although nails are preferable, staples can be adequate when properly applied and when a sufficient quantity is used.

  Except in the hottest parts of the State, it usually does not get warm enought to allow the self-tabbing adhesive to bond. Therefore in windy areas, hand tabbing is recommended.

3.5.6 Steep Roofs, Metal Panels

3.5.6.1 Weather Limitations

- Application during rain is generally acceptable, provided the following:

- o Where sealant or sealant tape is applied, contact faces must be dry. This can be very difficult, but it is achievable.

  Note: Some types of sealants may accommodate wet substrates, see Section 3.3.14.3.

- o An underlayment must be in place to prevent water from being entrapped within the insulation or deck system.

o System can be installed in moderately windy conditions. However the applicator must use caution to prevent loss of a panel(s), which could be hazardous to workers or cause property or panel damage.

o System can be installed in cold weather, provided sealant/sealant tape application occurs within the manufacturer's recommended temperature range. Normally cold weather application is limited by sealant or sealant tape requirements.

3.5.6.2 General

Metal roofings systems are very appropriate for many roofing projects. During the early 1980's, an abundance of various systems became available. Many systems can successfully withstand Alaskan conditions while others cannot.

3.5.6.3 Component Materials

o Decks: See Section 3.4.1. Often times, metal systems are installed directly over purlins, joists or beams, rather than decks.

Due to possible moisture entrapment, wood and plywood decks and wood nailers above the deck should be preservative treated (see Section 3.2.5.5).

o Vapor Retarder: Generally non-bituminous or plastic sheet, see 3.4.2.2 and 3.4.2.3.

- Insulation: See Section 3.4.3.

- Underlayment: The purpose of the underlayment is to provide protection for the insulation or deck system prior to the application of the metal roofing system. The underlayment should be resistant to water, but it should be permeable in order to allow vapor transmission (particularly if a ventilation space occurs between the underlayment and the metal roofing).

  Dupont "Tyvek" (spunbonded high density polyethylene fibers) has a greater water resistance than #15 felt, yet it has even greater moisture permeability. This or similar type products should make excellent underlayments. If the underlayment will be exposed for a considerable time under extreme conditions, EPDM may be appropriate since it is permeable and can be sealed watertight. Use of the metal roofing clips to secure the EPDM may be adequate, thereby minimizing underlayment installation cost.

- Metal Roofing: See Section 3.4.6.7.

  Traditional materials (i.e. copper) and methods (small field fabricated panels) have largely given way to preformed aluminum or steel. The traditional materials and methods are generally more expensive and often not as effective. Hence they are typically now used for restoration or special architectural treatment.

  Except for short life roofs (i.e. five years), only systems with concealed fastening systems shall be used.

  High standing ribs (i.e. 2½ inches) shall be used for roofs subjected to heavy ice daming. They are also preferable in areas with great wind driven water (i.e. Aleutian Chain).

  Systems with mechanically seamed seams are probably more resistant to water infiltration (due to ice dams or wind) than nested systems.

In coastal areas, galvanized steel panels should not be used due to potential corrosion from the ocean salts. Steel sheets that have been protected with a zinc/aluminum coating ("Zincalume") reportedly have improved corrosion resistance. However, **aluminum systems have long and successful experience in Coastal Alaska and are recommended until more definitive data is available on zinc/aluminum coated steel.**

3.5.6.4 Component Arrangement

- Metal systems offer a variety of system arrangement possibilities. Insulation may be placed above or below-deck. The metal panels may be placed directly on a deck, or over nailers on a deck, or they may be attached to purlins, joists, or beams.

- **In most instances, ventilating is relatively easy and should always at least be considered.** See Section 3.3.3.5.

- **If rain or snowfall is anticipated during roofing application, an underlayment should be considered.**

3.5.6.5 Special Considerations

- With metal roofing systems, design of the manufacturer's standard components (i.e. clips, closures, etc.) is critical. Also the design of the specific arrangement of various items for each specific roof is important. Therefore it is mandatory the manufacturer of the roofing system have an engineering department. With some systems, the manufacturer simply manufactures a machine for rolling panels. The machine is sold to Contractors who then roll their own panels. Unfortunately vital engineering back-up does not exist.

- Job site rolling of panels can be successfully done, however there are a number of special procedures that must be followed. Consultation with a reputable and experienced manufacturer is recommended.

- Job site storage and handling of materials is important in terms of technical performance and visual appearance. The recommendations of reputable manufacturers are generally adequate, assuming the Contractor complies with them.

  Loading bundles of panels on the roof via helicopter is sometimes advantageous. However consultation with an experienced manufacturer or consultant is recommended. Severe damage to the building or panels or personal injury can easily occur unless proper procedures are used.

- **All fasteners (i.e. clip and flashing screws) shall be stainless steel.**

3.5.7 Steep Roofs, Spray-Applied Polyurethane Foam

3.5.7.1 Weather Limitations

- **Application of foam shall not occur during rainy or misty weather. The substrate must be dry at the time of application. The foam must be coated prior to any rain or mist.**

- Since wind can effect surface texture (which effects membrane performance), at wind speeds of over 15 mph, wind shields are required. At speeds over 25 mph, application should not occur.

  Over-spray onto adjacent buildings, cars, etc. may be possible.

3.5.7.2 General

PUF materials are discussed in Section 3.4.5.10.

PUF is extremely demanding. It must be applied within a narrow range of weather conditions (which are difficult to meet in Alaska). Application equipment must be properly functioning and the applicator must be fully qualified and experienced. Substrate condition is also critical.

PUF is somewhat fragile and is vulnerable wherever a penetration in the coating occurs. It also requires recoating about every 8 to 10 years.

3.5.7.3 Recommendations

PUF may be the best choice for complex irregular shaped roofs. It may also be the best choice for existing buildings that are very lightly insulated and lack sufficient structural strength to carry increased dead load.

NOTE:

1. If the structure is near capacity, evaluate the effects of increased R-value, since additional snow load will occur.

2. Other systems are less demanding, yet offer lightweight (i.e. foam insulation boards and adhered or partially attached EPDM).

However, **PUF should only be used as a last resort in Alaska.** If it is used, thorough specifications must be prepared and the roof shall have full-time field observation by a qualified observer.

3.5.8 Steep Roofs, Other Materials

Included in this discussion are: Liquid Applied (3.4.6.11), Glass (3.4.6.12), and Fabrics (3.4.6.13).

3.5.8.1 Liquid Applied

Liquid applied may be used as the top coating on PUF or may be applied to other substrates (usually concrete or plywood).

Substrate preparation is critical, along with application workmanship.

Deck movement (i.e. cracking) can be harmful to the membrane.
As with PUF, **Liquid Applied should only be used as a last resort in Alaska.** If it is used, thorough specifications must be prepared and the roof shall have full-time field observation by a qualified observer.

3.5.8.2 Glass

This section refers to sloped field fabricated glazing. Factory fabricated skylights are discussed in Section 3.3.14.

Sloped glazing presents a challenge in terms of achieving successful performance. However it is sometimes the desired architectural treatment. The following items should be considered:

- o Avoid artificial humidification. If the space is humidified, condensation potential is increased.
- o Utilize double pane insulated units as a minimum. Consider triple glazing. Utilize a thermal break framing system. Glass type shall be in conformance with the Code.
- o Bathe glass with warm air.
- o Provide condensation gutters. Provide gutter drainage where considerable condensate is expected.
- o Use high performance sealant and follow good sealant application practices.
- o Place glazing system on high curb in order to avoid subjecting the framing system to wind driven water. See Section 3.3.14.1.

3.5.8.3 Fabrics

Fabrics can be used as the roof membrane for tent type structures or for air supported structures.

In Alaska, tent type structures will normally just be used during the summer. In Alaska, air supported structures will probably not be appropriate due to the snow load and energy loss. In either case, the use of fabrics is unique and should only be considered in unusual circumstances.

If fabrics are used, thorough research, detailing and specifications is required.

3.6 SPECIAL DESIGN REVIEWS

All roofing projects (both reroofing and roofs on new buildings) should be reviewed during design. Section 4 "**A/E SUBMITTAL REQUIREMENTS AND REVIEW CHECKLISTS**" lists information to be submitted by the designer and to be checked by the reviewer.

In addition to the normal review, some roofing projects should have special review during design. Examples of projects which should have special review are:

- Projects where the cost of roofing (including vapor retarder, insulation, membrane, sheet metal work, and roofing accessories) is in excess of one million dollars (based upon 1985 dollars).
- Complex projects. It often takes qualified experience to recognize which projects should receive special review. Many reroofing projects, swimming pools, unusual shaped roofs, etc. are likely candidates.
- Swimming pools.
- Experimental roofs (systems or materials).

The special review should always occur at the Schematic Design and Contract Document stages. Generally, the review should also include Design Development.

The Owner's Project Manager is responsible for initiating and ensuring the special review occurs. The Project Manager should advise the designer that a special review will occur.

If the designer believes a special review is warranted, the designer shall notify the Project Manager.

3.6.1 The Reviewer

The purpose of the special review is to minimize the likelihood of premature failure and to maximize the effectiveness of the money spent on roofing. Accordingly, it is mandatory for the reviewer to be very knowledgeable of:

- The proposed roofing system
- Roofing in general
- Weather conditions at the site (in terms of its impact during construction and service).
- Logistics

The review shall encompass both the drawings and technical specifications.

3.7 FIELD OBSERVATIONS

3.7.1 Observations During Design

For reroofing projects it is mandatory the designer conduct at least one field observation. Depending upon job complexity, several field trips will likely be required. This is further discussed in Section 9 **"REROOFING AND MAJOR ROOF REPAIR"**.

If new construction is to occur over or adjacent to an existing roof, observation of the existing roof during design is required. This is further discussed in Section 3.3.16.

3.7.2 Observations During Construction

All roofing projects should receive some degree of field observation by a qualified observer acting on the behalf of the Owner. The qualifications and duties of the observer are discussed in Section 6 "**ROOFING APPLICATION**".

As a minimum, observation should occur:

- o As a part of the Pre-Roofing Conference (as discussed in Section 6).

- o Shortly after the Pre-Roofing Conference. This can either be the same day as the conference, or the first day roofing occurs after the conference.

  The purpose of this early review is to ensure the work is initially being executed in accordance with the Contract Documents.

- o Upon Substantial Completion of the roofing system.

  Depending on magnitude/significance of the punch list, a follow-up observation may be appropriate.

- o If additional significant construction occurs after the substantial completion observation, the roof should be observed again to ensure it was not damaged by the subsequent work.

Some projects demand significantly greater observation. The amount may vary from a few hours per week, to a few hours per day, or it may be full time. In selecting the degree of observation, the criteria presented in Section 3.6 "**Special Design Reviews**" should be considered. Other factors to be considered include:

- o Characteristics of the roofing system: some systems are very demanding in terms of workmanship and weather conditions (temperature, wind, rain/snow).

- o Qualifications of the roofer. If the roofer is marginally qualified, greater observation should occur.

- o A reroofing project on a building with valuable contents (i.e. computers) or special occupancies (i.e. hospitals).

  Since the purpose of this type of observation is to help ensure the protection of property and safety of people, it may not be mandatory for the observer to be particularly knowledgeable of roofing.

The Owner's Project Manager is responsible for initiating and ensuring the field observations occur. The Project Manager should advise the designer the degree of observation that will occur and the qualifications of the observer.

If the designer believes additional observation is warranted or the observer is not qualified, the designer shall notify the Project Manager.

3.7.3 Maintenance Observations

Semi-annual Roof Observations and Special Roof Observations are discussed in Section 7 "**MAINTENANCE**".

3.8 WARRANTIES

3.8.1 General

A warranty assigns responsibility for a product's integrity. In the event of a failure, the entity whom the warranty responsibility was assigned is responsible for replacement or repair of the failure.

It is common for the general contractor and/or the roofer to be assigned the warranty for a two year period. However 10 and 15 year warranties (which are prevalent as of 1985) are normally assigned to the manufacturer of the primary roofing membrane material.

A warranty has the effect of limiting the liability of the manufacturer. Therefore it may not be in the best interest of the Owner to request or accept a warranty.

Under the U.S. Uniform Commercial Code, a manufacturer has the responsibility of producing a product suitable for its intended use. Because of the generalized nature of this Code, it is understandable why manufacturer's desire to issue their own warranty, which when accepted takes precedence over the Uniform Commercial Code. From the Owner's standpoint, the disadvantage of relying upon the Code is that it usually takes litigation to bring about relief. Whereas a warranty may bring about relief more expeditiously and economically.

3.8.2 Nullifying Provisions

Unfortunately for the Owner, **warranties usually include provisions that in essence cause the Owner to nullify the Warranty**, thereby absolving the manufacturer of responsibility under the Uniform Commercial Code and the warranty itself. Examples of these provisions are:

- Installation of equipment on the roof or making roof penetrations without notifying the Warrantor nullifies the warranty.

  For example, it is very likely the Owner will place a TV antenna on the roof. Afterwards, a failure of the roof is not covered by the warranty if notification was not given. This is true, even if the failure is hundreds of feet from the antenna and totally unrelated to it!

- Failure to give timely notice of failure.

  Usually the Owner is required to give the Warrantor notice within thirty days of the discovery of a failure. **The thirty day period can be easily run over and the warranty nullified.** For example, if a leak occurs in an office, it may be a day or two before maintenance is notified, and then it can be a few weeks before someone thinks of notifying the Warrantor.

- o If the Owner fails to comply with every term or condition of the warranty, the warranty is nullified, even if the Owner's failure is not of substance.

- o The warranty may be nullified if the failure is not **solely** due to workmanship or material failure. Therefore, if a failure is a result of material failure and design deficiency, the warranty is void.

- o The warranty usually does not include sheet metal flashing failures. Since many premature failures are related to these flashings, it is possible the warranty will be voided.

3.8.3 Limitation of Warranties

Even if the Owner does not nullify the warranty, there usually are provisions in the warranty that are not in the Owner's interest. For example:

- o The determination of the cause of the problem may rest **solely** with the Warrantor.

  In this instance, the Owner has no right of rebuttal if the Owner does not agree with the Warrantor's assessment of the problem.

- o The warranty usually limits the Warrantor's obligation regarding repair or replacement costs. Common limitations are: original cost of the roof (labor and materials), a proration of the original cost of the roof (based upon the roofs' age at the time of failure), or the original cost of the materials (this is clearly not an advantageous agreement for the Owner).

- o The warranty generally released the Warrantor from liability for consequential damages of any kind. For example, if a roof failure results in damage to computer equipment and interior finishes, the

Warrantor is held responsible only for repair/replacement of the roof. Consequential damages can be significantly greater than the direct cost related to the roof.

3.8.4 Warranty Benefits

Warranties may offer some benefits. Primarily they are:

- o The requirement of a warranty may cause additional review, inspection, or concern by the Warrantor. This in turn may lead to the elimination of a problem, which is everyone's goal.

- o A warranty that equitably places responsibility and liability may lead to quicker settlement and at less cost to the Owner.

3.8.5 Provisions of the Warranty

If a warranty is specified, the following provisions should be considered in the specification. However, the issues discussed in Section 3.8.6 must also be considered.

- o The Owner's rights against the Warrantor are not limited to the terms of the warranty.

- o The warranty for the roofing system includes materials and workmanship, including items integrally related and incidental to the roof, (i.e.: roof insulation and accessories, flashing and sheet metal).

  Performance of the roof deck and structure is not included in the warranty. However repair/replacement of these components is included in the warranty, if they are damaged by problems caused by failure of other elements included under the warranty.

- o If the ownership of the building is transferred, the warranty shall be transferred in tact to the new owner.

- If occupancy of the building changes, the warranty shall remain in tact. However, the Warrantor is not responsible for problems that are attributable to the occupancy change.

- If appearance of the roof is important (i.e. a domed roof), criteria regarding appearance should be included in the warranty. This might include discoloration and retention of form.

- Owner installation of equipment on the roof, or penetrations made by the Owner shall not nullify the warranty, if it is determined these acts were not of consequence regarding the roofing failure.

- The Owner shall not be required to give notification of failure within a given time period. However the Owner is expected to give timely notice.

  Note:

  - The Warrantor should have the opportunity to observe the alleged problem before the problem area is removed. However this is not always possible. For example, a wind blow-off generally must be at least temporarily reroofed to avoid great interior damage. **When conditions do not allow review by the Warrantor, the Owner shall document the failure as extensively as possible,** given the nature of the failure. See Section 8 "ROOF INVESTIGATIONS AND TESTING."

  - If there is a failure it is important to notify the Warrantor, **so** the Warrantor has the opportunity to limit the extent of damage the Warrantor is liable for.

- The warranty shall not be nullified by the Owner's non-compliance with the terms and conditions of the warranty, if the non-compliance is of insignificance.

- o The warranty shall not be nullified if the failure is not solely related to materials and/or workmanship. If there is contributory responsibility by parties other than the Warrantor, the liabilities shall be appropriately distributed.

- o Determination of the problem(s) and cause(s) rests jointly with the Owner and Warrantor, either by negotiation or litigation.

- o The Warrantor's obligation regarding repair or replacement costs shall include all materials and labor incidental to the work (i.e. demolition, sheet metal work, etc.), prorated as follows:

  Warrantor's obligation of the total cost of repair/replacement work (20 year warranty):

Age Of Roof At Time Of Failure	Warrantor's Obligation
0-5 years	100%
6 years	98
7 years	96
8 years	94
9 years	92
10 years	90
11 years	88
12 years	86
13 years	84
14 years	82
15 years	80
16 years	74
17 years	68
18 years	62
19 years	56
20 years	50

Warrantor has no obligation for failure after 20 years.

- The Warrantor is responsible for all consequential damages (building components and equipment/furnishings) during the life of the warranty, including incidental costs (ie. design, temporary facilities, etc).

3.8.6 Warranty Duration

The warranty should be in effect during the minimum expected life time for the roof. For most roofs, it is reasonable to expect a life of twenty years. Hence a twenty year warranty should normally be specified.

If major maintenance is anticipated (ie. recoating a smooth surface built-up membrane) this should be addressed in the warranty provisions. For example, if the Owner is responsible for recoating, but does not recoat, premature failure of the membrane is the Owner's responsibility if there are no other contributory problems.

3.8.7 Warranty Recommendations

Many of the provisions discussed in Section 3.8.5 and 3.8.6 may be unacceptable to may reputable manufacturers. Major issues are:

- Consequential Damages
- Limitation of Liability
- Duration of Warranty

The Owner may write whatever provisions deemed necessary. However this may result in no bids from major reputable manufacturers.

A policy and direction should be established by the State. However this is a major undertaking, which will require input and review by roofing technologists, attorneys and manufacturers. In the meantime, the issues and pitfalls of warranties discussed in Section 3.8 may be of value, although clear direction is lacking.

3.8.8 Special Considerations

- Does the system/materials warranted have a good reputation for successful performance?

  If they do not, or if they are new and therefore without a track record, consideration should be given to other systems/materials.

- Does the Warrantor have a good reputation for honoring it's obligations? Does the Warrantor have the assets to cover obligations and are these likely to be retained during the life of the warranty?

3.3.9 Further Information

See the Canadian Roofing Contractors Association, April 1985 Bulletin on **Product Warranties**. Also see "Warranties, Guaranties and Bonds" in the October and November issues of **Roofer Magazine**.

End Of Section 3
DESIGN CONSIDERATIONS AND CRITERIA

Appendix 3.9 Follows

APPENDIX 3.9.1

BIBLIOGRAPHY

A large variety of resource material was used in the preparation of this Section including periodicals, manufacturer's data, and technical publications published by numerous entities. The primary source documents were:

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- **Roofs**, by Maxwell C. Baker, 1980.
- **The NRCA Roofing and Waterproofing Manual**, Second Edition, 1985.
- The Roofing Industry Educational Institute's Course Manuals.

APPENDIX 3.9.2

FOOTNOTES

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26. Rene Dupuis, PhD., P.E., "Single-Play: Fundamentals for the New Roofing", **1982 Handbook of Single-Ply Roofing Systems**, RSI, 1982, p. 9.

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30. Baker, M.C., "New Roofing Systems", **Canadian Building Digest**, January 1964 (corrected May 1968), p. 49-3.

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4. A/E SUBMITTAL REQUIREMENTS AND REVIEW CHECKLISTS

4.1 GENERAL

In 1982, DOT/PF issued the "**Design Standards Manual For Buildings**".

- Section 6 of that manual included A/E submittal requirements for schematic design, design development, and construction document drawings.

  Appendix 4.3.1 of this manual includes revised submittal requirements. The Appendix only lists items related to roofing.

Review Checklists contained in Appendix sections 4.3.2, 4.3.3, and 4.3.4 shall be submitted along with the Design Narratives and Drawings. A written response to Review Checklist comments shall also be submitted.

4.2 CERTIFICATES

A number of certificates, as listed in Appendix 6.8.3 are required. The A/E shall submit the certificates the A/E is responsible for.

End of Section 4, A/E SUBMITTAL

REQUIREMENTS AND REVIEW CHECKLISTS

Appendix 4.3 Follows

APPENDIX 4.3.1

SUBMITTAL REQUIREMENTS FOR ROOFING SYSTEMS

Note: Refer to Section 6 of the DOT/PF "**Design Standards Manual for Buildings**".

SCHEMATIC DESIGN DRAWINGS

6.2.2 Architectural Drawings

B. Description of Roofing System(s):

Roof Plan showing roof drainage and slopes (direction and approximate amount).

If not included elsewhere show anticipated snow drifting patterns if a snow drift analysis is required as per Part I, Section 5.2.6. Only show drift patterns on Schematic Design (and perhaps Design Development), not on Contract Documents.

On reroofing projects a separate Demolition Plan (and perhaps Phasing) may be necessary to clearly show the work.

6.2.3 Structural Drawing(s)

A. Floor and Roof Plans showing framing concepts and approximate spans. Indicate type of decks.

B. Typical framing sections showing framing and vertical support concepts.

C. Both of the above may be submitted as sketched overlays of the architectural drawings. Such drawings shall be keyed to schematic narratives and calculations required in Part 1 Section 5.

6.2.4 Mechanical Drawings

A. Mechanical drawings submittal not required.

B. Mechanical space and clearance requirements to be shown on architectural plans and sections.

C. Major outside design features to be located and shown on architectural or civil preliminary site plans.

D. Sketch overlays or sepias of architectural drawings may be submitted to show major design concept features, if desired or considered necessary by the engineer.

6.2.5 Electrical Drawings

No submittal requirements relating to roofing.

DESIGN DEVELOPMENT DRAWINGS

6.3.2 Architectural Drawings

A. Roof Plan (1/16" = 1'-0" minimum scale)

1. Description of roofing system(s).

2. All expansion, seismic, and area divider joints.

3. Roof access (hatch, ladders).

4. All roof penetrations (including mechanical and electrical).

5. All slopes (direction and approximate amount), valleys, ridges, and crickets.

6. Applicable Wall Section references.

7. Plan Reference Grid.

8. Show ballast layout for PMR mortar faced insulation systems.

9. On reroofing projects, a separate Demolition Plan (and perhaps Phasing) may be necessary to clearly show the work.

E. Wall Sections(s) (3/4" = 1'-0" minimum scale)

1. All materials and systems required to adequately define wall and intersecting foundation, floor, and roof construction.

2. Sufficient detail to identify structural elements, wall and roof system(s), exterior closure materials, interstitial spaces, spaces above suspended ceiling, interior finishes, ceiling materials, etc.

3. Wall section references as required to locate wall sections on Floor and Roof Plan (where applicable).

6.3.3 Structural Drawings

C. Roof Framing Plan(s) (1/8" = 1'-0" minimum scale)

1. Type, size, and spacing of framing members.

2. Plan reference grid.

3. Structural walls, columns, and other vertical roof supports.

4. Type and size of roof deck(s).

6.3.4 Mechanical Drawings

B. Underfloor Plan

1. Show location of all piping.

2. Show location of all ducts.

3. Show utilidors, lift pumps, etc., with identification symbol, as applicable.

4. Show heat cables, if applicable.

5. Show location of all dry wells.

D. Roof Plan (same scale as Architectural)

1. Show location of all mechanical penetrations.

6.3.5 Electrical Drawings

D. Roof Plan (same scale as Architectural)

1. If there are any electrical penetrations, show location.

CONSTRUCTION DOCUMENT DRAWINGS

6.4.2 Architectural Drawings

D. Wall Sections

1. 1/2" scale minimum, 3/4" preferable.

2. Show in sufficient quantity to cover all changed structural conditions.

3. Provide material notations for all materials shown.

4. Reference all detail blow-ups.

5. Show direction of roof slope.

6. Provide vertical dimensioning from grade to highest elevation of section.

7. Show grid reference from plan.

8. Identify in detail all vapor retarder conditions.

9. Coordinate with structural details.

10. If elevation of roof at wall varies with respect to top of wall, indicate high and low point conditions (same detail may sufficient for both, with dotted line indicating condition opposite of that shown).

I. Roof Plan (1/16" minimum scale)

1. Description of roofing system.

2. All expansion, seismic, and area divider joints. Reference details.

3. Roof access (hatch, ladders). Reference details.

4. All roof penetrations, including mechanical and electrical. Reference details.

5. All slopes (direction and approximate amount), valleys, ridges, and crickets. Reference cricket details.

   NOTE: For slopes, indicate ±, unless slope is totally provided by tapered insulation. If slope is obtained by fills or sloping the structure, let the structural drawings specifically set the elevations/slopes.

6. Reference all roof edge details.

7. Reference applicable Wall Section references.

8. Plan Reference Grid.

9. Show ballast layout for PMR mortar faced insulation systems.

10. On reroofing projects, a separate Demolition Plan (and perhaps Phasing) may be necessary to clearly show the work.

J. Details

1. 1" scale minimum, preferable 1-1/2" and 3", as appropriate.

2. Roof details: Detail all conditions, include isometric drawings where necessary to clearly show the work.

   NOTE: Typical roof drains and V.T.R. should not be shown on Architectural -- these should be described in the specifications (Division 7 for roofing aspects and Division 15 for plumbing aspects).

6.4.3 Structural Drawings

D. Roof Framing Plan

1. 1/8" scale minimum.

2. Show plan reference grid.

3. Show all framing members and respective spacings.

4. Show plans for all contracted structures.

5. Show beams if applicable.

6. If roof slope is provided by sloping structure or fill, indicate elevations.

7. Show type and size of roof deck(s).

8. Reference details for all dissimilar framing conditions.

9. Indicate roof penetrations that require structural framing or other structural provisions.

6.4.4 Mechanical Drawings

B. Underfloor Plan

1. Show location and size of all piping.

2. Show location and dimensions of all ducts.

3. Show utilidors, lift pumps, etc., with size and capacities, or identification symbol, as applicable.

4. Show heat cables and note coordination requirements with electrical, if applicable.

5. Underfloor piping and ducting to be shown on separate underfloor plan(s) and not on first floor plan(s).

6. Show location of all dry wells. Reference details.

D. Roof Plan (same scale as Architectural)

1. Show location of all mechanical penetrations. Reference details.

G. Details:

1. Provide details, sections, partial large scale plans, etc., to clearly show installation requirements for all systems.

   At roofing penetrations, refer to the Architectural drawings for work that is not performed under Division 15.

2. Typical plumbing system details:

   a. Vent through roof.

   b. Floor drain.

   c. Roof drain and overflow roof drain.

   d. Domestic hot water heater.

   e. Water and fire service.

   f. Sump and sewage pumps.

   g. Others, as required.

3. Typical heating system details:

   a. Terminal heating units.

   b. Baseboard.

   c. Coils.

   d. Boiler water make-up.

   e. Chimney.

   f. Combustion air.

   g. Fuel system.

   h. Others, as required.

4. Typical air system details:

   a. Miscellaneous S/A and E/A systems.

   b. Roof and wall intake and exhaust.

   c. Equipment support.

   d. Others, as required.

6.4.5 Electrical Drawings

A. Roof Plan (same scale as Architectural)

   1. If there are any electrical penetrations, show locations.

   2. Show details if required to clearly indicate the work. Refer to architectural drawings for work that is not performed under Division 16.

APPENDIX 4.3.2

SCHEMATIC DESIGN REVIEW CHECKLIST

Note: See last page for instructions.

Date:____________________ See Review Comment

1. Facility or Project Name: ____________________ ____

2. Type of Facility: ____________________ ____

3. Facility Location: ____________________ ____

4. State's Project Number: ____________________ ____

5. Client Agency: ____________________ ____

6. Contracting Agency: ____________________ ____

7. "Designer": ____________________ ____

8. Were DOT/PF Roofing Standards reviewed and followed: ____
   Yes ____ No ____.

9. Type of Work: New Roof ____, Reroof ____, Roof Repair ____ ____

   Is this an historic building: Yes ____, No ____.

   If this is an existing building, has there been a change in occupancy type:
   YES ____, No ____.

   Has humidification been added: Yes ____, No ____.

10. If reroof or repair, was report on cause of leak prepared: ____
    Yes ____, NO ____. If prepared, attach to design narrative.

11. If reroof or repair, did designer make a field observation: ____
    Yes ____, NO ____.

12. Is Facility humidified: YES ____, No ____. If yes, designed humidity is ____%. ____

13. Does site have "Basic Wind Speed" (See Design Standards Manual For Buildings Part II, Section 3) of 100 mph or greater: ____
    YES ____, No ____.

14. Was basic wind speed determined from Section 3, Figure 6: ____
    Yes ____, NO ____. If no, what was data source________________.

15. Does design Basic Wind Speed reasonably reflect actual condition: ____
    Yes ____, DON'T KNOW ____.

16. Is additional wind data required: YES ____, No ____. ____

17. Was snow drift analysis performed: Yes ____, No ____. ____

18. Does snow drift pattern shown on schematic roof plan and drift loads in the structural narrative reasonably reflect actual conditions: Yes ____, DON'T KNOW ____. ____

19. Is additional snow load or drift data required: YES ____, No ____. ____

20. Roof Slope: DEAD LEVEL ____, flat ____, low slope ____ (1 1/2 to 12 - 3 to 12) ____, steep slope (greater than 3 to 12) ____. ____

21. Structural Roof Deck : precast or prestressed concrete ____, cast-in-place concrete ____, steel ____, steel with concrete topping ____ or other poured-in-place fill ____, plywood ____, don't know at this time ____, Other (note type) ______________. ____

22. Is this a Protected Membrane Roof: Yes ____, No ____. ____

23. If PMR, does slope exceed 1 in 12: YES ____, No ____. ____

24. If PMR, surface is: mortar topping ____, pavers ____, aggregate with filter fabric ____. ____

25. Vapor Retarder: None (PMR) ____, Bituminous ____, Kraft paper ____, plastic sheet ____, don't know at this time ____, Other (note type) ________. ____

26. Insulation: composite board (note type) ______________ extruded polystyrene _______, rigid fiberglas _______, perlite _____ polyisocyanurate ________, tapered (note type) ______________, fiberglass batts _______, don't know at this time _______, Other ______________. ____

27. Built-up membrane: Yes ____, No ____. ____

28. Nonconventional or elasto/plastic: Yes ____, No ____. ____

29. If elasto/plastic, membrane attachment is: FULLY ADHERED ____, PARTIALLY ATTACHED ____, BALLASTED ____, PMR ____. ____

30. Is the need for a temporary roof anticipated: YES ____, No ____. ____

31. Will construction work occur adjacent to or over a new or existing roof: Yes ____, No ____. ____

DO DRAWINGS SHOW:

32. Roof System Description: Yes ____, NO ____. ____

33. Roof drainage and direction: Yes ____, NO ____, and amount of slope: Yes ____, NO ____. Are there scuppers: YES ____, No ____. Are there gutters: YES ____, No ____. ____

34. Snow drift patterns: Yes ____, NO ____. ____

35. In reroofing, or repair, is separate demolition plan required: Yes ____, No ____. Is phasing plan required: Yes ____, No ____. Note: These additional plans are not required at Schematic Phase. ____

DOES NARRATIVE INDICATE:

36. Brief description of new and existing Roof System (deck, insulation, membrane): Yes ____, NO ____. ____

37. Why the chosen system was selected: Yes ____, NO ____. ____

38. If the building is humidified, is it explained how the roof system design accommodates it: Yes ____, NO ____.

39. If this is a steep or low slope roof, have the problems of water drainage at grade, snow and ice slides, and ice build-up been addressed: Yes ____, NO ____. ____

40. Is the roofing system selected, reasonably appropriate for the weather conditions (during application and in-service): Yes ____, NO ____. ____

41. Are logistics to the Project Site reasonably appropriate for the roofing system selected: Yes ____, NO ____. ____

42. Is full time field observation of the roofing work recommended: Yes ____, No ____ ____

THE FOLLOWING SHALL BE COMPLETED BY THE REVIEWER

A. Does it appear the Designer consulted and followed the DOT/PF Roofing Standards: Yes ____, No ____. ____

B. Is a special review conference warranted: Yes ____, No ____. ____

C. Based upon the Roofing Standards, is review by a specialized consultant recommended: Yes ____, No ____. ____

D. Reviewer: ______________________________

E. Review Date: ______________________________

INSTRUCTIONS TO REVIEWER

1. Attach review comments to this checklist and return to Designer.

   Place review comment number in the column at the right margin.

2. Carefully review/consider checked items with a bold underline.

APPENDIX 4.3.3

DESIGN DEVELOPMENT REVIEW CHECKLIST

Note: See last page for instructions.

Date:____________________ See Review Comment

1. Facility or Project Name: ____________________ ____
2. Type of Facility: ____________________ ____
3. Facility Location: ____________________ ____
4. State's Project Number: ____________________ ____
5. Client Agency: ____________________ ____
6. Contracting Agency: ____________________ ____
7. "Designer": ____________________ ____
8. Were DOT/PF Roofing Standards reviewed and followed: ____
   Yes ____ No ____.
9. Type of Work: New Roof ____, Reroof ____, Roof Repair ____. ____

   Is this an historic building: YES ____, No ____.

   If this is an existing building, has there been a change in occupancy type: YES ____, No ____.

   Has humidification been added: YES ____, No ____.

10. If reroof or repair, was report on cause of leak prepared: ____
    Yes ____, NO ____. If prepared, attach to design narrative.
11. If reroof or repair, did designer make a field observation: ____
    Yes ____, NO ____.
12. Is Facility humidified: YES ____, No ____. If yes, designed humidity is ____%. ____
13. Does site have "Basic Wind Speed" (See Design Standards Manual For Buildings Part II, Section 3) of 100 mph or greater: ____
    YES ____, No ____.
14. Was basic wind speed determined from Section 3, Figure 6: ____
    Yes ____, NO ____. If no, what was data source: ____________________.
15. Does design Basic Wind Speed reasonably reflect actual condition: ____
    Yes ____, DON'T KNOW ____.
16. Is additional wind data required: YES ____, No ____. ____
17. Was snow drift analysis performed: Yes ____, No ____. ____

18. Does snow drift pattern shown on schematic roof plan and drift loads in the structural narrative reasonably reflect actual conditions: Yes ____, DON'T KNOW ____. ____

19. Is additional snow load or drift data required: YES ____, No ____. ____

20. Roof Slope: DEAD LEVEL ____, flat ____, low slope (1 1/2 to 12 - 3 to 12) ____, steep slope (greater than 3 to 12) ____. ____

21. Structural Roof Deck: Precast or prestressed concrete ____, cast-in-place concrete ____, steel ____, steel with concrete topping ____ or other poured-in-place fill ____, plywood ____, don't know at this time ____, Other (note type) ____________________. ____

22. Is this a Protected Membrane Roof: Yes ____, No ____. ____

23. If PMR, does slope exceed 1 in 12: YES ____, No ____. ____

24. If PMR, surface is: mortar topping ____, pavers ____, aggregate with filter fabric ____. ____

25. Vapor Retarder: None (PMR) ____, Bituminous ____, Kraft paper ____, plastic sheet ____, don't know at this time ____, Other (note type) ________. ____

26. Insulation: composite board (note type) ____________________ ____
extruded polystyrene _______, rigid fiberglas _______, perlite _____
polyisocyanurate ________, tapered (note type) ____________________,
fiberglass batts _______, don't know at this time _______,
Other ____________________________.

27. Built-up membrane: Yes ____, No ____. ____

A. Bitumen: Asphalt ____, COAL TAR ____. ____

B. Felt: Fiberglass ____, OTHER (note type) ______________. ____

C. Base Sheet: YES ____, No ____. ____

D. Surfacing: PMR ____, aggregate ____, smooth ____, cut back ____, aluminum cut back ____, emulsion ____, mineral surface cap sheet ____, other (note type) _________. ____

28. Nonconventional or elasto/plastic: Yes ____, No ____. ____

A. Membrane: Cold process ____; modified bitumen SBS ____ or APP ____; neoprene ____, EPDM ____, PVC ____, Hypalon (CSPE) ____, CPE ____, PIB ____, Spray-applied polyurethane foam ____, Liquid applied ____, other (note type) _________. ____

B. If spray-applied polyurethane foam, coating is: acrylic ____, silicone ____, single component urethane ____, two-component urethane ____, other (note type) ___, with mineral granules ____ or without ____. ____

29. If elasto/plastic, membrane attachment is: fully adhered ____, partially attached ____, ballasted ____, PMR ____. ____

30. Sloped Roof: Yes ____, No ____.

A. Membrane: Composition shingles ____, wood shingles ____, clay or concrete tiles ____, synthetic tiles ____, metal panels ____, BUR (respond to #27) ____, elasto/plastic (respond to #28 and #29), Other (note type) ____. ____

31. Is the need for a temporary roof anticipated: Yes ____, No ____. ____

32. Will construction work occur adjacent to or over a new or existing roof: Yes ____, No ____. ____

DO DRAWINGS SHOW:

33. Min. scale of 1/16" = 1'-0": Yes ____, No ____. ____

34. Roof system description: Yes ____, No ____. ____

35. Roof drainage and direction: Yes ____, No ____, and amount of slope: Yes ____, No ____. Are there scuppers: Yes ____, No ____. Are there gutters: Yes ____, No ____. ____

36. All expansion, seismic, and area divider joints: Yes ____, No ____. ____

37. Do re-entrant corners occur: Yes ____, No ____. ____

38. Roof access (hatch, ladders): Yes ____, No ____. ____

39. All roof penetrations (including mechanical and electrical): Yes ____, No ____. ____

40. Applicable wall section references: Yes ____, No ____. ____

41. Plan reference grid: Yes ____, No ____. ____

42. Ballast layout for PMR mortar faced insulation: Yes ____, No ____, Not applicable ____. ____

43. Do wall sections show information required by Appendix 4.3.1, Section 6.3.2: Yes ____, No ____. ____

44. If deck is precast or prestressed concrete, steel without concrete topping or other poured-in-place fill, or plywood composite panels, are roof control joints provided at all changes in deck direction: Yes ____, No ____. ____

Are roof control joints provided at all changes in deck material: Yes ____, No ____. ____

45. Do mechanical drawings show all mechanical roof penetrations on a mechanical roof plan: Yes ____, No ____. ____

46. Are there any electrical roof penetrations: Yes ____, No ____. ____
If yes, are these shown on an electrical roof plan: Yes ____, No ____.

47. In reroofing, or repair, is separate demolition plan required: ____
Yes ____, No ____. Is phasing plan required: Yes ____, No ____.
Note: These additional plans are not required at Design Development Phase.

DOES NARRATIVE INDICATE:

48. Changes between Schematic Design and Design Development: ____
Yes ____, No ____, No changes ____.

49. Brief description of new and existing Roof System (deck, insulation, membrane): Yes ____, No ____. ____

50. Why the chosen system was selected: Yes ____, No ____. ____

51. If the building is humidified, is it explained how the roof system design accommodates it: Yes ____, No ____. ____

52. If this is a steep or low slope roof, have the problems of water drainage at grade, snow and ice slides, and ice build-up been addressed: Yes ____, No ____. ____

53. Is the roofing system selected, reasonably appropriate for the weather conditions (during application and in-service): Yes ____, No ____. ____

54. Are logistics to the Project Site reasonably appropriate for the roofing system selected: Yes ____, No ____. ____

55. Is full time field observation of the roofing work recommended: Yes ____, No ____ ____

56. Catalog cuts shall be submitted for unusual materials or systems, and for items not recommended in the DOT/PF Roofing Standards. Are catalog cuts included: Yes ____, No ____, Not Applicable ____. ____

57. Any material, system, detail, etc. not recommended by the Roofing Standards shall be identified and justification for its use presented. Is this applicable to this job: Yes ____, No ____. ____
If so, is justification given: Yes ____, No ____.

CODES:

In general, refer to Design Standards Manual For Buildings Part I, Section 8.1.

58. From U.B.C. (1982) Table 17A, Roof fire-resistive requirement in hours is: 2 ____, 1____, H.T. ____, N ____. ____

60. FM Windstorm Resistance Classification: ____
I-60 ____, I-90 ____, None (PMR) ____, None ____.

61. If Steel Deck, FM Fire Rating:
Class 1 ____, Class 11 ____, None ____, not a steel deck ____. ____

62. If wood deck, FM Fire Rating:
Class 1 (Fire Retardant Treated) ____, combustible ____,
not a wood deck ____. ____

63. If not a steel or wood deck, FM fire rating: noncombustible ____,
Class 1 ____, Deck is steel or wood ____. ____

64. The following sections of the Uniform Building Code (1982 edition) are applicable:

Yes	No	Section
____	____	910: Explosion Venting (also see U.F.C.)
____	____	1710: Projections
____	____	1712: Foam Plastic Insulation
____	____	1713: Insulation and Vapor Retarders
____	____	1714: Solar Collectors (also see 5214)
____	____	Table 17-A
____	____	1806: Roof Construction, Type I Buildings
____	____	1906: Roof Construction, Type II Buildings
____	____	2305: Structural Roof Design. Note: also refer to Design Standards Manual Part II Section 3 - Structural Criteria
____	____	2306: Live Load Reduction. Note: also refer to Design Standards Manual Part II Section 3 - Structural Criteria
____	____	2311: Wind Design. Note: also refer to Design Standards Manual Part II Section 3 - Structural Criteria
____	____	Chapter 32: Roof Construction and Covering (also see Appendix Chapter 32 for reroofing)
____	____	3205: Attic Space (access, draft stop, ventilation)
____	____	3206: Smoke and Heat Venting (also see 3901, 3906 and U.F.C.)
____	____	3207: Roof drainage
____	____	3306: Stairway to Roof, Roof Hatch at Stairways
____	____	3401: Skylights (also see 5207)
____	____	3601: Penthouses and Roof Structures
____	____	3602: Towers and Spires
____	____	3901: Stage Roof Ventilators
____	____	3906: Platform roof ventilator
____	____	Table 43-C
____	____	4504: Balconies and Appendages
____	____	4505: Marquees Roof Construction
____	____	4506: Awnings (also see 5211)
____	____	Chapter 52: Light-transmitting Plastics
____	____	5206: Plastic Roof Panels
____	____	5207: Skylights
____	____	5211: Awnings and Patio covers (also see Appendix Chapter 49)
____	____	5212: Greenhouses (also see 2311 and 3401)

___ ___ 5213: Solar Collectors
___ ___ Appendix Chapter 32: Reroofing
___ ___ Appendix Chapter 49: Patio Covers
___ ___ Appendix Chapter 55: Membrane Structures (air-inflated, air-supported, or membrane-covered cable or frame structure). Also see U.F.C.

65. The following Sections of the Uniform Fire Code (1982 Edition) are applicable.

Yes	No	Section
___	___	Article 32: Membrane Structures (air-inflated, air-supported, or membrane-covered cable or frame structure). Also see U.F.C.
___	___	Article 76: Explosion Venting
___	___	Article 81: Venting of high-piled combustible stock

66. The following sections of the Uniform Mechanical Code (1982 Edition) are applicable.

Yes	No	Section
___	___	710: Furnaces installed on roofs
___	___	906: Appliance Vent Termination
___	___	907: Appliance Vent Termination
___	___	912: Factory-Built Chimneys
___	___	913: Masonry Chimneys
___	___	914: Metal Chimneys
___	___	2002: Kitchen Ventilation Outlets

67. The following sections of the Uniform Plumbing Code (1982 Edition) are applicable:

Yes	No	Section
___	___	304: Connection of Roof rain water to sewer
___	___	506: Plumbing vent termination
___	___	1317: Water heater vent terminations
___	___	Appendix D: Rainwater Systems (Roof drains and gutters)

THE FOLLOWING SHALL BE COMPLETED BY THE REVIEWER

A. Were Schematic Design review comments adequately addressed and resolved: Yes ____, No ____. ____

B. Does it appear the Designer consulted and followed the DOT/PF Roofing Standards: Yes ____, No ____. ____

C. Is a special review conference warranted: Yes ____, No ____. ____

D. Based upon the Roofing Standards guidelines, is review by a specialized consultant recommended: Yes ____, No ____.

E. Reviewer: ______________________________

F. Review Date: ___________________________

INSTRUCTIONS TO REVIEWER

1. Attach review comments to this checklist and return to Designer.

   Place review comment number in the column at the right margin.

2. Carefully review/consider checked items with a bold underline.

APPENDIX 4.3.4

CONTRACT DOCUMENTS REVIEW CHECKLIST

Note: See last page for instructions.

Date:________________________ See Review Comment

1. Facility or Project Name: ______________________________ ____
2. Type of Facility: ______________________________ ____
3. Facility Location: ______________________________ ____
4. State's Project Number: ______________________________ ____
5. Client Agency: ______________________________ ____
6. Contracting Agency: ______________________________ ____
7. "Designer": ______________________________ ____
8. Were DOT/PF Roofing Standards reviewed and followed: Yes ____ No ____. ____
9. Type of Work: New Roof ____, Reroof ____, Roof Repair ____. ____

   Is this an historic building: YES ____, No ____.

   If this is an existing building, has there been a change in occupancy type: YES ____, No ____.

   Has humidification been added: YES ____, No ____.

10. If reroof or repair, was report on cause of leak prepared: Yes ____, NO ____. If prepared, attach to design narrative. ____
11. If reroof or repair, did designer make a field observation: Yes ____, NO ____. ____
12. Is Facility humidified: YES ____, No ____. If yes, designed humidity is ____%. ____
13. Does site have "Basic Wind Speed" (See Design Standards Manual For Buildings Part II, Section 3) of 100 mph or greater: YES ____, No ____. ____
14. Was basic wind speed determined from Section 3, Figure 6: Yes ____, NO ____. If no, what was data source: ____
15. Does design Basic Wind Speed reasonably reflect actual condition: Yes ____, DON'T KNOW ____. ____
16. Is additional wind data required: YES ____, No ____. ____

17. Was snow drift analysis performed: Yes ____, No ____. ____

18. Does snow drift pattern shown on schematic roof plan and drift loads in the structural narrative reasonably reflect actual conditions: Yes ____, DON'T KNOW ____. ____

19. Is additional snow load or drift data required: YES ____, No ____. ____

20. Roof Slope: DEAD LEVEL ____, flat ____, low slope (1 1/2 to 12 - 3 to 12) ____, steep slope (greater than 3 to 12) ____. ____

21. Structural Roof Deck: Precast or prestressed concrete ____, cast-in-place concrete ____, steel ____, steel with concrete topping ____ or other poured-in-place fill ____, plywood ____, don't know at this time ____, Other (note type) ____________________. ____

22. Is this a Protected Membrane Roof: Yes ____, No ____. ____

23. If PMR, does slope exceed 1 in 12: YES ____, No ____. ____

24. If PMR, surface is: mortar topping ____, pavers ____, aggregate with filter fabric ____. ____

25. Vapor Retarder: None (PMR) ____, Bituminous ____, Kraft paper ____, plastic sheet ____, don't know at this time ____, Other (note type) ________. ____

26. Insulation: composite board (note type) ____________________ extruded polystyrene _______, rigid fiberglas _______, perlite _____ polyisocyanurate ________, tapered (note type) ____________________, fiberglass batts _______, don't know at this time _______, Other ____________________. ____

27. Built-up membrane: Yes ____, No ____. ____

    A. Bitumen: Asphalt ____, COAL TAR ____. ____

    B. Felt: Fiberglass ____, OTHER (note type) ____________. ____

    C. Base Sheet: YES ____, No ____. ____

    D. Surfacing: PMR ____, aggregate ____, smooth ____, cut back ____, aluminum cut back ____, emulsion ____, mineral surface cap sheet ____, other (note type) ________. ____

28. Nonconventional or elasto/plastic: Yes ____, No ____. ____

    A. Membrane: Cold process ____; modified bitumen SBS ____ or APP ____; neoprene ____, EPDM ____, PVC ____, Hypalon (CSPE) ____, CPE ____, PIB ____, Spray-applied polyurethane foam ____, Liquid applied ____, other (note type) ________. ____

B. If spray-applied polyurethane foam, coating is: acrylic ____, silicone ____, single component urethane ____, two-component urethane ____, other (note type) ___, with mineral granules ____ or without ____.

29. If elasto/plastic, membrane attachment is: fully adhered ____, partially attached ____, ballasted ____, PMR ____.

30. Sloped Roof: Yes ____, No ____.

A. Membrane: Composition shingles ____, wood shingles ____, clay or concrete tiles ____, synthetic tiles ____, metal panels ____, BUR (respond to #27) _____, elasto/plastic (respond to #28 and #29), Other (note type) ____.

31. Is the need for a temporary roof anticipated: Yes ____, No ____.

32. Will construction work occur adjacent to or over a new or existing roof: Yes ____, No ____.

DO DRAWINGS SHOW:

33. Min. scale of 1/16" = 1'-0": Yes ____, No ____.

34. Roof system description: Yes ____, No ____.

35. Roof drainage and direction: Yes ____, No ____, and amount of slope: Yes ____, No ____. Are there scuppers: Yes ____, No ____. Are there gutters: Yes ____, No ____.

36. All expansion, seismic, and area divider joints: Yes ____, No ____.

37. Do re-entrant corners occur: Yes ____, No ____.

38. Roof access (hatch, ladders): Yes ____, No ____.

39. All roof penetrations (including mechanical and electrical): Yes ____, No ____.

40. Applicable wall section references: Yes ____, No ____.

41. Plan reference grid: Yes ____, No ____.

42. Ballast layout for PMR mortar faced insulation: Yes ____, No ____, Not applicable _____.

43. Do wall sections show information required by Appendix 4.3.1, Section 6.3.2: Yes ____, No ____.

44. If deck is precast or prestressed concrete, steel without concrete topping or other poured-in-place fill, or plywood composite panels, are roof control joints provided at all changes in deck direction: Yes ____, No ____. ____

Are roof control joints provided at all changes in deck material: Yes ____, No ____.

45. Do mechanical drawings show all mechanical roof penetrations on a mechanical roof plan: Yes ____, No ____. ____

46. Are there any electrical roof penetrations: Yes ____, No ____. If yes, are these shown on an electrical roof plan: Yes ____, No ____. ____

47. In reroofing, or repair, is separate demolition plan required: Yes ____, No ____. Is phasing plan required: Yes ____, No ____. ____

DOES NARRATIVE INDICATE:

48. Changes between Design Development and Contract Documents? Yes ____, No ____, No changes ____. ____

49. Brief description of new and existing Roof System (deck, insulation, membrane): Yes ____, No ____. ____

50. Why the chosen system was selected: Yes ____, No ____. ____

51. If the building is humidified, is it explained how the roof system design accommodates it: Yes ____, No ____. ____

52. If this is a steep or low slope roof, have the problems of water drainage at grade, snow and ice slides, and ice build-up been addressed: Yes ____, No ____. ____

53. Is the roofing system selected, reasonably appropriate for the weather conditions (during application and in-service): Yes ____, No ____. ____

54. Are logistics to the Project Site reasonably appropriate for the roofing system selected: Yes ____, No ____. ____

55. Is full time field observation of the roofing work recommended: Yes ____, No ____. ____

56. If reroofing, or working over or adjacent to a new roof, will NDE be performed prior to construction: Yes ____, No ____. ____

57. Any material, system, detail, etc. not recommended by the Roofing Standards shall be identified and justification for its use presented. Is this applicable to this job: Yes ____, No ____. If so, is justification given: Yes ____, No ____. ____

57.1 Have live load deflections been considered: Yes ____, No ____.

CODES:

In general, refer to Design Standards Manual For Buildings Part I, Section 8.1.

58. From U.B.C. (1982) Table 17A, Roof fire-resistive requirement in hours is: 2 ____, 1____, H.T. ____, N ____. ____

60. FM Windstorm Resistance Classification: I-60 ____, I-90 ____, None (PMR) ____, None ____. ____

61. If Steel Deck, FM Fire Rating: ____ Class 1 ____, Class 11 ____, None ____, not a steel deck ____.

62. If wood deck, FM Fire Rating: ____ Class 1 (Fire Retardant Treated) ____, combustible ____, not a wood deck ____.

63. If not a steel or wood deck, FM fire rating: noncombustible ____, Class 1 ____, Deck is steel or wood ____. ____

64. The following sections of the Uniform Building Code (1982 edition) are applicable:

Yes	No	Section
____	____	910: Explosion Venting (also see U.F.C.)
____	____	1710: Projections
____	____	1712: Foam Plastic Insulation
____	____	1713: Insulation and Vapor Retarders
____	____	1714: Solar Collectors (also see 5214)
____	____	Table 17-A
____	____	1806: Roof Construction, Type I Buildings
____	____	1906: Roof Construction, Type II Buildings
____	____	2305: Structural Roof Design. Note: also refer to Design Standards Manual Part II Section 3 - Structural Criteria
____	____	2306: Live Load Reduction. Note: also refer to Design Standards Manual Part II Section 3 - Structural Criteria
____	____	2311: Wind Design. Note: also refer to Design Standards Manual Part II Section 3 - Structural Criteria
____	____	Chapter 32: Roof Construction and Covering (also see Appendix Chapter 32 for reroofing)
____	____	3205: Attic Space (access, draft stop, ventilation)
____	____	3206: Smoke and Heat Venting (also see 3901, 3906 and U.F.C.)
____	____	3207: Roof drainage
____	____	3306: Stairway to Roof, Roof Hatch at Stairways
____	____	3401: Skylights (also see 5207)
____	____	3601: Penthouses and Roof Structures
____	____	3602: Towers and Spires
____	____	3901: Stage Roof Ventilators

Yes	No	Section
____	____	3906: Platform roof ventilator Table 43-C
____	____	4504: Balconies and Appendages
____	____	4505: Marquees Roof Construction
____	____	4506: Awnings (also see 5211)
____	____	Chapter 52: Light-transmitting Plastics
____	____	5206: Plastic Roof Panels
____	____	5207: Skylights
____	____	5211: Awnings and Patio covers (also see Appendix Chapter 49)
____	____	5212: Greenhouses (also see 2311 and 3401)
____	____	5213: Solar Collectors
____	____	Appendix Chapter 32: Reroofing
____	____	Appendix Chapter 49: Patio Covers
____	____	Appendix Chapter 55: Membrane Structures (air-inflated, air-supported, or membrane-covered cable or frame structure). Also see U.F.C.

65. The following Sections of the Uniform Fire Code (1982 Edition) are applicable.

Yes	No	Section
____	____	Article 32: Membrane Structures (air-inflated, air-supported, or membrane-covered cable or frame structure). Also see U.F.C.
____	____	Article 76: Explosion Venting
____	____	Article 81: Venting of high-piled combustible stock

66. The following sections of the Uniform Mechanical Code (1982 Edition) are applicable.

Yes	No	Section
____	____	710: Furnaces installed on roofs
____	____	906: Appliance Vent Termination
____	____	907: Appliance Vent Termination
____	____	912: Factory-Built Chimneys
____	____	913: Masonry Chimneys
____	____	914: Metal Chimneys
____	____	2002: Kitchen Ventilation Outlets

67. The following sections of the Uniform Plumbing Code (1982 Edition) are applicable:

Yes	No	Section
____	____	304: Connection of Roof rain water to sewer
____	____	506: Plumbing vent termination
____	____	1317: Water heater vent terminations
____	____	Appendix D: Rainwater Systems (Roof drains and gutters)

SPECIFICATIONS

68. Are specifications in compliance with Section 5 of the DOT/PF Roofing Standards: Yes ____, No ____. ____

69. If temporary roofing is required, has it been thoroughly specified: Yes ____, No ____, Not Applicable ____. ____

70. If reroofing, have special considerations been addressed: Yes ____, No ____, Not Applicable ____. ____

71. If working adjacent to or over a new or existing roof, have special considerations been addressed: Yes ____, No ____, Not Applicable ____. ____

THE FOLLOWING SHALL BE COMPLETED BY THE REVIEWER

A. Were Design Development review comments adequately addressed and resolved: ____ Yes ____, No ____.

B. Does it appear the Designer consulted and followed the DOT/PF Roofing Standards: Yes ____, No ____. ____

C. Is a special review conference warranted: Yes ____, No ____. ____

D. Based upon the Roofing Standards guidelines, is review by a specialized consultant recommended: Yes ____, No ____. ____

E. Reviewer: ______________________________

F. Review Date: ______________________________

INSTRUCTIONS TO REVIEWER

1. Attach review comments to this checklist and return to Designer.

   Place review comment number in the column at the right margin.

2. Carefully review/consider checked items with a bold underline.

5. MASTER SPECIFICATIONS

Note:

1. Specification Section titles and numbers are based upon CSI **Masterformat**, 1983 Edition.
2. Appendix 5 will be issued in the future.

5.1 General

The Master Specifications in Appendix 5.4 shall be edited, updated, and tailored by the designer to meet the requirements of each specific roofing project.

5.2 Related Specifications

5.2.1 General

Each specification section should cross reference all other sections that specify related work. Typically this is done under Item B, "Related Work Specified Elsewhere". Item B is in paragraph 1.02 **"DESCRIPTION OF WORK"**. See Appendix 5.4 for example.

Verify Section titles and numbers (this manual is based upon CSI **Masterformat**, 1983 Edition).

5.2.2 Demolition

Roofing demolition is usually specified in Division 7. However, the roofing section should cross reference general demolition (if it occurs), which is normally specified in Section 02050.

5.2.3 Roof Decks

The roofing section should reference the Roof Deck Section, which will normally be:

- Cast-In-Place Concrete: 03300
- Metal Decking: 05300
- Rough Carpentry: 06100

If the roofing bears directly on the superstructure rather than a deck, the section specifying the structure should be referenced.

See Sections 3.3.10 **"Roof Decks"** and 3.4.1 **"Roof Deck Materials"** for deck discussions.

5.2.4 Metal Framing, Carpentry and Insulation

Related metal framing or carpentry (ie.: parapet walls) and building insulation (ie. control curb insulation) should be referenced. For example:

- o Metal Framing: 05400
- o Rough Carpentry: 06100
- o Parapet and Curb Insulation: 07210

Note: Above deck insulation is normally specified in the roofing section, while below-deck insulation is usually specified in "Building Insulation 07210".

5.2.5 Flashing and Sheet Metal

Normally metal copings, counterflashings, etc. are specified in "Flashing and Sheet Metal: 07600".

See Section 3.3.14 for flashing discussion.

5.2.6 Roof Accessories

Roof hatches and smoke vents are normally specified in "Roof Accessories: 07720."

See Sections 3.3.7 **"Roof Access"** and 3.3.8 **"Explosion, Smoke, and Heat Venting** for accessories discussions. Also see Section 3.3.14.

5.2.7 Skylights

Skylights are usually specified in 07800 (glazing may be specified in 08800).

See Sections 3.3.14 "**Roof Penetrations and Perimeters, Flashings and Sealants**" and 3.4.6.12 "**Glass**" for skylight discussions.

5.2.8 Sealant

Sealant is normally specified in 07900.

See Section 3.3.14 "**Roof Penetrations and Perimeters, Flashings, and Sealants**" for sealant discussion.

5.2.9 Mechanical and Electrical

Related mechanical and electrical work is specified in Divisions 15 and 16. Work generally relates to roof drains, plumbing vents (VTR), and curbs/flashings for mechanical and electrical penetrations.

See the following sections for discussions related to mechanical and electrical equipment:

- 3.2.4.4 "**Outside Air Intakes**". This discusses snow considerations.
- 3.3.2.5 "**Roof Drainage**".
- 3.3.9 "**Transporting Heavy Equipment Across A Roof**".
- 3.3.14 "**Roof Penetrations and Perimeters, Flashings, and Sealants**".
- 3.3.15 "**Roof-Top Equipment**".

5.2.10 Other Roofing Sections

If a project includes two or more different roofing systems (and therefore two or more Roofing Sections), or if an alternate type of system is specified, each Roofing Section should reference the other Section(s).

5.3 Special Deck Considerations

As discussed in Section 3.3.6, re-entrant corners present special problems to adhered roofing systems.

With adhered systems, re-entrant corners should be eliminated. However, if they occur, the deck should be securely fastened. The following specifications are recommended for metal and plywood decks (note: additional fasteners may be required to accommodate high shear loads).

5.3.1 Re-entrant corner specification for metal decks (place in Part 3 of Section 05300):

Roof Re-entrant Corners

- o At re-entrant corners, ensure metal deck is secured to framing below. Weld within 3", 6", 12" and 15" either side of the corner.

- o At the nearest deck side lap, weld the side lap within 3" from wall and at 6" o.c. for a distance of 36" from wall.

5.3.2 Re-entrant corner specification for plywood decks (place in Part 3 of Section 06100):

Roof Re-entrant Corners

- o At re-entrant corners, ensure plywood deck is secured to framing below. Nail within 3", 6", 12" and 15" either side of the corner.

- o At the nearest plywood side lap, nail the side lap within 3" from wall and at 6" o.c. for a distance of 36" from wall.

5.4 Roof Protection

If work occurs over or adjacent to a new or existing roof, the specification shall thoroughly address roof protection. See Section 3.3.16.

End of Section 5, MASTER SPECIFICATIONS

Appendix 5.5 Follows

6. ROOFING APPLICATION

Note: Appendix sections 6.8.4 - 6.8.9 will be issued at a later date.

6. ROOFING APPLICATION

6.1 GENERAL

6.1.1 Testing of the roof system:

- o Is generally not required during or after application.
- o If the designer believes testing is warranted, this should be specified in the technical specifications.
- o If problems develop during or after application, testing may be appropriate. Testing is further addressed in Section 8 "ROOF INVESTIGATIONS AND TESTING".
- o If the Project involves work adjacent to, or over an existing roofing, non-destructive evaluation before and after construction is recommended. This is further discussed in Section 3 "DESIGN CONSIDERATIONS AND CRITERIA" and Section 8 "ROOF INVESTIGATIONS AND TESTING".

6.1.2 The key to a successful application is founded upon:

- o Proper selection, arrangement, and detailing of materials.
- o Thorough specifications and drawings.
- o Materials manufactured in accordance with the Contract Documents.
- o Competent applicators executing the Work in accordance with the Contract Documents.
- o Execution of Work in proper weather conditions.

- Proper protection of the completed Work.

If any of the above items are deficient, steps must be taken to compensate for the deficiency.

6.2 SUBMITTALS

6.2.1 The specifications should require a thorough roofing submittal.

- This will help insure the roofer has complete application instructions. Since the specifications depend heavily upon manufacturer's recommendations, this is paramount.

- If problems arise, complete submittals are extremely beneficial in terms of potential litigation and in performing repairs or replacement.

  A record of what was installed is important, particularly with elasto/plastics. Often, it is difficult to determine what material was used. This information is vital if repairs are required.

6.2.2 Submittal review should be thorough. All specified submittals should be submitted by the Contractor, and resubmitted until approval is obtained for each item.

The reviewer should be extremely cautious in approving materials, systems, and details not in accordance with Contract Documents. Minor changes may affect code compliance, warranties, and performance.

The reason for changes, and the reasons for accepting the change shall be documented and submitted on the Submittal Review Certificate (Appendix 6.8.1).

6.3 PRE-ROOFING CONFERENCE

A Pre-Roofing Conference shall be specified. The following items shall be reviewed at the conference:

1) Review salient features of the specification, including:

   - o Demolition (if applicable)
   - o Product delivery, storage, and handling.
   - o Roof loading
   - o Weather conditions
   - o Protection of other work
   - o Unique or critical items specified in Part 3 - Execution
   - o Protection of the completed roofing

2) Review the drawings, paying particular attention to unique or critical aspects.

3) Review submittal problems.

4) Insure the Contractor has a copy of the approved submittals at the job site.

5) Insure the Contractor has a copy of the documents referenced in the specifications under "Quality Assurance".

6) Discuss Contractor's responsibilities regarding notification (for purposes of field observation) prior to roofing.

7) Establish lines of communication between the field observer (if it is someone other than the Designer), Contractor, Designer, and the Owner's Project Manager.

8) All persons attending the conference shall review all roof decks ready for roofing. Review shall include parapet walls, curbs, penetrations, etc.

   If a roof area is not ready, an additional conference shall be held to review that area prior to roofing.

   All areas shall be reviewed prior to roofing.

   If corrective work is required, this shall be reviewed prior to roofing.

9) Minutes of the conference shall be written by the Designer and distributed.

6.4 FIELD OBSERVATION

Field observation (either periodic or full time) by a knowledgeable observer is paramount.

The decision to utilize periodic or full time observation is discussed in **Section 3 "DESIGN CONSIDERATIONS AND CRITERIA"** and **Section 9 "RE-ROOFING AND MAJOR ROOF REPAIR"**.

It is imperative the observer thoroughly understand the system being installed. There is little value in an observer who does not have the required knowledge. The observer shall:

1) Be provided with a copy of the Contract Documents related to roofing.

2) Be provided with a copy of the documents referenced in the specifications under "Quality Assurance".

3) Be provided with copies of all changes related to roofing.

4) Be provided with copies of all approved submittals.

5) Attend the Pre-Roofing Conference.

6) Maintain Observation checklists (see Appendix 6.8).

7) Submit Observation Certificate (Appendix 6.8.2).

8) Communications: The lines of communications between the Field Observer, the Contractor, the Designer and the Owner's Project Manager shall, be established during the Pre-Roofing Conference.

9) Duties: **Normally, the Field Observer does not have the authority to make or authorize changes to the Contract Documents.**

   If there is need for change, this should be brought to the Owner's Project Manager's attention. The Project Manager should then consult with the designer.

The duty of the Field Observer is to observe the Work and help insure it is being executed in accordance with the Contract Documents. **If the Work is not in accordance with the Documents, the Field Observer shall:**

1) Notify the Contractor and Owner's Project Manager. The Project Manager should then notify the designer.

2) Provide written documentation of the deficiency.

3) If conditions warrant, initiate Stop Work Notice (in accordance with the Contract Documents).

Observation certificates and checklists are discussed in Section 6.5 and 6.6 and are found in Appendix 6.8.

6.5 FIELD OBSERVATION CHECKLISTS

The following checklists are in Appendix 6.8:

- o Decks: 6.8.4
- o Vapor Retarders: 6.8.5
- o Insulation: 6.8.6
- o Built-up Membrane: 6.8.7
- o EPDM Membrane: 6.8.8
- o Flashing and Sheet Metal: 6.8.9

If these checklists are not applicable to the roofing system being installed, similar checks should be made, with appropriate adjustments to suit the particular system.

6.6 SUBMITTAL REVIEW AND OBSERVATION CERTIFICATES

The submittal reviewer shall fill out and sign the Submittal Review Certificate, Appendix 6.8.1.

The Field Observer shall fill out and sign the Field Observation Certificate, Appendix 6.8.2.

6.7 PROJECT CLOSE-OUT CERTIFICATE

The Owner's Project Manager shall fill out and sign the Close-Out Certificate, Appendix 6.8.3.

End of Section 6, ROOFING APPLICATION

Appendix 6.8 Follows

APPENDIX 6.8.1

SUBMITTAL REVIEW CERTIFICATE

1. Facility or Project Name: ____________________

2. Type of Facility: ____________________

3. Facility Location: ____________________

4. State's Project Number: ____________________

5. Client Agency: ____________________

6. Contracting Agency: ____________________

7. "Designer": ____________________

8. Submittal Reviewer: ____________________

9. General Contractor: ____________________

10. Roofer: ____________________

11. The Submittal Reviewer hereby certifies that all specified submittals for the roofing and items integrally related to the roofing were submitted and "Approved" or "Approved as Noted."

12. The specifications appear to be adequate regarding required submittals: Yes ___, No ___.

13. Were there changes to specified materials, systems, or details: Yes ___, No ___.

    If there were changes, on an attachment hereto, indicate the changes, reasons for the changes, and justify the final solution.

14. The following specification Sections are applicable:

CSI Section	Title
________	____________________
________	____________________
________	____________________
________	____________________
________	____________________
________	____________________

Note: Typically, this may include flashing and sheet metal, roof accessories (roof hatch), skylights, sealants, and roof drains.

15. Reviewer's signature ____________________
16. Date: ________

APPENDIX 6.8.2

FIELD OBSERVATION CERTIFICATE

1. Facility or Project Name: ______________________________

2. Type of Facility: ______________________________

3. Facility Location: ______________________________

4. State's Project Number: ______________________________

5. Client Agency: ______________________________

6. Contracting Agency: ______________________________

7. "Designer": ______________________________

8. Submittal Reviewer: ______________________________

9. General Contractor: ______________________________

10. Roofer: ______________________________

11. Field Observer: ______________________________

12. The "Field Observer" hereby certifies the roofing and items integrally related to the roofing appeared to be installed in accordance with the Contract Documents (including the approved submittals).

13. Were there field changes to the approved materials, systems, or details: Yes ___ , No ___ .

    If there were changes, indicate the changes, reasons for the changes, and justify the final change on an attachment to this certificate.

    (Note: The above information may be more appropriately addressed by the "Designer". If so, obtain the information from the Designer and attach to this certificate).

14. On an attachment, list when field observation(s) occurred.

15. Attach copies of the observation checklists (as found in Appendix 6.8).

16. Field Observer's Signature: ______________________________

17. Date: __________

APPENDIX 6.8.3

PROJECT CLOSE-OUT CERTIFICATE

NOTE: This document shall be filled out by the Owner's Project Manager.

1. Facility or Project Name ______________________________
2. Type of Facility: ______________________________
3. Facility Location: ______________________________
4. State's Project Number: ______________________________
5. Client Agency: ______________________________
6. Contracting Agency: ______________________________
7. "Designer": ______________________________
8. Submittal Reviewer: ______________________________
9. General Contractor: ______________________________
10. Roofer: ______________________________
11. Field Observer: ______________________________
12. Owner's Project Manager: ______________________________
13. The following items are in the Project files: ______________________________

Yes	No	
___	___	Schematic Design Narrative
___	___	Schematic Design Checklist
___	___	Response to S.D. Review Comments
___	___	Design Development Narrative
___	___	Design Development Checklist
___	___	Response to D.D. Review Comments
___	___	Contract Documents
___	___	Response to C.D. Review Comments

Yes	No	
___	___	Minutes of the Pre-Roofing Conference
___	___	All construction correspondence related to roofing
___	___	Field Observation Reports
___	___	Submittal Review Certificate (Appendix 6.8.1)
___	___	Field Observation Certificate (Appendix 6.8.2)
___	___	Record Copy of Submittals, Specifications, and Drawings related to roofing.
___	___	Warranties
___	___	Project Close-out Certificate (Appendix 6.8.3)

14. The following items are in the Maintenance Department files:

Yes	No	
___	___	Minutes of the Pre-Roofing Conference
___	___	All construction correspondence related to roofing
___	___	Field Observation Reports
___	___	Submittal Review Certificate (Appendix 6.8.1)
___	___	Field Observation Certificate (Appendix 6.8.2)
___	___	Record Copy of Submittals, Specifications, and Drawings related to roofing
___	___	Warranties
___	___	Membrane sample and manufacturer's maintenance and repair instructions (if an elasto/plastic membrane was used).
___	___	Project Close-Out Certificate (Appendix 6.8.3).

15. Note:

- o Following Final Completion, all correspondence regarding the roofing should be placed in the Project and Maintenance files.
- o On an attachment, explain all "no" responses.

16. Project Manager's Signature: ______________________________

17. Date: __________

7. MAINTENANCE

7.1 GENERAL

7.1.1 All roofing systems require maintenance.

Do not accept manufacturer's claims that maintenance is not required! Depending on the roofing system, maintenance may only have to be periodic observation, or it may involve extensive work. However, what ever the degree required, maintenance has an important role in assisting the roofing system reach its full life. By early detection and correction of minor problems, widespread damage may be prevented, along with interruption of the internal functions of the building.

Of equal importance, a smooth functioning maintenance program will allow capital expenditure requests on an orderly basis. This will assist in obtaining **adequate funding** for major maintenance/repairs. Also a good program will allow forecasting when the roof will reach the end of its economic life. Hence, adequate funding may be sought in advance, adequate time will be available for design of the new system, and the system can be installed at the most advantageous time of the year.

Without a good maintenance program, minor problems that are inexpensive to repair often lead to complete loss of the system. Problems go unnoticed until leaks occur and begin to cause interior damage to the building and equipment. Functions are interrupted. Emergency repair or reroofing is often mandated, which usually means inadequate funding and design time, which is sometimes compounded by work in poor weather conditions. The end result is all too often a new system with built-in demands for extra maintenance, short economic life, and a poor investment for the building Owner.

Maintenance work should be in compliance with applicable fire regulations. See Section 3.2.8.

7.1.2 Establishing a Maintenance Program

A planned maintenance program is simply a program of **scheduled inspection and corrective action.**

It is based upon the following elements, which are discussed in detail in this Section:

- o Maintaining an historical file.
- o Semi-annual roof observations.
- o Special roof observations.
- o Minor repairs.
- o Major roof repair/maintenance.

Use caution and concern while on the roof. Personnel safety and inadvertant roof damage must be recognized. For example, do not step on blisters or walk on cold exposed membranes.

7.1.3 Warranties

Copies of Warranties should be kept in the historical file. **Be aware of terms and exclusions. It is easy to inadvertently void a warranty.** If problems develop, carefully follow notification procedures noted on the warranty.

Even if there is no warranty, the materials manufacturer, roofer, or General Contractor may be liable to the Owner, if negligence or breach of implied warranties under the Uniform Commercial Code can be proven.

7.2 HISTORICAL FILE

7.2.1 For new buildings and reroofing projects, obtain:

1) Minutes of the Pre-Roofing Conference.

2) All construction correspondence related to roofing.

3) Field observation reports.

4) Submittal Review and Field Observation Certificates (Appendix 6.8.1. and 6.8.2).

5) Project Close-out Certificate (Appendix 6.8.3).

6) Record copy ("as-built") of the submittals, specifications, and drawings.

7) Warranties

8) Membrane sample and manufacturer's maintenance and repair instructions (if an elasto/plastic membrane was used).

9) All post-construction correspondence related to roofing.

10) Non-Destruction Evaluation report (this should occur approximately one year after Substantial Completion Inspection and just prior to the expiration of the Roofing Warranty).

11) Report of each "Semi-annual" or "Special" Roof Observation.

12) Documentation of repair work.

13) Documentation of changes (new penetrations, equipment, etc.).

7.2.2 If a building has more than one roof system, roofs of different ages, or perhaps roofs on several levels, a historical file should probably be established for each roof area.

7.2.3 If a historical file does not currently exist, it should immediately be initiated with as much historical data as possible.

7.2.4 If an elasto/plastic membrane was used, thorough Record information is vital. When future recoating or repairs are required, it is mandatory to know what the existing material is. Identification of elasto/plastics can be difficult, costly, and time consuming.

Also, with elasto/plastics a sample of the membrane should be kept in the file, along with the manufacturer's maintenance/ repair instructions.

7.2.5 The historical file should be permanently kept on file for the life of the roof.

7.3 SEMI-ANNUAL ROOF OBSERVATIONS

7.3.1 The single most important maintenance function is to perform semi-annual roof observations.

These may be performed by maintenance staff or other Owner personnel, architects, roof consultants, or roofers. The person must be knowledgeable of the roofing system being observed. Ideally, the same person would perform the observation year after year, since changes to the roof would probably be more readily apparent.

Economic reality may not allow a knowledgeable person to perform this task. If this is the situation, as a bottom line effort, the following should be done twice yearly:

- Look for obvious gross deficiencies (splits, missing sheet metal flashings, etc.). Specifically, look for problems at re-entrant corners.
- Perform the repair work listed under item 7, "Repair Work by Owner."

These minimal tasks can be performed by a person without roofing knowledge. Unfortunately, they will miss many early warning signs of impending problems. Also, there is the risk that they will inadvertently cause damage. However, the benefits probably outweigh the risks.

7.3.2 The observation should be performed in the spring and fall. There are advantages in seeing the roof when it is wet and when it is dry. Ideally, one observation would be during dry conditions and the next in wet.

Observing a roof when it is covered with frost or a thin layer of snow may be beneficial. This is known as "poor man's thermography." If "thermal bridges" show up, they may be caused by areas of wet insulation. These observations should probably be limited to those roofs that can easily be seen from adjacent buildings. The risk of doing damage to a cold membrane or falling from an icy roof probably out weighs the benefit, unless a known problem is trying to be identified.

7.3.3 Care should be taken while performing the observation, particularly if the roof system is fragile (such as spray-applied polyurethane foam).

7.3.4 Problems that are built into a new roof usually are not apparent for two to five years. Hence, special effort in observing new roofs for five years is important. After five years, if problems have not developed, a sound roof probably occurs. Minimal maintenance will probably be required during its economic life.

7.3.5 For the observations to be of value, it is mandatory to correct deficiencies that are found.

The first observation of an old roof may generate a lengthy list of corrective items. If this list is too great to correct within the given cost or time restraints, **prioritize the work**.

7.3.6 Checklist is found in Appendix 7.11.

7.4 SPECIAL ROOF OBSERVATIONS

Special observations should be conducted soon after major windstorms and earthquakes. If snow removal occurs, a special observation should occur the following spring. If new construction occurs adjacent to a new or existing roof or work occurs over an existing roof, the existing roof should be reviewed upon completion of the work. **These special observations should occur for the following five years, since damage may not be immediately apparent.**

This special observation also applies to repair work and minor work such as new roof penetrations.

See item 7.6.1 regarding precautions and worker safety.

7.5 REPAIR OR REPLACE

7.5.1 If there are problems, determine the causeof the problem before repairs or replacement occurs. The exception of course being emergency repairs.

If the cause of the problem is not determined and corrected, the repair or replacement work may soon also suffer. For example, if a split occurs and is simply patched, the patch will also probably split if the cause is discontinuous attachment of the insulation boards. Another example is the classical case of interior water damage, followed by reroofing, followed by more water damage, followed by the realization the problem was dripping condensation (hence the original roof need not have been replaced).

Determining the cause may be very simple or very difficult and expensive. However, this step is economically prudent. Problem identification is discussed in Section 8 "**Roof Investigations and Testing.**"

7.5.2 Repair or Replacement Criteria:

7.5.2.1 If it costs more to repair than to replace with a "good" roof then replace. A "good" roof is defined in Section 3 "**DESIGN CONSIDERATIONS AND CRITERIA.**"

7.5.2.2 If the membrane has enough years of expected life to justify the cost of the repairs, and if the insulation is generally dry, then repair.

Membrane life and insulation moisture conditions are further discussed in Section 9 "**REROOFING AND MAJOR ROOF REPAIR.**"

7.5.2.3 Recognize that a roof is a system--it is an array of independent elements. These elements must function and work together as intended. Prior to repairing one of the components (such as the membrane), be sure other items such as the deck or sheet metal flashings) are not in need of repair. If they are in need, repairs to the total system may not be economically justifiable. **Do not continue to unknowingly throw money at one problem after another.**

7.5.2.4 **Do not prematurely replace a roof.** The roof is an investment that may be extended by judicious expenditure for repair.

However the roof should be replaced prior to complete failure. Complete failure can be considered to be a condition where virtually all the insulation is wet and considerable water infiltration is occurring. Once this condition occurs, removal of the existing insulation is usually mandatory. Hence, the potential of water damage during reroofing is great. Also, the opportunity to retain existing insulation is lost.

7.6 REPAIRS: EMERGENCY, TEMPORARY, AND PERMANENT

7.6.1 Emergency repairs relieve an immediate problem. Water leaking into the building is usually associated with this type of repair.

These repairs are often made during poor weather conditions by unskilled workers using incorrect materials. Thus temporary or permanent repairs usually follow. To facilitate this later work, record the location of the emergency repair and record what was done. **Lastly, schedule follow-up repairs.**

Due to the nature of conditions under which emergency repairs often take place, be aware of the following:

- Generally, a work crew should consist of at least two people.
- Beware of "downed" electrical lines in stormy conditions.

- o If there are plugged roof drains, structural collapse may be a problem. Upon checking the roof, if it appear this is a potential, evacuate the area below and proceed with caution.

- o If plugged roof drains are discovered, first clean debris from the dome (strainer). Do not remove the dome to reach into the drain, as sudden cleaning may cause dangerous suction.

7.6.2 Temporary repairs are intended to extend the life of roof a few years or until a decision is made to make permanent repairs or replace the roof. **Temporary repairs will probably need continual periodic maintenance.**

7.6.3 Permanent repairs are intended to last the remaining life of the roof. they should not require maintenance after their periodic observation.

7.7 REPAIR WORK BY OWNER

7.7.1 Usually, the Owner does not have a maintenance staff that is qualified to do most roof repair work. However, the following items may be within the Scope of Work that can be reasonably executed.

1) Clean roof drains, gutters, downspouts.

2) Remove debris (rocks, cans, etc.)

   Note: if these have become embedded in a built-up membrane, patch with plastic cement. Use glass fabric mesh for deep penetrations.

3) Check/refill pitch pockets.

   Note: usually, plastic cement is used for refilling.

4) Repair wind scour (aggregate dislocation). If the roof is aggregate surfaced built-up, embed the aggregate in plastic cement.

   If the aggregate is loose over a protected membrane roof or ballasted roof, consider placing pavers in the scoured area. Provide for separation between the pavers and membrane and base flashing (see Section 3, "DESIGN CONSIDERATIONS AND CRITERIA").

5) Resecure and reseal exposed fasteners.
6) Replace failed sealants.
7) Repair fishmouth (built-up membrane).
   Note: Repair of fishmouths in elasto/plastic membranes is probably beyond the Owner's staff expertise.
8) Check guy wires and resecure.

7.7.2 Other repair work is probably more appropriately left for roofers.

7.7.3 Many items do not lend themselves to repair, such as ridging. These are premature failures that are very difficult or costly to effectively repair.

7.7.4 **Snow removal should not be required.** However, if it occurs, do not scrape down to the membrane (leave about six inches of snow), flag VTR's and similar items so they are not damaged, and cover walls so they are not damaged. **Prior to removal, be certain this drastic action in required.** See Section 3.2.3.3 and 3.2.4.6.

7.8 SPECIAL CONSIDERATIONS

7.8.1 Built-up membranes

1) Smooth surface roofs require recoating approximately every 5 - 7 years. Recoating is discussed in Section 9, "REROOFING AND MAJOR ROOF REPAIR."

2) The most versatile patching material is plastic cement and glass fabric mesh. For economy, plastic cement should be purchased in 5 gallon cans. Once opened, unused material may be protected by pouring a small amount of naptha over what remains in the can before resecuring the lid.

   Use asphalt plastic cement for asphalt roofs and coal tar plastic cement for coal tar roofs. In Alaska, coal tar roofs are rare. See Section 8 **"ROOF INVESTIGATIONS AND TESTING"** for discussion on determining if the roof is asphalt or coal tar.

3) Modified bitumen sheet membranes are very effective patching materials. This material is discussed in Section 3 **"DESIGN CONSIDERATIONS AND CRITERIA."**

7.8.2. Elasto/Plastic Membranes

These membranes present some unusual problems. Many of the materials needed for repair have a very short shelf life. Hence it is impractical to stock these in the maintenance department.

Specific repair techniques depend upon which elasto/plastic membrane you have. As discussed earlier in this Section, identifying which elasto/plastic membrane you have may be very difficult.

With membranes utilizing contact adhesive (such as EPDM), cleaning the old membrane prior to patching may be particularly difficult. In addition to using solvent and primers, wire brushing the membrane may be advisable. If possible, **review specific repair procedures with the manufacturer prior to repairing.**

7.8.3. Spray-applied Polyurethane Foam Roofing (PUF)

PUF roofs are fragile. They can be damaged by bird pecking, hail (although in Alaska, this usually isn't a problem), and foot traffic.

Soft soled shoes should be worn on this roof type. If work is performed on roof top equipment, care should be taken to avoid membrane damage due to dropped tools, setting aside cowlings, etc.

The foam coating naturally weathers away. It should be recoated about every 8 - 10 years. When recoating, extreme care should be exercised regarding preparation of the existing membrane and selection of the particular recoating material

Semi-annual and special observations are critical. If the membrane coating over the foam is damaged, early detection and repair is vital. Without the coating protection, the foam is rapidly degraded by sun light and water.

Depending upon the coating color, it is easy to see coating damage. Upon exposure to sunlight, within a few days, the foam is characteristically yellow ocher in color.

Refer to "Preliminary Guidelines for Maintenance of Polyurethan Foam (PUF) Roofing Systems", Technical Note N1691, Naval Civil Engineering Laboratory, March 1984.

7.8.4. New Penetrations and Equipment

Check the warranty prior to making new penetrations. Special notification/procedures may have to be followed to prevent voiding the warranty.

New penetrations should be prepared and flashed by someone knowledgeable of the particular roof system in question. Usually, the flashing should be performed by a roofer--not Owner personnel or other subcontractors.

In addition to penetrations, be sensitive to items that are merely set on the roof, such as an antenna with a pedestal. Simply resting something on a membrane may lead to a problem.

Antennas are of great concern. They are often very inappropriately installed. Also, those concerned with building maintenance are many times unaware of their installation until damage has occurred.

If repair work is done on roof top equipment, provide pads to protect the membrane.

> **Be cautious in removing and replacing roof top mechanical equipment. "Walking" heavy equipment over the roof may cause membrane damage.** Damage (which may not be immediately apparent) can occur even if rollers are used. Cranes or helicopters should generally be used for heavy items.

7.8.5. Inappropriate Repairs

Many times inappropriate techniques and/or materials are used for "temporary" repairs. For example: plastic cement for EPDM.

For "Emergency" repairs, virtually anything to plug the leak is acceptable. However, this is not true with temporary repairs.

The reasons that proper techniques and materials should be used are:

- o To avoid compatibility problems and damage to sound roofing components.

- o To avoid making future investigations and/or repairs difficult. For example, coating a problem area with plastic cement can make future work very time consuming.

7.9 RESOURCES AND LITERATURE

7.9.1. The following documents were used for the preparation of this Section:

1) Roofing Industry Educational Institute (RIEI) **Basic Roofing Technology** Course Manual (Seminar 101, Roofing Technology), 1980:

   - o "Roof Surveys and Inspections"

- o "Maintenance and Repairs"
- o "Roof Maintenance"

  Note: "Maintenance and Repairs" can be separately purchased from RIEI.

2) RIEI **Roof Inspection, Diagnosis, and Repair** course manual (Seminar 102), 1982:

   - o "The Roof Survey And The Inspection Checklist"
   - o "Repair Materials for Roof Maintenance"

3) **RSI**, November 1983, p. 34.

7.9.2 Other resource material:

- o In addition to the items listed above, the Appendix in the "Roof Maintenance" manual (Item 7.9.1.1) lists several other literature resources. In particular, the Tremco document (Guidelines to Maintaining Good Roofs) has good photographs of typical built-up membrane problems.

- o Although it is old, **Maintenance and Repair of Roofs** (Army TM 5-617) by the Department of the Army, Navy, Air Force, and Marine Corps, January, 1974, has good information. Particularly on older roofing systems (i.e. asbestos - cement roofing).

- o **Roof Inspection and Maintenance**, Public Works, Canada, September, 1983.

- o See Section 2, **"RESOURCES AND LITERATURE."**

7.10 CHECKLISTS

Appendix 7.11.1 is a Semi-annual Roof Observation checklist. This document will be applicable to many roofs. Modify as required for any specific building.

End of Section 7, MAINTENANCE

Appendix 7.11 Follows

APPENDIX 7.11.1

SEMI-ANNUAL ROOF OBSERVATION CHECKLIST

NOTE:

A. This checklist is based upon "Semi-Annual Maintenance Inspection Checklist" found in the RIEI Roof Maintenance Manual, published by the Roofing Industry Educational Institute.

B. Modify to suit the particular building/roofing system.

1. Facility Name: ______________________________

2. Type of Facility: ______________________________

3. Facility Location: ______________________________

4. State's Project Number: ______________________________

5. Client Agency: ______________________________

6. Has the building been humidified since the last Roof Observation: Yes ___, No ___.

7. Are the building occupants aware of any leaks: Yes ___ , No ___. If yes, initiate determining the cause and scheduling repair.

   Date of Repair: ______________________

8. Does water (ice) drip from the soffit, or between the building face and edge flashing or gutter: Yes ___, No ___. If yes, initiate determining cause and scheduling repair.

   Date of Repair: ______________________

9. Has insulation been added below the roof deck since the last observation: Yes ___, No ___.

10. Have changes or additions been made to the roof since the last observation: Yes ___, No ___.

11. Have new penetrations been made since the last observation: Yes ___, No ___ .

	OK	Problem Minor	Problem Major	Observation	Date of Repair
12. **Supporting Structure**					
Exterior and Interior Walls					
Expansion/Contraction					
Settlement Cracks					
Deterioration					
Moisture Stains					
Physical Damage					
Other					
Exterior and Interior Roof Deck					
Securement to Supports					
Expansion/Contraction					
Structural Deterioration					
Water Stains					
Physical Damage					
Attachment of Felts/Insulation					
New Equipment/Alterations					
Other					
13. **Roof Condition**					
A. General Appearance					
Debris					
Drainage					
Physical Damage					
General Condition					
New Equipment/Alterations					
Other					
B. Surface Condition					
Bare Spots in Gravel					
Alligatoring/Cracking					
Slippage					
Other					
C. Membrane Condition					
Blistering					
Splitting					
Ridging					
Fishmouthing					
Loose Felt Laps					
Punctures					
Securement to Substrate					
Fasteners					
Membrane Slippage					
Other					
14. **Flashing Condition**					
A. Base Flashing					
Punctures					
Deterioration					
Blistering					
Open Laps					
Attachment					
Ridging or Wrinkling					
Other					
B. Counter Flashing					
Open Laps					
Punctures					
Attachment					
Rusting					
Fasteners					
Caulking					
Other					

	OK	Problem Minor	Problem Major	Observation	Date of Repair
Flashing Condition (cont'd.)					
C. Coping					
Open Fractures					
Punctures					
Attachment					
Rusting					
Drainage					
Fasteners					
Caulking					
Other					
D. Wall					
Mortar Joints					
Spalling					
Movement Cracks					
Other					
15. Roof Edging/Fascia					
Splitting					
Securement					
Rusting					
Felt Deterioration					
Fasteners					
Punctures					
Other					
16. Roof Penetrations					
A. Equipment Base Flashing					
Open Laps					
Punctures					
Attachment					
Other					
B. Equipment Housing					
Counter Flashing					
Open Seams					
Physical Damage					
Caulking					
Drainage					
Other					
C. Equipment Operation					
Discharge of Contaminants					
Excessive Traffic Wear					
Other					
D. Roof Jacks/Vents					
Attachment					
Physical Damage					
Vents Operable					
Other					
17. Expansion Joint Covers					
Open Joints					
Punctures/Splits					
Securement					
Rusting					
Fasteners					
Other					
18. Pitch Pans					
Fill Material Shrinkage					
Attachment					
Other					

19. Roof Drains: Check for blockage, condition of screens or domes, flashing and clamp rings.

20. Inspector: ______________________________

21. Date: __________

22. Note:

a. Immediately initiate scheduling "Emergency" repairs.

b. Initiate prioritizing and scheduling temporary and/or permanent repairs.

c. Initiate scheduling of further investigation/testing, reroofing, or major roof repair.

* * * * *

8. ROOF INVESTIGATIONS AND TESTING

Note: Footnotes are referenced by a number within a bracket, ie. [1]. The footnotes occur in Appendix 8.5.2.

8.1 GENERAL

8.1.1 The purpose of "Roof Investigations and Testing" is related to roofing system problems that occur during or after construction.

Semi-annual roof observations are distinctly different. These are discussed in Section 7 **"MAINTENANCE"**.

When system problems occur, it is mandatory to determine the cause and extent. With that information, decisions can be prudently made regarding reroofing or repairing. Section 7 **"MAINTENANCE"** presents parameters regarding replacement or repair, and Section 9 **"REROOFING AND MAJOR ROOF REPAIR"** specifically addresses the work.

8.1.2 Problem identification (cause and effect) may be simple or it may be very difficult. Whoever is doing the work should be knowledgeable of the system in question. **Usually it will be necessary to have this work performed by a roofing consultant, or an architect or engineer with special expertise.**

8.1.3 Usually "a problem" is made up of multiple problems. Generally there will be one or more primary problems and several other items that may or may not be contributing to "the problem".

8.1.4 Special investigation/testing should be considered when:

- A new roof is tied into or occurs immediately adjacent to an existing roof.
- Construction occurs above or adjacent to a new roof.
- Construction occurs above or adjacent to an existing roof.

The objective is to determine the condition of the roof before and after construction, in order to determine if the construction was detrimental to the roof.

An initial investigation of the existing roof should occur during project design. If it is determined the existing roof is worth saving, the Contract Documents should address this issue. See Section 3.3.16 "Work Over, or Adjacent to a New or Existing Roof", Section 5 "MASTER SPECIFICATIONS" and Section 9 "REROOFING AND MAJOR ROOF REPAIR".

If it is determined the existing roof is to remain, Non-Destructive Evaluation (NDE) should be performed. The preferred NDE method will probably be infrared thermography or capacitance. This is further discussed in Section 8.4.

By scanning the roof prior to construction, an accurate moisture condition can be determined and documented. After construction, the roof is once again scanned. If moisture conditions have changed, it can probably be directly correlated to construction inadequacies.

Scanning aids the Contractor as well as the Owner. If the roof contained excessive moisture prior to construction, this is known. Hence later manifestations of this condition are not incorrectly attributed to the Contractor.

Protected Membrane Roofs can not be effectively evaluated by NDE.

8.1.5 Another type of special investigation/testing relates to problems during construction. These are generally related to quality control. Examples:

- o Weather conditions (rain/snow, humidity, temperature).
- o Temperature of applied material.
- o Workmanship (embedment of felt, inadequate pressure when rolling seams, etc).
- o Material deficiencies (pin holes in sheet membranes).

The objective of this investigation/testing is to determine if there are inadequacies in application or materials.

Usually, destructive testing is required. These tests normally require laboratory facilities. Laboratories in Alaska can perform some tests. However, many types of tests will have to be performed out of the State. Destructive testing is further discussed in Section 8.3.

8.1.6 **If the roof system is suitable for NDE, all new roofs should be tested approximately one year after Substantial Completion Inspection and just prior to the expiration of the roofing warranty.** Infrared thermography or capacitance will probably be the preferred method.

8.2 ROOF INVESTIGATION

8.2.1 **The investigator must be knowledgeable of the system being investigated.**

For example, a person who is qualified to investigate built-up systems, but knows little about EPDM, should not investigate EPDM systems.

8.2. It is beyond the scope of this document to educate a person to the point where they can investigate roofs. Also, it is beyond the scope to indicate all of the things to look for, and what the causes are, of a host of problems.

Obtaining the necessary expertise to perform investigations is a time consuming process that requires "office" and "field" study.

The following education and experience is vital for the investigator:

- It is mandatory to have a sound theoretical/technical background on roofing systems. This includes the building structure, structural deck, vapor retarder, roof insulation, and membrane; as well as all other items discussed in Section 3 "DESIGN CONSIDERATIONS AND CRITERIA".

- **An excellent source of information in addition to this document is the Roofing Industry Educational Institute (RIEI). As of 1985, RIEI has six excellent courses:**

- o Basic Roofing Technology
- o Roof Inspection, Diagnosis, and Repair
- o Single Ply Roofing Systems
- o Design and Specifications of Roofing Systems
- o Standing Seam Metal Roofing Systems
- o Roofing Update

The courses are presented by the Industry's leading authorities. Many slides and movies are shown, which helps obtain a "hands-on" sensitivity to the subject. Over time, additional courses will be added to the curriculum. See Section 2 for further RIEI information.

o Field experience must supplement the "classroom" education. Through slides and movies, much can be learned. But it is vital that an "investigator trainee" spend time on roofs with a "veteran".

o It is important for the investigator to remain current. For example, systems or materials that were installed in the recent past may begin to fail. If this is reported in periodicals and if the investigator is aware of the article, the investigator will more likely correctly diagnose the problem.

Periodicals listed in Section 2 are an excellent resource for this continuing education.

8.2.3 Basic elements of the investigation:

o **Prior to the investigation, assume that litigation is potential.** Therefore, the investigation should be conducted with this potential in mind.

Hopefully, litigation can be avoided, however at the outset of the investigation, this is unknown. As discussed in Section 9 **"REROOFING AND MAJOR ROOF REPAIR"**, problems are rarely caused by "aging failure" or acts of nature. They are usually caused by inadequacies of any or all of the following: design, application, material, abuse, or lack of maintenance. Therefore, in the litigious climate of the 1980's it is common to see attorneys involved with roofing problems.

o **When an investigation is performed, look at everything related to the roof.** By doing so, not only will the primary problem(s) be identified, but other minor items will hopefully also be identified. These minor deficiencies can then be scheduled for repair, or they may affect the decision regarding repair or replacement.

o Prior to observing the roof, review the drawings, specifications, and any other documentation that is readily available.

Many times, the problem is apparent just by reviewing these documents. However, field investigation is still mandatory.

o Field Investigation:

1) For a successful investigation, good weather is important. The entire roof surface must be free of snow. High winds and/or rain makes it difficult for the investigation.

   It should not be raining when taking samples.

2) Meet with the building's occupants and discuss areas of water infiltration. Is the infiltration associated with heavy rain, melting snow, or strong wind (if so, does wind direction have any significance)?

   Is the building humidified? If so, was humidification added or originally constructed.

   Has the occupancy type changed?

3) On a drawing, mark the location of known leaks and when they occured. Photograph the ceilings and walls where water damage occurred.

   Observe and photograph the area above the ceiling where leaks occurred.

Are the leaks associated with something other than roofing problems? Examples: leaking pipes, water drippage from a humidified duct, or condensation?

Condensation problems may not be readily apparent, particularly at certain times of the year.

4) After reviewing the interior, go to the roof-top and attempt to correlate leak location below with a problem at the roof.

   If nothing is immediately obvious on the roof, mark the location where water has entered below.

   An effective means for temporarily marking areas that will be looked at in more detail later in the investigation is to use surveyor's flagging. This may be tied onto things such as vent stacks, or it can be taped in place with duct tape.

5) Next, make an in depth look at the membrane and flashing. **Every square foot should be visually examined.**

   Mark items that need closer examination later in the investigation.

   The Semi-Annual Roof Observation Checklist (Appendix 7.11.1) may be helpful for this and subsequent tasks.

6) After developing an overall impression of the roof, review the exterior of the building.

   If there are settlement cracks, moisture stains, etc., attempt to correlate these with roofing system problems.

7) Items that were previously flagged should be further explored. During this step, photographs and samples are taken. This is further discussed in Items 8) and 9).

Detailed review is also made of all penetrations.

Review should include any walls that occur above the roof. Water infiltration could be occurring at the wall and be totally unrelated to the roof.

8) Photographs should be taken to show the general character of the roof. Detailed photographs should be taken of problem areas and of all samples.

Where possible, the object being photographed should be marked with the investigator's initials, date, and project number. If the photo is a sample, the sample number should be marked. Also on samples, a north arrow should be placed. Samples should also be marked to indicate if the photo is of the top or bottom side.

Color print film should be used.

9) Destructive sampling is almost always necessary. The number of samples will vary from roof to roof, but a range of 10-20 samples is common. Of these, perhaps 3-6 samples may require laboratory testing. For further information, see Section 8.3.

The investigator may be able to learn a great deal from close observation of sample delamination.

Samples that are taken for lab testing should be carefully removed from the roof and numbered. This will avoid delaminating during the removal process. To further assure the sample is not delaminated during removal, at least one full thickness sample (membrane and insulation) should be approximately 24 inches square. Other samples will usually be 18 inches square. Lab samples should be immediately wrapped in plastic bags and sealed with duct tape. Sample locations and their number should be recorded on a roof plan.

Prior to sampling, the membrane should be free of moisture.

10) Prior to leaving the field, a relatively strong hypothesis regarding the problem should be developed by the investigator.

- The next phase of the investigation is to correlate background information with the field investigation and laboratory analysis. The various items are discussed, conclusions presented, and general recommendations made. Cost estimates are also usually presented.

  The report should identify all problems and should indicate whether the particular problem is the primary cause of failure, or perhaps just contributing to the primary cause, or simply a defect that has no impact on the current failure. Each deficiency should be attributed to design, workmanship, material, abuse, lack of maintenance, or acts of nature.

  The report should include a roof plan (which indicates sample locations) and color photographs. Usually several copies (each with color photos) will be required.

- To supplement the investigation, NDE may be desirable. See Section 8.4.

8.3 DESTRUCTIVE TESTING

Refer to "Roof Cuts" in the RIEI course manual for **Roof Inspection, Diagnosis, and Repair**.

8.3.1 Destructive testing may be required for the following reasons:

- Quality Control: traditionally, 4" x 40" cuts were taken from new built-up roofs and lab tested to determine if the application was in accordance with the specifications (in terms of bitumen weight, head laps, number of plies, ply and asphalt type, workmanship, etc.).

These tests are generally conducted in accordance with ASTM D 3617 and D 2829.

Most manufacturers of built-up materials and NRCA (Handbook of Accepted Roofing Knowledge, XXIV, page 27, February 1980) do not recommend using test cuts for determining the quality of the roof system. Also see "Test Cuts: Is This Really The Best Way To Evaluate The Total Roof", **Roofing Spec**, December 1982.

Test cuts should not be routinely specified and taken. If there are reasons to believe there are problems with the application, destructive testing is probably in order. However, in addition to 4" x 40" cuts, several larger cuts are recommended [see Item 9) Section 8.4].

o Establishing data base lines for or confirming results of NDE: A minor amount of destructive testing is required for NDE, as discussed in item 4 (page G-9).

Destructive testing can be adequately accomplished by using a "CRREL TEST CORE". The U.S. Army Cold Regions Research and Engineering Laboratory (CRREL) has developed a coring device and patching procedure (see RIEI course manual for **Roof Inspection, Diagnosis, and Repair**). The corer can be purchased through advertisements in **The Roofing Spec**.

After taking the core, lab testing is usually performed.

Destructive testing can also be accomplished with a Delmhorst Moisture Meter. The two small holes can be patched as described in the CRREL document, except that insulation plugs are not necessary. This type of testing is faster and cheaper than coring and lab testing. However the results are not as reliable.

o Investigations: as previously discussed, destructive sampling for visual and lab analysis is vital.

8.3.2 Prior to cutting the roof, be sure the cut is in compliance with the terms of any applicable warranty.

Also, be sure a qualified person is on hand to patch the roof.

8.3.3 Samples should be labeled, photographed, and bagged as discussed in items 8) and 9) in Section 8.2.3. The location of each sample should be marked on a roof plan.

The number and size of samples is discussed in item 9) in Section 8.2.3.

8.3.4 Specific detailed directions should be issued for the type of patch to be made.

8.3.5 Items that are commonly evaluated during lab testing are:

- Moisture content of insulation and membrane (built-up).

- Number of plies, interply mopping weight and type of asphalt, weight of top coating (smooth surface built-up membrane).

- Seam strength (elasto/plastic membranes).

- Material properties (usually applies to elasto/plastic membranes, but may be of interest in some built-up applications).

- Defects such as interply holidays, lack of ply embedment, interply blisters, asphalt pinholes, air voids, etc.

Depending on each specific job, special testing may be required, such as determining if screws are stainless steel.

8.3.6 Testing bitumen to determine if it is asphalt or coal tar is discussed in Appendix 8.5.1.

8.4 NON-DESTRUCTIVE EVALUATION (NDE)

8.4.1 Refer to the RIEI course manual for Roof Inspection, Diagnosis and Repair. Also see Section 2 **"RESOURCES AND LITERATURE"**.

A glossary of terms associated with NDE occurs in the RIEI course manual for **Roof Inspection, Diagnosis and Repair**.

8.4.2 During the 1970's three non-destructive techniques were developed to find wet insulation in roofs. The primary purpose of each technique is to find wet insulation so that repair or replacement efforts can be concentrated in problem areas in order to maximize the economic value of an existing roof.

The techniques use infrared scanners, nuclear meters, or capacitance meters. Each of these methods is discussed in detail below.

NDE does not define the degree of wetness, however this may change with technological advances. Degree of wetness can be determined by destructive testing. NDE devices do not find water directly. NDE hardware merely locates anomalies, which oftentimes are caused by water.

8.4.2.1 NDE should always be verified by destructive testing. The exception being the testing of an existing roof before and after new construction. In this case, destructive testing is only necessary if there is an apparent increase in moisture following the new construction.

8.4.3 **Ballasted and Protected Membrane Roofs and roofs with no place for moisture to accumulate are not suitable for NDE.**

8.4.4 As previously noted, NDE should be considered when:

- o A new roof is tied into or occurs immediately adjacent to an existing roof.

- Construction occurs above or adjacent to a new roof.
- Construction occurs above or adjacent to an existing roof.
- Reroofing or major roof repair is planned. This is further discussed in Section 9.
- Necessary to supplement visual investigations and/or destructive testing.
- The roofing warranty is nearing expiration.

8.4.5 Infrared Thermography

This technique is also known as Thermal Imaging or Scanning. Thermography works on the principle that wet insulation transmits heat more rapidly than dry insulation, and wet material stores more heat than dry material does. The thermal image of the roof is seen on a screen similar to a T.V. screen. The images are in black and white or color, depending upon the equipment being used. For roof surveys, black and white is adequate. Depending on the equipment, the image can be preserved by a photograph (35 mm or instant print) or by video which can be played on a VCR. These visible light records are called thermograms.

Most scanners use liquid nitrogen (-300°F.) This must be stored in special containers, **which usually can be carried on commercial aircraft, but special limitations and conditions are imposed.** The nitrogen can cause frostbite if spilled. It can also damage a roof by thermal shock if spilled.

Thermography equipment is substantially more expensive than nuclear or capacitance meters. In 1983, suitable thermography equipment cost approximately $20,000 - $25,000.[1]

The roof surface must be free of moisture when it is scanned. Also it should not be scanned within a few hours of rainfall, even if the surface has since dried.

The scan should occur during darkness. If scans must be made during the summer when very little darkness occurs, the scan should take place at the darkest hours. Since the work will occur in darkness on the roof, caution is required. On complex or dangerous roofs, the survey team should briefly walk over the area during daylight hours.

Scanning requires a team of two people - the scanner operator and an assistant to spray paint (outline) areas of wet insulation. The scanner operator should be knowledgeable of roofing technology and experienced with the infrared equipment being used. Knowledge is necessary in order to properly interpret what is seen on the screen.

If no distinctive pattern is seen, it is not easy to distinguish a uniformly dry roof from a uniformly wet roof. Destructive testing is necessary to establish a base line, except as noted in 8.4.2.1.

The pattern of wetting varies with the insulation type. Wet-fill insulation (which is not common in Alaska) retains or takes on water in irregular ways, often producing ill-defined images of varying brightness. This insulation type is difficult to scan.

Perlite, wood fiberboard, rigid fiberglass, and expanded polystyrene (EPS, bead board) are usually wet board-by-board and are easy to detect when they are wet. Urethane and isocyanurate boards wet from the edges in. When wet, their perimeters are outlined on the screen.

After scanning and outlining the anomalies at night, a visual inspection of the anomalies and destructive testing is made. This should occur within a day or two of the scan. All test locations should be immediately repaired as previously discussed.

The cause of all anomalies must be diagnosed and all those that are not associated with wet insulation isolated. Typical "false" anomalies are:

- o Varying thickness of roof aggregate, membrane, insulation, or deck.
- o Different types of insulation (hence different R-value).
- o Heat sources under the roof (i.e, cabinet unit heater at the ceiling).

- o Heat radiated from nearby walls.
- o Hot rooms (i.e., boiler rooms).
- o Heat radiated from parapets.
- o Hot air from exhaust fans or relief air hoods.
- o Differences in the roof due to patches.

Capacitance meters may be useful in identifying false anomalies. See the Spring 1985 issue of the **Infraspection Institute Newsletter**.

It is possible to survey with scanners in fixed-wing aircraft or helicopters. This technique may be of reconnaissance value where many buildings occur in one area. Airborne surveys are a means of finding large problem areas, but they miss small wet areas. Airborne surveys should be supplemented with on-the-roof surveys. Perhaps as much as 500,000 square feet of roof area in the same geographic location is needed to economically justify an airborne survey.[2]

The results of the survey should be documented and forwarded to the Owner. The report should include thermograms and a roof plan which delineates anomalies associated with wet insulation and false anomalies. Destructive test locations, test method and test results should be included. Thermograms should be included in or accompany the report.

Depending on the scope of work the NDE report may give analysis and recommendations, or it may just present relatively raw data. In either event, the cause and effect of problems should be fully understood prior to initiating repair or replacement.

The Infraspection Institute (see Section 2) has a Thermographic Certification Program. **By the late 1980's it may be resonable to require this certification.** Note: The Institute periodically publishes a newsletter.

8.4.6 Nuclear Meters

Nuclear meters consist of a radiation source, a radiation counter, and a counter display. The meter is placed on the roof and turned on. A stream of high velocity neutrons are emitted. When the neutrons strike a hydrogen atom, they are slowed down and counted. Since water molecules contain hydrogen atoms, their presence is recorded. However, other items have hydrogen atoms, such as bitumen and concrete. Hence even a dry roof will have some reading on the meter. This is referred to as the background reading, or reference level.

Meter readings higher than the reference level indicate water. False anomalies can be created by:

- Additional plies (typical at base flashings and penetrations).
- Variation in interply mopping weight.
- Moisture located at different levels in the insulation (due to the number of neutrons bounced back to the counter being inversely proportional to the square of the distance from the counter to the hydrogen concentration).
- Variation in insulation thickness (due to same reason as noted above).
- Over a deck of varying thickness (primarily affects tests over pre-cast concrete tees or concrete waffle slabs).
- Dirty aggregate surfacing with intermitent moisture.
- Uneven aggregate surface.

The meter tests the roof at only one point. Each point covers an area approximately two square feet. Therefore the survey is performed by laying out a grid and testing at each grid line intersection. Grids are usually 10 feet x 10 feet or 5 feet x 5 feet. When the grid is halved, the number of tests is multiplied by four. Accuracy is increased, but so is the cost. The meter can usually test only 8" into the roof.

Radiation is emitted and counted approximately 15 seconds at each grid point.

In order to establish the reference level, destructive testing is required, except as noted in 8.4.2.1. Samples are taken from several areas that represent the range of nuclear readings from high to low.

Since the meter contains a radiation source, the meter is regulated by the Nuclear Regulatory Commission. The meter can be flown on cargo flights, but not on commercial. The operator needs special training and is required to wear a Dosimeter. Although special training is required, the knowledge base for nuclear is insignificant compared to what is necessary for infrared.

After obtaining field data, data reduction is required. A plan is prepared showing the grid readings. Wet areas are delineated. The borders may be estimated by hand-plot or by computer. Contours may be drawn to indicate relative wetness of the insulation. However the accuracy of contours is questionable. Since the boundary between wet and dry insulation is usually abrupt, contouring is usually of little value.

A calibration line is generated by plotting the moisture content of each sample location. A line is run to generate a counts-to-water content relationship. Ideally the line would be straight, but it may be a curve.

The disadvantage of nuclear compared to other types of NDE is that nuclear does not see the entire roof. Wet areas can be easily missed. The advantage of nuclear is that it can be used in weather conditions that prevent the use of thermography.

The results of the survey should be documented and forwarded to the Owner. The report should include a roof plan which delineates area of wet insulation. Destructive test locations, test method, test results, and the calibration line (curve) should also be included.

Depending on the scope of work, the NDE report may give analysis and recommendations, or it may just present the reduced data. In either event, the cause and effect of problems should be fully understood prior to initiating repair or replacement.

8.4.7 Capacitance Meters

A capacitance meter creates an alternating current electrical field in the materials below it. The ability of those materials to store and dissipate electrical energy is related to their dielectric properties. The dielectric properties of water are significantly different from those of most roofing materials. When water exists in the electric field, the reading on a capacitance meter increases.

Capacitance meters are very sensitive to moisture just below their base. **Hence, this is the best NDE method to detect interply moisture.** However, due to this sensitivity near the base, **the membrane surface must be dry.** Differences in aggregate thickness can move the capacitance away from moist areas enough to significantly affect its readings. **Current (1985) hardware has the capability to only penetrate three inches below the roof surface.**

Since metal within the electrical field short-circuits the meter, meaningful readings cannot be taken over membranes or insulation systems with metal films. Steel decks and mechanical fasteners can also distort readings, however these distortions may be tuned out with the newer hardware. Conductive surfaces (i.e. metal faced membranes and EPDM) do not permit the use of capacitance meters.

Capacitance surveys originally were done on a grid similar to nuclear surveys. However, hardware is now available that allows continuous moving readings, thereby allowing full inspection of the roof surface.

Capacitance meters give an instantaneous reading.

As with thermography and nuclear, destructive testing is required for base line verification, except as noted in 8.4.2.1. Capacitance data reduction is somewhat similar to nuclear.

Survey results should be presented, as discussed under nuclear in Section 8.4.6.

Changes in capacitance technology may occur in the future. For updates, consider contacting TRAMEX Electronics, Inc. (P.O. Box 1310, Topanga, CA 90290).

End of Section 8, ROOF INVESTIGATIONS AND TESTING

Appendix 8.5 Follows

APPENDIX 8.5.1

FIELD TESTS

1. Test for determining if a bitumen is asphalt or coal tar:

   Place a specimen (in solid form) in a jar of mineral spirits and shake. If the material begins to dissolve, it is asphalt.

CRUDE FIELD TESTS

The following tests may be helpful in obtaining a preliminary material identification. **These tests should be verified by lab testing.**

1. To determine if a felt is organic or asbestos:

   Burn a specimen. If considerable residue remains, it is probably asbestos felt.

2. To determine if a sheet membrane is EPDM or neoprene:

   Burn a specimen. If a greenish color occurs in the flame, it is probably neoprene.

APPENDIX 8.5.2

FOOTNOTES AND BIBLIOGRAPHY

FOOTNOTES

1. RIEI Seminar; Denver, Colorado, 1983.

2. Ibid.

BIBLIOGRAPHY

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"What You Should Know About Nuclear Meters". **Roofing/Siding/Insulation** (RSI). February, 1980.

The discussion on Roof Investigations is primarily based upon the expertise of Thomas Lee Smith, AIA, CSI, and his previous collaboration with roofing consultants Paul Tente (Denver) and Dr. Raymond W. LaTona (Simpson Gumpertz and Heger; San Francisco).

9. REROOFING AND MAJOR ROOF REPAIR

9.1 GENERAL

9.1.1 Roof Failures:

Definition of roof failure: **"When a roof experiences or manifests some signs that may result in serious and costly consequences."[1]**

Roofs experience two different modes of failure - **premature failure** and **aging failure.** Aging failure is the desired and normal failure of a roof. This failure is governed by the chemical stability of the materials of the roofing system and by material fatigue due to thermally induced expansion and contraction. Premature failure results from inadequacies of any or all of the following: design, application, material, abuse, lack of maintenance, or acts of nature.

9.1.2 Consequences of Failure:

1) Failure to prevent entrance of water or excessive condensation may result in:

   - o Very costly damage to electronic equipment.

   - o Costly damage to interior finishes and building contents.

   - o Degradation of thermal resistance, resulting in increased energy consumption.

   - o Degradation of structural integrity of building components, possibly resulting in component failure and/or building collapse.

2) Failure to carry live loads:

   - o Wind forces can blow off portions of a roof, including the structural deck. This can expose the building to water infiltration and freeze-up. In extreme, but not unusual cases, the building may not be habitable until expensive repairs are completed. Injuries from wind blown debris are possible.

- o Ponding water or snow drifts may cause permanent structural deformation or roof structure collapse.

3) Failure to minimize fire spread from internal and external fire exposure:

- o Some roofing systems actually promote rather than retard fire spread, thereby increasing losses of property and perhaps life.

4) Visual Failures:

- o Visual failures usually do not have economic or other types of impact, except for the degradation of the visual aspects of the built environment.

9.1.3 Causes of Failure:

o According to a large New Jersey based roofing consulting firm, during the 1960's and 70's they experienced that design contributed to failure 15 to 20% of the time, materials approximately 5%, and workmanship 75 to 80%. [2]

This of course does not take into consideration any acts by the Owner that may have contributed to the failure.

o One consultant's experience with failure investigations has almost always shown **contribution from design and application.** [3] Rarely has he seen materials contributing to failure - although frequently inappropriate materials were used (this was a design problem). In almost all cases, he has seen Owner contribution to the problem. Many times this is direct - such as improper installation of a T.V. antenna. In other cases, it is lack of maintenance.

9.1.4 When Failure Occurs:

1) If there is failure, determine the cause of the failure before repairs or replacement occurs. The exception of course being emergency repairs.

Problem identification is discussed in Section 8 "**ROOF INVESTIGATION AND TESTING**". Once the cause and extent of the problem is determined, decisions regarding reroofing or repairing can be made. Criteria regarding repairing or replacement is presented in Section 7 "**Maintenance**".

This Section specifially addresses work involved with reroofing and major roof repair.

2) **If failure occurs, legal remedy should be pursued only as a last resort. However, it is important that any action taken does not jeopardize future litigation.**

Litigation is expensive, but perhaps more important is the time implication. A problem roof may have to remain in place to allow investigation and reinvestigation by two or more parties. Also remember the Owner may be somewhat responsible for the problem - vis-a-vis improper installation of items after roof construction or failure to properly maintain.

Lastly, the cause of failure may be one of an Industry nature and therefore very difficult or impossible to collect on. An example of this is blistering over urethane boards. This failure phenomenon was not known until after a few years of in-field experience. This failure may have affected just about every manufacturer, roof designer, and roofer who used urethane in the 1970's. **There are risks in construction, and when Owner's decide to construct, they inherit a portion of the risk.**

3) Be aware of any warranties (either expressed or implied) relating to the failing roof. Be sure that steps taken after noticing the failure do not void the warranty.

There may be time limitations and restrictions on cutting the membrane prior to notifying the manufacturer.

9.1.1.5 In addition to specific information in this Section, the **DESIGN CONSIDERATIONS AND CRITERIA** in Section 3 are applicable.

9.1.1.6 Major System Change:

Major roof repair will usually utilize materials and design somewhat similar to the existing system. **However reroofing will often times utilize a radically different system.** When designing a reroof, it is vital to keep a very open mind. All of the vast array of materials and systems presented in Section 3 are available. **Make a selection based upon their ability to respond to the problems presented by the existing building and roof.**

A somewhat common example of a radical change is a new sloping metal or shingle system over a previously flat built-up roof. Usually this occurs when the original design choose BUR for a location that generally experiences rain (such as Adak). This new design is not as dependent upon dry weather as the BUR is. A radical change such as this may be very expensive, but the likelihood of achieving a good roof with long life is greatly enhanced. Hence in terms of life cycle costing, the new system is probably cost effective.

9.1.1.7 Prior to reroofing or doing major roof repair on a historical building, see "**Historical Roof Restoration**" in Section 3.3.17.

9.2 THERMAL UPGRADE

Under certain conditions it is relatively economical to add thermal insulation to the roof envelope without actually reroofing. Prior to the mid

1970's it was common in many parts of Alaska to only have an R-value of less than 10 for the roof insulation. **With increased fuel costs, it may be prudent to upgrade the roof insulation.**

Prior to initiating the work, three steps should be taken:

- o Evaluate the impact of the increased thermal resistance upon the building's internal fire resistance. See Section 3.2.8.4.
- o Evaluate the existing roofing system. It if is in poor condition, roofing work should be a part of the thermal upgrade or the upgrade should be held until roofing work can occur.
- o Estimate the cost of the thermal upgrade and perform life-cycle cost analysis.

  Note: Rarely will it be cost effective to replace a good roof in order to just increase R-value.

Without reroofing, there are two options regarding new insulation location:

- o Below-deck.
- o Above-membrane.

9.2.1 Below-Deck

With this option, insulation is placed below the structural roof deck. Therefore in most cases, the insulation occurs between the ceiling and deck.

Below-deck insulation is usually fiberglass (batts or blow-in) or cellulose fill, since these types are less expensive than rigid roof insulation.

In addition to providing thermal insulation, acoustical benefits are also inherent.

Below-deck retrofit may be difficult due to mechanical and electrical items, ceiling suspension wires, etc.

Caution must be exercised to prevent condensation problems. Dew point calculations (see "**Thermal Insulation and Heat Flow**" in Section 3.3.12) should be performed. If too much insulation is placed below the deck, the under-side of the deck could become cool enough to allow condensation. A sufficient amount of condensate could easily accumulate and saturate the below-deck insulation. After the saturation point is reached, water dripping will occur. This condensation problem could perhaps be overcome with a vapor retarder below the new insulation. However, **an effective vapor retarder may be extremely difficult to achieve** in retrofit applications, especially if there are a number of hanger wires or rods penetrating it.

Below-deck thermal up-grade will rarely be a viable solution.

9.2.2 Above-Membrane

With this option, insulation is placed above the existing membrane. If the existing roof is not a Protected Membrane Roof, then the additional insulation placement is classified as "major roof repair" and is discussed in Section 9.4.3.7.

If the existing roof is a Protected Membrane Roof, the placement of additional insulation is relatively easy. The following items should be considered:

- When the existing ballast is removed, do not temporarily store it on the roof in concentrations exceeding the design live load.

- If the ballast is pavers, but aggregate occurs along the base flashings (which was a typical detail in the 1970's), remove all aggregate.

  Place a premolded expansion joint filler (see Section 5 "**MASTER**

SPECIFICATIONS") between the base flashing and the new layer of insulation, in accordance with current detail procedures. Since the top layer of insulation will probably extend past the bottom layer, additional pavers will likely be required.

Consideration should be given to protecting the base flashings as discussed in Section 3.5.2.

o If the ballast is pavers, but aggregate occurs at the roof drains, remove the aggregate.

Extend the new layer of insulation over the drains in accordance with current detail procedures.

o If the ballast is aggregate, place a filter fabric (See Section 5 "MASTER SPECIFICATIONS") over the insulation prior to reinstalling the aggregate.

Even if the existing roof does not have fabric, fabric shall be installed as part of the thermal upgrade.

o **If the existing insulation is adhered to the membrane, special consideration is required.** In Alaska, this situation should be rare.

When additional insulation is added, the ballast load required to resist the buoyancy must be increased, or the degree of floatation will be increased if standing water occurs. Hence if the bottom layer of insulation is adhered, additional insulation with the same ballast load may allow floatation of the bottom board. If this occurs, **damage to the membrane may result.**

The solution may be to add ballast (after determining the structure has the capacity of accepting additional load), or it may be best to not thermally upgrade.

- Due to the light weight of the insulation, generally insulation up to 4" thick can be added without overloading the structure. However all roofs should be evaluated before adding any additional dead load.

- Insulation should be extruded polystyrene specifically manufactured for use in Protected Membrane Roof systems (see "**Extruded** Poly-**styrene**" in Section 3.4.3.3).

  Installation should be in accordance with the applicable portions of the specifications in Section 5 "**MASTER SPECIFICATIONS**".

9.3 ELEMENTS COMMON TO REROOFING AND MAJOR ROOF REPAIR.

9.3.1 When there is failure, check to see if there has been a **change in occupancy or humidity**. A change in either of these could be the underlying cause of the problem. Hence, the solution must consider and resolve the impacts of these changes.

For example, converting a warehouse to a manufacturing facility could result in the discharge of harmful products onto the roof.

While it is rare for an occupancy change to be the cause of a roofing problem, it is common in Alaska for a humidity change to result in a problem. For example, an office building may originally be constructed without a humidification system. But due to the addition of computers, a humidification system could be added. This could result in condensation and/or a build-up of moisture in the roofing system. Humidification and the affects of it are discussed in detail in Section 3.2.5.

Also be aware of buildings originally designed for humidity. Malfunctioning controls could allow a substantially greater level of humidity than intended. Also, with swimming pools, failure or improper adjustment of the ventilation system could allow very high humidity.

9.3.2 Wet insulation generally has the potential to be harmful to the roofing system. In extreme cases, wet insulation could lead to structural collapse due to corrosion of steel or decay of wood components. Depending upon the insulation material, the insulation itself may become inadequate to support the membrane. This is typical with perlite, which becomes mushy and easily compressible when wet. Under these conditions, membrane splitting or blow-off may occur. Wet insulation may also be the cause of blistering and ridging.

Wet insulation also results in increased fuel consumption due to decreased R-value.

Whether reroofing or repairing, it is usually imperative to remove wet insulation.

If the insulation is damp, it may be permissible to leave it in place. Determining what is "dry", "damp", or "wet" is subjective. Deciding whether a specific situation requires removal requires experience, judgement, and evaluation of the roofing system.

As discussed in Section 3.3.12, **flat roofs cannot be effectively ventilated.** However, if the source of water infiltration has been repaired and the insulation is damp rather than wet, over time the insulation may dry due to natural drying trends.

Wet insulation is further discussed in Section 9.4.2 and 9.5.3.

Wet insulation may be found using non-destructive evaluation as described in Section 8 "**ROOF INVESTIGATIONS AND TESTING**". Another technique is to make test cuts on a ten or twenty foot grid. However, grid testing may miss substantial areas of wet insulation.

9.3.3 As discussed in Section 7 "**MAINTENANCE**", review the total roofing system and determine the cause of the problems.

Repair or replacement work that occurs without a full understanding of the existing condition and problems may prematurely fail.

Often times, problems with sealants, copings, and metal flashings are overlooked. Also, defects in walls above roofs can be the source of water within a roof system.

9.3.4 Repair or replacement work must be in compliance with fire regulations. It is easy to inadvertently perform work that adversely affects fire resistance performance. See Section 3.2.8 "Fire (UL and FM)".

9.3.5 Specifying cleaning and priming of the existing substrate is critical if new components are to be adhered. Specific cleaning and priming procedures will depend upon the substrate.

9.3.6 See Section 7.8.2 and 7.8.3 for discussion on elasto/plastics and spray-applied polyurethane foam.

9.3.7 Construction Documents for repair and replacement work must be thorough. It is not unusual for reconstruction documents to be substantially more complex than documents for new roofs.

The documents must be based on adequate field investigation (see Section 9.6). Even if "as-built" documents are available, it is mandatory to verify the existing composition. The investigation should identify the type, thickness and condition of the roof system components. The investigation shall include the structural system, since various components may have been damaged due to water infiltration.

The documents must describe in detail the materials to be demolished. This will enable the Contractor to more accurately determine the cost of the work.

The use of photographs and isometric drawings is often necessary to describe the work.

The documents must require adequate protection for existing roofs that are to remain. Examples are given in Section 5 "MASTER SPECIFICATIONS". As discussed in Section 8 "ROOF INVESTIGATIONS AND TESTING", non-destructive evaluation should be performed in many reroofing and major roof repair projects.

9.4 MAJOR ROOF REPAIR

9.4.1 Section 7 "MAINTENANCE" discussed three types of repair: emergency, temporary, and permanent. Major roof repair is considered a permanent repair, although many permanent repairs are minor. Section 7 also discusses repair work by the Owner. Generally major repairs are beyond the Owner's expertise.

Major repairs are either very technical or complex, very extensive, or very costly. Examples are:

1. Recoating smooth surfaced built-up membrane.
2. Recoating polyurethane foam roof.
3. Partial replacement of membrane (and probably insulation).
4. Replacement of partial blow-off.
5. Repairing adhesion failure of adhered elasto/plastic membranes.
6. Repairing attachment failures of partially attached elasto/plastic membranes.
7. Conversion of a non-protected membrane roof to a protected membrane roof.
8. Extensive base flashing repair.
9. Installation of a large number of new penetrations or installation of a major piece of roof-top equipment.

Each of the above is discussed in detail within Section 9.4.3.

9.4.2 As previously discussed, it is imperative to determine the cause of the problems prior to doing major roof repair. Non-destructive evaluation is often a vital tool in determining the suitability of the roof for repair.

Wet insulation can be the cause of many membrane problems, which in turn leads to premature failure. If the roof system is built-up or adhered elasto/plastic, it is important to find and remove the wet insulation. Other roof systems may be more tolerant of wet insulation, however, there still remains the possibility of drippage and structural degradation.

If it appears the remaining life of the membrane is short, roof replacement should probably occur rather than major repair. Extensive blistering, ridging, wrinkling or splits are generally indicative of short membrane life.

Successful repairs may be achieved when the membrane has a substantial remaining life and all of the problems of the roof are identified and corrected.

9.4.3 The following is a detailed discussion of the major repairs previously identified:

9.4.3.1 **Recoating smooth surfaced built-up membranes:** Natural weathering breaks down the asphalt glaze coat, emulsion or cut-back coating. Recoating is required to prevent the weathering process from extending further into the membrane, which would eventually lead to leakage.

If done at the appropriate time, either a cut back or emulsion coating may be applied to the properly prepared roof. Cut backs and emulsions are discussed in Section 3.4.4.3. If the surface has deep alligatoring, a polyester fabric should be applied in addition to the coating.

Section 5 contains a Master Specification for recoating.

In lieu of recoating, consideration should be given to converting the roof to a Protected Membrane Roof. See Section 9.4.3.7.

9.4.3.2 **Recoating polyurethane foam roofs:** Natural weathering also breaks down the coating on these roofs in approximately 8-10 years. In recoating PUF, a critical design aspect is determining what type of material the existing coating is. Without a reliable historical file, this will require laboratory testing. The new coating must be compatible with the existing coating. A high performance long life coating should generally be used. It is also important to determine if the foam insulation is dry. Wet material is likely to be .

9.4.3.3 **Partial replacement of membrane (and probably insulation):** This generally occurs where a membrane or flashing defect has allowed water to infiltrate a portion of the roof. If the majority of the roof is in good condition, it may be possible to save it by removing the defective area and replacing with new. Usually the repair materials will be similar to the existing. The critical design aspect is the tie-in of the new to the existing. This is usually best accomplished by installing a control joint (see typical detail in Section 3.9.3).

9.4.3.4 **Replacement of partial blow-off:** This work may be similar to that discussed in Section 9.4.3.3, except for the failure mode. Usually permanent repairs are preceded by emergency repairs.

The separation can be between the membrane plies, between the membrane and insulation, between layers of insulation, or between the insulation and deck. The critical aspect is ensuring adequate bonding of the new system, if an adhered system is installed.

Prior to performing permanent repairs, the cause of blow-off should be determined. Corrective measures may be necessary to prevent future blow-off of the portions of the roof that remained.

Occasionally, when a blow-off occurs, there is bonding failure in the portion of the remaining roof. This may be difficult to recognize. If it isn't recognized, the unattached section may easily blow off in the future, or there may be membrane splits due to stress concentrations.

9.4.3.5 **Repairing adhesion failures of adhered elasto/plastic membranes:** Adhesion failures can occur for a variety of reasons. These failures have a great potential for leading to membrane blow-off. Wind can cause the unattached area to flutter, which stresses the outer boundary of the unadhered area. Since the adhesive is weak in peeling shear, the area of unattachment can be easily increased. Failure is progressive. The larger the unattached area, the greater the boundary flutter forces and hence the spread of the unattachment.

If the unattached area is on only a few inches in diameter and occurs in only a few areas on the roof, there is probably little concern. When the condition is first noticed, permanently mark the boundary of the unattached area on the membrane and record the area on the roof plan. During each subsequent semi-annual roof observation, look at each unattached area - if it has grown, mark the new boundary. If the unattached area is near a corner and reaches 12 inches in diameter, repair should occur. If the area is in the field of the roof, repair should occur if the unattachment reaches 24 inches in diameter.

If the unattachment occurs in a large number of areas, a significant problem may be imminent, even if each area is small. Defective materials or workmanship would be suspected.

Whether the defect is isolated or spread over most of the roof, the membrane manufacturer and roofer should be advised of the problem. If the defect is isolated, the repair would consist of opening up the membrane at the unadhered area, applying new adhesive to the properly prepared insulation and membrane, resetting the membrane, and applying a top patch. Another method would be to apply bars or discs around and just beyond the perimeter of the unattached area. These bars or discs would be the type used by the membrane manufacturer for their partially attached membrane. The bars should be discontinuous, to allow water drainage. The bars or discs are screwed through the insulation, and deck. Hence thermal bridges are created. In the colder parts of the State, condensation on the fastener on the underside of the deck may result in problems which nullify this solution. Condensation problems could also occur in milder parts of the State in humidified buildings.

Where the unattached areas occur throughout the roof, or there is reason to believe that in the future they may occur, **the membrane should be analyzed as a partially attached system**, thereby discounting all blow-off resistance afforded by the adhesive. Bars or discs would be installed just as if the system were only partially attached. If condensation problems prevent the use of mechanical fasteners, usually there are only two alternatives. Either tear off the membrane (and perhaps the insulation) and begin anew, or install a Protected Membrane Roof. A PMR may be possible, if mortar faced insulation is used (see Section 9.4.3.7).

What may appear to be an adhesion failure between the membrane and insulation, may actually be a failure within the insulation itself. There has been at least one installation in Alaska where failure occurred between the insulation facer and the foam insulation.[4] The repair for this type of failure would be similar to that discussed above. However, since this type of failure may be due to a manufacturing defect, and since progressive failure throughout the system may occur, a complete partially attached or PMR retrofit should probably occur.

9.4.3.6 **Repairing attachment failures of partially attached elasto/plastic membranes:** The literature reports a number of failures of partially attached systems.[5] The failure mode is usually related to screws working through the membrane, or working loose from the deck, or adhesion failures between discs and the membrane (in this case, the discs are located under the membrane). These problems are generally associated with progressive failure associated with wind flutter or ballooning.

The problem should be brought to the attention of the manufacturer and roofer. Repair generally is related to installing additional fastening bars or discs. If the problem is related to a defective design in the fastening hardware, hopefully the manufacturer will have a new and improved version.

Perhaps the problem can be solved by installing a Protected Membrane Roof (see Section 9.4.3.7). However, before his is done, all membrane punctures must be repaired and there must be high confidence the fasteners will not continue to work through the membrane. Also the new insulation board may cause the fastener to wear through its protective covering strip. This concern may be overcome by placing a filter fabric between the membrane and insulation.

These problems and hence the solutions are quite new (early 1980's). If this problem is encountered, consult the literature for the latest developments.

9.4.3.7 **Conversion of a non-protected membrane roof to a protected membrane roof:** In lieu of recoating a smooth surfaced built-up membrane, consideration should be given to converting the roof to a PMR. This will alleviate the necessity of future recoatings. In addition it increases the thermal performance of the roof. See Section 9.2.2 and 9.4.3.1. Prior to installing the new insulation/ballast, the existing BUR membrane should be cleaned, primed, and flood coated with asphalt (45 pounds per square).

Adhesion failures of attached elasto/plastic membranes and attachment failures of partially attached elasto/plastic membranes can perhaps be solved by converting to a PMR (see Section 9.4.3.5 and 9.4.3.6). **Air pressure from below the membrane should be evaluated**, as discussed in Section 3.5.2.

When considering PMR conversion:

- The existing roofing system should be in (or brought up to) good condition prior to conversion.
- Verify the structure can accommodate the additional ballast load.
- Typically a non-protected membrane roof in Alaska will have a vapor retarder. The effectiveness of the retarder should be evaluated. This will normally include non-destructive and destructive techniques.

If the vapor retarder is ineffective, a sufficient amount of insulation should be added to place the dew point above the membrane

Insulation should be extruded polystyrene specifically manufactured for use in Protected Membrane Roof systems (see "**Extruded Polystyrene**" in Section 3.4.3.3).

Installation should be in accordance with the applicable portions of the specifications in Section 5 "**MASTER SPECIFICATIONS**".

9.4.3.8 **Extensive base flashing repair:** It is common for base flashings to be in poor condition while the remainder of the roof system is still good.

With built-up membranes, depending upon the existing materials and condition, recoating the base flashing with plastic cement may be acceptable. However, if the base flashing has pulled away from the wall or is in very poor condition, complete replacement may be necessary. A modified bitumen sheet (see Section 3.4.5.2) is probably the best replacement material.

There have been reports of early rapid deterioration of neoprene base flashings.[6] If this condition is encountered, consult the manufacturer. Repair may consist of applying a hypalon coating, adhering new flashing to the existing, or removal of the old flashing and applying new flashing to the substrate. Actual repair techniques will depend upon the specifics of each situation.

Protection of base flashings should be considered as discussed in Section 3.5.2.

9.4.3.9 **Installation of a large number of new penetrations or installation of a major piece of roof-top equipment:** All penetrations should be made by a person knowledgeable of the roofing system involved. While a few penetrations may be considered as minor work, a large number should be considered as major. Thus, additional precautions and controls should occur, which should help ensure a proper job.

Due to the potential damage that can occur when installing a major piece of roof-top equipment, this work should be considered as major repair. The problems/solutions of this issue are addressed in Section 3.3.9 and 3.3.15.

9.5 REROOFING

Reroofing projects are usually very complex and difficult. This is due to:

- o Existing conditions may present severe obstacles in achieving a good new roof.

- o Since the building is probably in use, reroofing may severely interrupt its continued occupancy during roof application.

  If this is unacceptable, this is another set of parameters that must be addressed by the designer and contractor.

- o The potential for water damage during reroofing may be great. Hence this too must be addressed by the designer and contractor.

Because of the complexities that may be present, **many** reroofing projects should only be designed by someone with considerable roofing design expertise and experience. Likewise, special quality assurance requirements should be placed upon the roofer. See Section 5 **"MASTER SPECIFICATIONS"**.

Many projects should have an independent review of the design (beginning at schematics and following through Contract Documents) by someone with considerable roof design expertise and experience. See Section 9.6.1.

In order to achieve a successful reroof, it is often necessary to have a liberal budget for design and construction. **Unless adequately funded,**

cost cutting actions may impair the effectiveness of the new roof. This could easily result in a poor economic investment for the Owner.

As noted in Section 9.1.1.6, it is vital to keep a very open mind when designing a reroof. A major system change utilizing a radically different system may be appropriate.

If possible, retain the existing roofing system. This saves the cost of demolition, retains the R-value of the existing insulation, (at no additional cost) and **most importantly, this minimizes occupancy interruption and the potential for water infiltration during construction.**

If the existing system is to be retained, there are two basic options: 1) **Adhered** or 2) **Ballasted Loose-Laid** or **Partially Attached. These two variations require distinctly different substrate conditions.** With the adhered option:

- o The existing system components must be very well attached to one another and to the structural deck.
- o The existing system components must be "dry".
- o The existing membrane must be relatively free of defects such as blisters, ridges and wrinkles.

With the ballasted loose-laid or partially attached option, the existing system does not have to be well attached, it does not have to be "dry", and membrane defects can be accommodated.

When conditions do not permit retaining the existing roof, tear-off is required. This will usually include removal of the insulation and perhaps the vapor retarder. The two basic options for use when the existing roofing remains are also applicable when tear-off occurs. If the adhered option is selected, deck preparation is critical.

Unless the project is in a dry portion of the State, a system that allows quick "dry-in" is desirable.

If ponding conditions occurred on the existing roof, the use of tapered insulation should be considered in the new design.

9.5.1 Adhered System

Examples of a new adhered system to an existing roof:

- o Modified Bitumen
- o Spray-Applied Polyurethane Foam Roof
- o Liquid Applied Membrane
- o Additional Plies of Felt and Bitumen

Of these, (as well as other possibilities), the modified bitumen is perhaps the best for application to an existing built-up membrane.

Due to the stringent substrate requirements, it will be rare that an adhered system will be suitable.

The adhered option may consist of only the membrane and flashing, or it may also include additional insulation.

9.5.2 Ballasted Loose-Laid Or Partially Attached

Examples of new system to an existing roof:

- o Loose-laid EPDM (Ballasted or Protected)
- o Partially Attached EPDM
- o Shingles or Tiles
- o Metal Panels

Additional insulation may be a part of the installation.

Since this system is divorced from the existing, some degree of water within the existing system is acceptable. Damp conditions may be acceptable (depending on deck type). However, saturated material should be removed.

Generally the existing membrane should be broom clean prior to application of new materials. Gross defects (such as very high blisters) may have to be removed in order for the new system to lay properly.

With EPDM, loose laying thin 4' x 8' sheets of tongue and groove insulation below the membrane will provide a good bed. Application of EPDM to existing roofing is specified in Section 5 "**MASTER SPECIFICATIONS**".

A Loose-Laid Protected EPDM Membrane roof is an extremely forgiving system when properly designed and installed. This system has many strong attributes that makes it favorable for reroofing.

9.5.3 Wet Insulation

As previously discussed, depending upon the system chosen, the existing insulation must be "dry" or "damp". If portions of the insulation are too damp or wet these areas may require removal.

If the new system is adhered, the new insulation must also be adhered. If the new system is loose, the new insulation may also usually be loose.

If large areas of insulation are replaced it may have to be attached to meet blow-off requirements as discussed in Section 3.5.2.

If the project is remote, it may be advisable to include a substantial amount of "fill-in" insulation as a part of the Contract. If it is needed, the cost of installation can be handled by Change Order. This will alleviate air freighting insulation. An example is given in Section 5 "**MASTER SPECIFICATIONS**" Section 07552.

9.6 FIELD OBSERVATIONS

9.6.1 Observations During Design

Observations during design were discussed in Section 3.7.1, 9.3.3 and 9.3.5. **On roofing and major roof repair projects, it is mandatory for the designer to conduct at least one field observation.**

There must be an adequate amount of field time, otherwise, the likelihood of a successful roofing project is jeopardize.

9.6.2 Observations During Construction

Observations during construction were discussed in Section 3.7.2 and 6.4. Generally reroofing and major roof repair projects should have more observations than roofs on new buildings.

During construction, particular attention by the Contractor and the Owner's observer should be given to protection of existing roofs that are to remain. The Contract Documents should have clearly set out what is required. Adherence to and enforcement of those provisions is necessary.

End of Section 9
REROOFING AND MAJOR ROOF REPAIR

Appendix 9.7.1 Follows

APPENDIX 9.7.1

FOOTNOTES AND BIBLIOGRAPHY

Footnotes

1. "BUR Failures Exaggerated", **The Roofing Spec**, July 1981, p. 35.

2. "Roofing Applications and Problems", **Building Operating Management**, October 1981, p. 64.

3. Personal experience of Thomas Lee Smith, between 1979-1986.

4. Personal experience of Thomas Lee Smith, regarding a project in Anchorage during 1984.

5. "The Partially Attached Single-Ply System", **1983 Handbook of Single-Ply Roofing Systems, RSI**, 1983, p. 51.

6. RIEI Seminar, Denver, 1983.

Bibliography

This section is primarily based upon the expertise of Thomas Lee Smith, AIA, CSI and "Reroofing and Retrofit" from the RIEI **Basic Roofing Technology** Couse Manual, September 1980.

10. GLOSSARY

NOTE

1. The **Manual of Built-Up Roof Systems** by C.W. Griffin (Second Edition, 1982) and **Roofs** by Maxwell C. Baker (1980) contain glossaries. These are similar to the RIEI and NRCA glossaries, but contain a few additional terms and slightly different definitions.

2. A Glossary also occurs at the beginning of Section 3 "**DESIGN CONSIDERATIONS AND CRITERIA**".

3. Items 10.4, 10.5, and 10.6 will be issued in the future.

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Glossary of Terms

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

Alligatoring — The cracking of the surfacing bitumen on a built-up roof, producing a pattern of cracks similar to an alligator's hide; the cracks may not extend through the surfacing bitumen.

Application rate — The quantity (mass, volume or thickness) of material applied per unit area.

Asbestos — A group of natural fibrous impure silicate materials.

Asphalt — A dark brown to black cementitious material in which the predominating constituents are bitumens which occur in nature or are obtained in petroleum processing.

Asphalt, air blown — An asphalt produced by blowing air through molten asphalt at an elevated temperature to raise its softening point and modify other properties.

Asphaltene — A high molecular weight hydrocarbon fraction precipitated from asphalt by a designated paraffinic naphtha solvent at a specified temperature and solvent-asphalt ratio.

NOTE — The asphaltene fraction should be identified by the temperature and solvent-asphalt ratio used.

Asphalt felt — An asphalt-saturated felt.

Asphalt, steam blown — An asphalt produced by blowing steam through molten asphalt to modify its properties.

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

Backnailing — The practice of blind-nailing roofing felts to a substrate in addition to hot-mopping to prevent slippage.

Bald roof — **See smooth-surfaced roof.**

Bitumen — *(1)* A class of amorphous, black or dark colored, (solid, semi-solid, 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 (1) heated to a liquid state, (2) dissolved in a solvent, or (3) emulsified.

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

Bituminous emulsion — *(1)* A suspension of minute globules of bituminous material in water or in an aqueous solution.

Blister — An enclosed pocket of air mixed with water vapor, trapped between impermeable layers of felt, etc.

Blueberry — See Strawberry

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

Brooming — Embedding a ply by using a broom to smooth it out and ensure contact with the adhesive under the ply.

Built-up roofing — 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).

Cant strip — A beveled strip used under flashings to modify the angle at the point where the roofing or waterproofing membrane meets any vertical element.

Cap flashing — **See Flashing**

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

Cationic emulsion — An emulsion in which the emulsifying system establishes a predominance of positive charges on the discontinuous phase.

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

Cavity wall — A wall built of masonry units arranged to provide a continuous air space within the wall (with or without insulating material) and in which the inner and outer wythes of the wall are tied together with metal ties or headers.

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

Coal tar felt — A felt that has been saturated with refined coal tar.

Coal tar pitch — A dark brown to black, solid cementitious material obtained as residue in the partial evaporation or distillation of coal tar.

Coated sheet (or felt) — *(1)* An asphalt felt that has been coated on both sides with harder, more viscous asphalt;

(2) A glass fiber felt that has been simultaneously impregnated and coated with asphalt on both sides.

Cold process roofing — A continuous, semiflexible membrane consisting of plies of felts, mats, or fabrics laminated on a roof with alternate layers of roof cement and surfaced with a cold applied coating.

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. $C = W/m^2 \cdot K (C = Btu/h \cdot ft^2 \cdot °F)$.

Conductivity, thermal — The thermal transmission, by conduction only, in unit time through unit area between two isothermal surfaces of an infinite slab of a homogeneous material of unit thickness, in a direction perpendicular to the surface, when unit temperature difference is established between the surfaces. $k = (W/m \cdot K (k = Btu/h \cdot ft^2 \cdot °F)$.

Coping — A covering on top of a wall exposed to the weather, usually sloped to carry off water.

Counterflashing — Formed metal or elastomeric sheeting secured on or into a wall, curb, pipe, roof-top unit, or other surface, to cover and protect 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.

Cutback — Solvent-thinned bitumen used in cold process roofing adhesives, flashing cements, and roof coatings.

Cutoff — A detail designed to prevent lateral water movement into the insulation where the membrane terminates at the end of a day's work, or used to isolate sections of the roofing system. It is usually removed before the continuation of the work.

Dampproofing — Treatment of a surface or structure to resist the passage of water in the absence of hydrostatic pressure.

Dead level — Absolutely horizontal, or zero slope (see also **slope**).

Dead level asphalt — A roofing asphalt conforming to the requirements of Specification D312, Type I.

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

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

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

Direction change — A change in the orientation of the principal dimension of the support of adjoining units of the roofing system.

Edge stripping — Application of felt strips cut to narrower widths than the normal felt roll width to cover a joint between flashing and built-up roofing.

Edge venting — The practice of providing regularly spaced protected openings at a roof perimeter to relieve water vapor pressure in the insulation.

Efflorescence — A deposit or encrustation of soluble salts, generally white and most commonly consisting of calcium sulface, that may form on the surface of stone, brick, concrete, or mortar when moisture moves through and evaporates on the masonry. Often caused by free alkalies leached from mortar, grout, or adjacent concrete.

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.

Envelope — A continuous edge seal formed by extending one ply of felt beyond the edge of the assembly. After other plies or insulation are in place, the extended ply is turned back and adhered.

Equilibrium moisture content — *(1)* The moisture content of a material stabilized at a given temperature and relative humidity, expressed as percent moisture by weight;

(2) The typical moisture content of a material in any given geographical area.

Expansion joint — A structural separation between two building elements that allows free movement between the elements without damage to the roofing or waterproofing system.

Exposure — *(1)* The transverse dimension of a roofing element not overlapped by an adjacent element in any roofing system. The exposure overlapped by an adjacent element in any roofing system. The exposure of any ply in a membrane may be computed by dividing the felt width minus 51 mm (2 in.), by the number of shingled plies; thus, the exposure of a 914 mm (36 in.) wide felt in a shingled, four ply membrane should be 216 mm (8½ in.);

(2) The time during which a portion of a roofing element is exposed to the weather.

Extra steep asphalt — See super steep asphalt.

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

Factory square — 10m² (108 ft²).

Fallback — A reduction in bitumen softening point, sometimes caused by refluxing or overheating in a relatively closed container. (See also **softening point drift).**

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), asbestos fibers (asbestos felts), or glass fibers (glass fiber felts).

Felt mill ream — The mass in pounds of 480 ft² of dry, unsaturated felt, also termed "point weight."

Fine mineral surfacing — Water insoluble inorganic material, more than 50% of which passes the 500 um (No. 35) sieve, used on the surface of roofing.

Fishmouth — *(1)* A half cylindrical or half conical opening formed by an edge wrinkle or failure to embed a roofing felt;

(2) In shingles, a half conical opening formed at a cut edge.

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.

Flashing cement — A trowelable mixture of cutback bitumen and mineral stabilizers including asbestos or other inorganic fibers.

Flat asphalt — A roofing asphalt conforming to the requriements of Specification D 312, Type II.

Flood coat — The top layer of bitumen used to hold the aggregate on an aggregate surfaced, built-up 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 normally do not incorporate reinforcement.

"Free carbon" in tars — The hydrocarbon fraction that is precipitated from a tar by dilution with carbon disulfide.

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

Glass mat — A thin mat of glass fibers with or without a binder.

Glaze coat — *(1)* The top layer of asphalt in a smooth surfaced built-up roof assembly;

(2) A thin protective coating of bitumen applied to the lower plies or top ply of a built-up membrane, when application of additional felts, or the flood coat and aggregate surfacing are delayed.

Granule — See Mineral Granules.

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

Gravel stop — A flanged device, frequently metallic, designed to prevent loose aggregate from washing off the roof and to provide a continuous finished edge for the roofing.

Headlap — The minimum distance, measured at 90 degrees to the eave along the face of a shingle or felt as applied to a roof, from the upper edge of the shingle or felt, to the nearest exposed surface.

Holiday — An area where a liquid applied material is missing.

"Hot stuff" or "hot" — A roofer's term for hot bitumen.

Hygroscopic — Attracting, absorbing, and retaining atmospheric moisture.

Incline — The slope of a roof expressed in percent or in the number of vertical units of rise per horizontal unit of run.

Inorganic, adj. — Being or composed of matter other than hydrocarbons and their derivatives, or matter that is not of plant or animal origin.

Insulation — See thermal insulation.

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

Mesh — The square opening of a sieve.

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

Mineral fiber felt — A felt with rock wool as the principle component.

Mineral granules — Opaque, natural, or synthetically colored aggregate commonly used to surface cap sheets, granule surfaced sheets, and roofing shingles.

Mineral stabilizer — A fine, water insoluble inorganic material, used in admixture with solid or semisolid bituminous materials.

Mineral surfaced roofing — Built-up roofing whose top ply consists of a granule surfaced sheet.

Mineral surfaced sheet — A felt that is coated on one or both sides with asphalt and surfaced with mineral granules.

Mole run — A meandering ridge in a membrane not associated with insulation or deck joints.

Mop-and-flop — A procedure in which roofing elements (insulation boards, felt plies, cap sheets, etc.) are initially placed upside down adjacent to their ultimate locations, are coated with adhesive, and are then turned over and adhered to the substrate.

Mopping — The application of hot bitumen with a mop or mechanical applicator to the substrate or to the plies of a built-up 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.

Mud cracking — Surface cracking resembling a dried mud flat.

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 — A synthetic rubber (polychloroprene) used in liquid or sheet applied elastomeric roofing membranes or flashing.

Nineteen-inch selvage — A prepared roofing sheet with a 432 mm (17 in.) granule surfaced exposure and a 483 mm (19 in.) selvage.

Ninety-pound — A prepared roll roofing with a granule surfaced exposure that has a mass of approximately 4400 g/m² (90 lb/108 ft²).

One-on-one — The application of a single ply of roofing over the substrate, followed by the application of a second single ply over the first (phased application).

Organic, adj. — Being or composed of hydrocarbons or their derivatives, or matter of plant or animal origin.

Parapet wall — That part of any wall entirely above the roof.

Penetration — The consistency of a bituminous material expressed as the distance in tenths of a millimetre (0.1 mm) that a standard needle penetrates vertically a sample of material under specified conditions of loading, time, and temperature. A cone is sometimes used for special purposes instead of a needle.

Perlite — An aggregate used in lightweight insulating concerete and in preformed perlite insulating board; formed by heating and expanding siliceous volcanic glass.

Permeance — The rate of water vapor transmission per unit area at a steady state through a membrane or assembly, expressed in ng/ Pa.s.m² (grain/ft².h.in. Hg).

Phase application — The installation of a roofing or waterproofing system during two or more separate time intervals; a roofing system not installed in a continuous operation.

Petroleum pitch — A dark brown to black, predominantly aromatic, solid cementitious material obtained by the processing of petroleum, petroleum fractions, or petroleum residuals.

Picture framing — A rectangular pattern of ridges in a membrane over insulation or deck joints.

Pinhole — A tiny hole in a film, foil, or laminate comparable in size to one made by a pin.

Pitch — **See incline; coal tar pitch; or petroleum pitch.**

Pitch pocket — A flanged, open bottomed metal container placed around a column or other roof penetration, and filled with hot bitumen or flashing cement to seal the joint.

Plastic cement — **See flashing cement.**

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

Plying cement — Any bituminous material used for adhering layers of felts, fabrics, or mats to structural surfaces and to each other.

Point weight — **See felt mill ream.**

Pointing — *(1)* Troweling mortar into a joint after masonry units are laid.

(2) Final treatment of joints in cut stonework. Mortar or a putty-like filler is forced into the joint after the stone is set.

Pond — A surface which is incompletely drained.

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

Raggle — Slot or groove cut in masonry to receive mortared-in flashing.

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

Raspberry — **See strawberry**

Reentrant corner — An inside corner of a surface, producing stress concentrations in the roofing or waterproofing membrane.

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

Reinforced membrane — A roofing or waterproofing membrane reinforced with felts, mats, fabrics, or chopped fibers.

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.

Resistance, thermal — The average temperature difference between two defined surfaces of a particular body or assembly when unit thermal transmission in unit time through unit area is established between the surfaces. $R = K.m^2/W$ ($R = °F.h.8ft^2/Btu$).

Ridging — An upward, tenting displacement of a membrane, frequently over an insulation joint.

Roll roofing — Coated felts, either smooth or mineral surfaced.

Roof cement — **See flashing cement.**

Roofing system — An assembly of interacting components designed to weatherproof, and normally to insulate, a building's top surface.

Rubber — A material that is capable of recovering from large deformations quickly and forcibly, and can be, or already is, modified to a state in which it is essentially insoluble (but can swell) in boiling solvent such as benzene, methyl ethyl ketone, and ethanoltoluene azeotrope.

Selvage — An edge or edging which differs from the main part of: (1) a fabric; or (2) granule surfaced roll roofing.

Shark fin — An upward curled felt sidelap or endlap.

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.

Sieve — An apparatus with square apertures for separating sizes of material.

Slippage — Relative lateral movement of adjacent components of a built-up membrane. It occurs mainly in roofing membranes on a slope, sometimes exposing the lower plies or even the base sheet to the weather.

Slope — The tangent of the angle between the roof surface and the horizontal plane, expressed as a percentage, or in inches of rise per foot of horizontal distance. (See also **incline**).

Smooth surfaced roof — A built-up roof without mineral aggregate surfacing.

Softening point — The temperature at which a bitumen becomes soft enough to flow as determined by an arbitrary, closely defined method.

Softening point drift — A change in the softening point during storage or application. (See also **fallback**).

Solid mopping — **See mopping.**

Split — A membrane tear resulting from tensile stress.

Split sheet — **See nineteen inch selvage.**

Spot mopping — **See mopping.**

Sprinkle mopping — **See mopping.**

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 in a built-up roofing system to relieve the pressure exerted by water vapor between the roofing membrane and the vapor retarder or deck.

Steep asphalt — A roofing asphalt conforming to the requriements of Specification D 312, Type III.

Strawberry — A small bubble or blister in the flood coating of a gravel surfaced membrane.

Stripping — Strip flashing:

(1) The technique of sealing a joint between metal and built-up membrane with one or two plies of felt or fabric and hot or cold applied bitumen.

(2) The technique of taping joints between insulation boards or deck panels.

Substrate — The surface upon which the roofing or waterproofing membrane is placed (structural deck or insulation)

Super steep asphalt — A roofing asphalt conforming to the requirements of Specification D 312, Type IV.

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

System — **See roofing system.**

Tapered edge strip — A tapered insulation strip used to elevate the roofing at the perimeter and at penetrations of the roof.

Tar — A brown or black bituminous material, liquid or semisolid in consistency, in which the predominating constituents are bitumens obtained as condensates in the processing of coal, petroleum, oil-shale, wood, or other organic materials.

Thermal insulation — A material applied to reduce the flow of heat.

Thermal shock — The stress producing phenomenon resulting from sudden temperature drops in a roof membrane when, for example, a rain shower follows brilliant sunshine.

Through wall flashing — A water resistant membrane or material assembly extending totally through a wall and its cavities, positioned to direct any water within the wall of the exterior.

Tuck pointing — The filling in with fresh mortar of cut-out or defective mortar joints in masonry.

Vapor migration — The movement of water vapor from a region of high vapor pressure to a region of lower vapor pressure.

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

Vermiculite — An aggregate used in lightweight insulating concrete, formed by heating and expanding a micaeous mineral.

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

Wythe — A masonry wall, one masonry unit, a minimum of two inches thick.

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Terminology Pertaining To Elastomeric and Plastomeric Material

Absorption — Ability of a porous solid material to hold within its body relatively large quantities of gases or liquid.

Acidity -- Quantitative capacity of aqueous solutions to react with hydroxyl ions. It is measured by titration with a standard solution of a base to a specified end point. Usually expressed as milligrams of calcium carbonate per litre.

Addition polymerization — Polymerization in which monomers are linked together without the splitting off of water or other simple molecules.

Adhesion — The state in which two surfaces are held together by interfacial forces which may consist of molecular forces or interlocking action or both. Measured in shear and peel modes. (B. F. Goodrich, 1979)

Adsorption — The adhesion of an extremely thin layer of molecules (of gases, or liquids) to the surface of solids or liquids with which they are in contact.

Aging — The effect on materials of exposure to an environment for an interval of time. The process of exposing materials to an environment for an interval of time.

Air lance — A device used to test, in the field, the integrity of field seams in plastic sheeting. It consists of a wand or tube through which compressed air is blown.

Aliphatic — See **hydrocarbons.**

Alkalinity — The capacity of water to neutralize acids, a property imparted by the water's content of carbonates, bicarbonates, hydroxides, and occasionally borates, silicates, and phosphates. It is expressed in milligrams of calcium carbonate equivalent per litre.

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.

Analysis — The determination of the nature or proportion of one or more constituents of a substance, whether separated out or not. (Webster's New World Dictionary)

Antioxidant — A substance which prevents or slows down oxidation of material exposed to air.

Aromatic — See **hydrocarbons.**

Ash — The incombustible material that remains after a substance has been burned.

Atactic -- A chain of molecules in which the position of the side methyl groups is more or less random. (Phillips Chemical)

Banbury mixer — A heavy-duty batch mixer with two counter rotating rotors. Used mainly in the rubber industry.

Block copolymer — An essentially linear copolymer in which there are repeated sequences of polymeric segments of different chemical structure.

Blocking -- Unintentional adhesion usually occurring during storage or shipping between plastic films or between a film and another surface.

Bloom -- A visible exudation or efflorescence on the surface of a material. (1972)

Blowing agent — A compounding ingredient used to produce gas by chemical or thermal action, or both, in manufacture of hollow or cellular articles.

Bodied solvent adhesive — An adhesive consisting of a solution of the membrane compound used in the seaming of membranes.

Boot — A bellows-type covering to exclude dust, dirt, moisture, etc., from a flexible joint. (B.F. Goodrich, 1979)

Breaking factor — Tensile at break in force per unit of width; units, SI: Newton per meter, customary: pound per inch.

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.

Calender — A precision machine equipped with three or more heavy internally heated or cooled rolls, revolving in opposite directions. Used for preparation of highly accurate continuous sheeting or plying up of rubber compounds and frictioning or coating of fabric with rubber or plastic compounds. (B.F. Goodrich, 1979)

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.

Coated fabric — Fabrics which have been impregnated and/or coated with a plastic material in the form of a solution, dispersion, hotmelt, or powder. The term also applies to materials resulting from the application of a preformed film to a fabric by means of calendering.

Cold flow — See **creep.**

Compound — An intimate admixture of a polymer(s) with all the materials necessary for the finished product. (1973)

Compression — The decrease in length produced in a test specimen during a creep test.

Compressive deformation — The decrease in length produced in the gage length of the test specimen by a compressive load. It is expressed in units of length. (ASTM D-1621)

Compressive strain — The ratio of compressive deformation to the gage length of the test specimen — that is, the change in length per unit of original length along the longitudinal axis. It is expressed as a dimensionless ratio.

Compressive strength — Procedure A — The stress at the yield point if a yield point occurs before 10% deformation (as in Fig. 1A). In the absence of such a yield point, it is the stress at 10% deformation (as in Fig. 1B).
Procedure B — The same as in Procedure A except substitute "2% strain" for "10% deformation." (ASTM D-1621)

Compressive stress — A diagram in which values of compressive stress are plotted as ordinates against corresponding values of compressive strain as abscissas. (ASTM D-1621)

Compressive stress (nominal) — The compressive load per unit area of minimum original cross section within the gage boundaries carried by the test specimen at any given moment. It is expressed in force per unit area. (ASTM D-1623)

Compressive yield point — The first point on the stress-strain diagram at which an increase in strain occurs without an increase in stress (ASTM D-1621)

Condensation polymerization — Polymerization in which monomers are linked together with the splitting off of water or other simple molecules.

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

Creep — The dimensional change with time of a material under load, following the initial instataneous elastic deformation. Creep at room temperature is sometimes called *cold flow.* (Phillips Chemical)

Creep modulus — The ratio of initial applied stress to creep strain.

Creep Strain — The total strain, at any given time, produced by the applied stress during a creep test. (Note) The term creep, as used in this method, reflects current plastics engineering usage. Plastics have a wide spectrum of retardation times and the elastic portions of strain cannot be separated in practice from nonelastic.

Crosslinking — A general term referring to the formation of chemical bonds between polymeric chains to yield an insoluble, three dimensional polymeric structure. Crosslinking of rubbers is vulcanization, qv.

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 crosslinking.) (ISO) (1973)

Curing — See **vulcanization**.

Deflection — Crosshead movement after the loading plates contact the specimen. It is expressed in millimeters or inches. (ASTM D-1621)

Deflection — The change in mid-span position of a test specimen during a creep test.

Degradation — A deleterious change in the chemical structure, physical properties, or appearance of a plastic. (1980)

Denier — A unit used in the textile industry to indicate the fineness of continuous filaments. Fineness in deniers equals the mass in grams of 9,000 meter length of the filament.

Dielectric seaming — See **heat seaming**.

Diffusion — The material permeation of two or more substances due to the kinetic activity of their molecules, so that a uniform mixture or solution results. Diffusion occurs with all forms of matter; it is more rapid for gases, somewhat slower for liquids and for solids in solution.

Elasticity — The property of matter by virtue of which it tends to return to its original size and shape after removal of the stress which caused the deformation. (B.F. Goodrich, 1979)

Elastomer — See **rubber**.

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.

Epichlorohydrin rubber — This synthetic rubber includes two epichlorohydrin-based elastomers which are saturated, high molecular weight, aliphatic polyethers with chloro-methyl side chains. The two types include a homopolymer (CO) and a copolymer of epichloro-hydrin and ethylene oxide (ECO). These rubbers are vulcanized with a variety of reagents that react difunctionally with the chloromethyl group; including diamines, urea, thioureas, 2-mercaptoimidazoline, and ammonium salts.

EVA — Family of copolymers of ethylene and Vinyl Acetate used for adhesives and thermo-plastic modifiers. They possess a wide range of melt indexes.

Extension — The increase in length produced in the gage length of a test specimen during a creep test.

Extractables — Components or substances removable from a solid or liquid mixture by means of an appropriate solvent.

Extruder — A machine with a driven strew that forces ductile or semi-soft solids through a die opening of appropriate shape to produce continuous film, strip, or tubing.

Fabric-reinforcement — A fabric, scrim, etc., used to add structural strength to a 2 or more ply polymeric sheet. Such sheeting is referred to as "supported."

Fill — As used in textile technology refers to the threads or yarns in a fabric running at right angles to the warp. Also called filler threads. (Rubber Manufacturers Assn., 1969)

Film — Sheeting having nominal thickness not greater than 10 mils.

Fleece — Term used to describe mats or felts of usually non-woven fibers.

Glass transition — The reversible change in an amorphous polymer or in amorphous regions of a partially crystalline polymer from (or to) a viscous or rubbery condition to (or from) a hard and relatively brittle one.

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.

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 (CH_4, ethylene, butadiene), liquid (hexene, benzene), or solid (natural rubber, napthalene, cis-polybutadiene).

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

Leno fabric — An open fabric in which two warp yarns wrap around each fill yarn in order to prevent the warp or fill yarns from sliding over each other.

Macromolecule — A large molecule in which there is a large numbe of one or several relatively simple structural units, each consisting of several atoms bonded together.

Membrane — In this Manual, the term membrane applies to a continuous sheet of material whether it is prefabricated as a flexible polymeric sheeting or is sprayed or coated in the field.

Mer — The repeating structural unit of any high polymer.

Modulus of elasticity — The ratio of stress (nominal) to corresponding strain below the proportional limit of a material. It is expressed in force per unit area based on the minimum initial cross-sectional area.

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

Neoprene (Polychloroprene) — Generic name for a synthetic rubber based primarily on chloroprene, i.e. chloro-butadiene. Vulcanized generally with metal oxide. Resistant to ozone and aging and to some oils.

Nitrile rubber — A family of copolymers of butadiene and acrylonitrile that can be vulcanized into tough oil resistant compounds. Blends with PVC are used where ozone and weathering are important requirements in addition to its inherent oil and fuel resistance.

Nylon — Generic name for a family of polyamide polymers characterized by the presence of the amide group -CONH. Used as a scrim in fabric reinforced sheeting. (Con. Chem. Dict., 1977)

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 mass %. (1973)

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.

Osmosis — The diffusion of fluids through a semi-permeable membrane or porous partition.

Permeability — *(1)* The capacity of a porous medium to conduct or transmit fluids. (ASCE, 1976)

(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. (Wren, 1971)

(3) The product of vapor permeance and thickness (for thin films, ASTM E96; over ⅛", ASTM C355). Usually reported in perm-inches or grain/h.ft^2 in Hg per inch of thickness.

pH — *(1)* The negative log of the hydrogen ion concentration, a measure of acidity and alkalinity.

(2) A measure of the relative acidity of alkalinity for water. A pH of 7.0 indicates a neutral condition. A greater pH indicates alkalinity and a lower pH, acidity. A one unit change in pH indicates a tenfold change in acidity and alkalinity.

Plastic — A material that contains as an essential ingredient one or more organic polymeric substances of large molecular weight, is solid in its finished state and at some stage in its manufacture or processing into finished articles, can be shaped by flow. (ASTM D883)

Plasticizer — A plasticizer is a material, frequently "solvent-like", incorporated in a plastic or a rubber to increase its ease of workability, its 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 (E/VA). The most important use of plasticizers is with PVC where the choice of plasticizer will dictate under what conditions the membrane may be used.

Plastisols — Mixtures of resins and plasticizers which can be cast or converted to continuous films by the application of heat.

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. It varies in consistency from a viscous liquid to a rubber-like solid with corresponding variation in molecular weight from 1,000 to 400,000. (Phillips Chemical)

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.

Polymeric liner — Plastic or rubber sheeting used to line disposal sites, pits, ponds, lagoons, canals, etc.

Polypropylene — A tough, lightweight rigid plastic made by the polymerization of high-purity propylene gas.

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.

Proportional limit — The greatest stress which a material is capable of sustaining without any deviation from proportionality of stress to strain (Hooke's law). It is expressed in force per unit area. (ASTM D-1621).

Puncture resistance — Extent to which a material is able to withstand the action of a sharp object without perforation.

Reinforcement — A strong inert material bound into a plastic to improve its strength, stiffness, and impact resistance. Reinforcements are usually long fibers of glass, sisal, cotton, etc. — in woven or nonwoven form. To be effective, the reinforcing material must form a strong adhesive bond with the resin.

Roll goods — A general term applied to rubber and plastic sheeting whether fabric reinforced or not. It is usually furnished in rolls.

Rubber — A polymeric material which, at room temperature, is capable of recovering substantially in shape and size after removal of a deforming force. Refers to both synthetic and natural rubber. Also called an elastomer.

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

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

Sheeting — A form of plastic or rubber in which the thickness is very small in proportion to length and width and in which the polymer compound is present as a continuous phase throughout, with or without fabric.

Solubility — The amount of a substance that can be dissolved in a given solvent under specified conditions.

Stress — 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 applied load to the initial cross-sectional area, or the maximum stress in the outer fibers due to an applied flexural load. (ASTM D-2990)

Stress Concentration — A condition in which a stress distribution has high localized stresses; usually induced by an abrupt change in the shape of a member.

Stress relaxation — The time-dependent change in the stress which results from the application of a constant total strain to a specimen at a constant temperature. The stress-relaxation at a given elapsed time is equal to the maximum stress resulting when the strain is applied minus the stress at the given time. (ASTM D-2991)

Strikethrough — A term used in the manufacture of fabric-reinforced polymeric sheeting to indicate that two layers of polymer have made bonding contact through the scrim.

Supported sheeting — See **fabric-reinforcement.**

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

Tear strength — The maximum force required to tear a specified specimen, the force acting substantially parallel to the major axis of the test specimen. Measured in both initiated and uninitiated modes. Obtained value is dependent on specimen geometry, rate of extension, and type of fabric reinforcement. Values are reported in stress, e.g. pounds, or stress per unit of thickness, e.g. pounds per inch.

Tensile strength — 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 — pound per square inch.

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

Thermoplastic — Capable of being repeatedly softened by increase of temperature and hardened by decrease in temperature. The thermoplastic form allows for easier seaming both in the factory and on the field.

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

Thermoplastic resin — A material with a linear macromolecular structure that will repeatedly soften when heated and harden when cooled.

Thread count — The number of threads per inch in each direction with the warp mentioned first and the fill second, e.g. a thread count of 20 x 10 means 20 threads per inch in the warp and 10 threads per inch in the fill direction.

Ultimate elongation — The elongation of a stretched specimen at the time of break. Usually reported as percent of the original length. Also called elongation at break.

Unsupported sheeting — A polymer sheeting one or more plies thick without a reinforcing fabric layer or scrim.

Vulcanizate — A term used to denote the product of the vulcanization of a rubber compound without reference to shape or form.

Vulcanization — An irreversible process during which a rubber compound, through a change in its chemical structure, e.g. crosslinking, becomes less plastic and more resistant to swelling by organic liquids, and elastic properties are conferred, improved, or extended over a greater range of temperature. (ASTM D-883)

Warp — In textiles,the lengthwise yarns in a woven fabric. (Rubber Manufacturers Assn., 1969)

Water vapor transmission - (WVT) — Water vapor flow normal to two parallel surfaces of a material, through a unit area, under the conditions of a specified test such as ASTM E96. Customary units are grains/h.ft^2.

Weatherometer — An instrument which is used to subject specimens to accelerated weathering condition, e.g. rich U.V. source and water spray.

For more complete lists of definitions, see:

ASTM D883 Standard Definitions of Terms Relating to Plastics

C1566 Standard Definitions of Terms Relating to Elastomers

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GLOSSARY

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

Alligatoring: the cracking of the surfacing bitumen on a built-up roof, producing a pattern of cracks similar to an alligator's hide; the cracks may or may not extend through the surfacing bitumen.

Application Rate: the quantity (mass, volume or thickness) of material applied per unit area.

Area Divider: a raised, double wood member attached to a properly flashed wood base plate that is anchored to the roof deck. It is used to relieve the stresses of thermal expansion and contraction in a roof system where no expansion joints have been provided. (See NRCA Construction Detail D-1.)

Asbestos: a group of natural, fibrous, impure silicate materials.

Asphalt: a dark brown to black cementitious material in which the predominating constituents are bitumens, which occur in nature or are obtained in petroleum processing.

Asphalt, Air Blown: an asphalt produced by blowing air through molten asphalt at an elevated temperature to raise its softening point and modify other properties.

Asphalt Felt: an asphalt-saturated felt or an asphalt-coated felt.

Asphalt Mastic: a mixture of asphaltic material and graded mineral aggregate that can be poured when heated but requires mechanical manipulation to apply when cool.

Asphalt, Steam Blown: an asphalt produced by blowing steam through molten asphalt to modify its properties, normally used for highway bitumen.

Backnailing: the practice of blind nailing (in addition to hot-mopping) all the plies of a substrate to prevent slippage. (See BLIND NAILING.)

Base Flashing: see FLASHING.

Base Ply: the first ply of roofing material in a roof membrane assembly.

Base Sheet: a saturated or coated felt placed as the first ply in some multi-ply, built-up roof membranes.

Bitumen: the generic term for an amorphous, semi-solid mixture of complex hydrocarbons derived from any organic source. Asphalt and coal tar are the two bitumens used in the roofing industry.

Bituminous: containing or treated with bitumen. Examples: bituminous concrete, bituminous felts and fabrics, bituminous pavement.

Bituminous Emulsion: (1) a suspension of minute globules of bituminous material in water or in an aqueous solution; (2) a suspension of minute globules of water or an aqueous solution in a liquid bituminous material (invert emulsion).

Bituminous Grout: a mixture of bituminous material and fine sand that will flow into place without mechanical manipulation when heated.

Blind Nailing: the practice of nailing the back portion of a roofing ply.

Blister: a spongy raised portion of a roof membrane, ranging in area from 1 inch in diameter and of barely detectable height upwards. Blisters result from the pressure buildup of gases entrapped in the membrane system. These gases most commonly are air and/or water vapor. Blisters usually involve delamination of the underlying membrane plies.

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

Brooming: embedding a ply of roofing material by using a broom to smooth out the ply and ensure contact with the adhesive under the ply.

BTU: (British Thermal Unit)—The heat energy required to raise the temperature of 1 pound of water 1 degree Fahrenheit.

Built-Up Roof Membrane: a continuous, semi-flexible roof membrane assembly, consisting of plies of saturated felts, coated felts, fabrics or mats between which alternate layers of bitumen are applied, generally surfaced with mineral aggregate, bituminous materials, or a granule surfaced roofing sheet. (Abbreviation: BUR.)

Cant Strip: a bevelled shaped strip of wood or wood fiber that fits into the angle formed by the intersection of a horizontal surface and a vertical surface. The 45° slope of the exposed surface of the cant strip provides a gradual angular transition from the horizontal surface to the vertical surface.

Cap Flashing: see FLASHING.

Capillarity: the action by which the surface of a liquid (where it is in contact with a solid) is elevated or depressed, depending upon the relative attraction of the molecules of the liquid for each other and for those of the solid.

Cap Sheet: a granule-surfaced coated sheet used as the top ply of a built-up roof membrane or flashing.

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

Coal Tar Bitumen: a dark brown to black, semi-solid hydrocarbon formed as a residue from the partial evaporation or distillation of coal tar. It is used as the waterproofing agent in dead-level or low-slope built-up roofs. It differs from COAL TAR PITCH in having a lower front-end volatility. (For specification properties, see ASTM Standard D 450, Type III.)

Coal Tar Felt: See TARRED FELT.

Coal Tar Pitch: a dark brown to black, semi-solid hydrocarbon formed as a residue from the partial evaporation or distillation of coal tar. It is used as the waterproofing agent in dead-level or low-slope built-up roofs. (For specification properties, see ASTM Standard D 450, Types I and II.)

Coated Base Sheet (or Felt): a felt that has been impregnated and saturated with asphalt and then coated on both sides with harder, more viscous asphalt to increase its impermeability to moisture; a parting agent is incorporated to prevent the material from sticking in the roll.

Cold-Process Roofing: a continuous, semi-flexible roof membrane, consisting of plies of felts, mats, or fabrics that are laminated on a roof with alternate layers of cold-applied roof cement and surfaced with a cold-applied coating.

Condensation: the conversion of water vapor or other gas to liquid as the temperature drops or the atmospheric pressure rises. (See DEW-POINT.)

Coping: the covering piece placed on top of a wall that is exposed to the weather. It is usually sloped to shed water.

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

Course: (1) the term used for each application of material that forms the waterproofing system or the flashing; (2) one layer of a series of materials applied to a surface (i.e., a five course wall flashing is composed of three applications of mastic with one ply of felt sandwiched between each layer of mastic).

Coverage: the surface area (in square feet) to be continuously coated by a specific roofing material, with allowance made for a specific lap.

Crack: a separation or fracture occurring in a roof membrane or roof deck, generally caused by thermally induced stress or substrate movement.

Creep: the permanent deformation of a roofing material or roof system caused by the movement of the roof membrane that results from continuous thermal stress or loading.

Cricket: a superimposed construction placed in a roof area to assist drainage. (See NRCA Construction Detail **P**.)

Cutback: any bituminous roofing material that has been solvent thinned. Cutbacks are used in cold-process roofing adhesives, flashing cements, and roof coatings.

Cutoff: a material seal that is designed to prevent lateral water movement into the edge of a roof system where the membrane terminates at the end of a day's work or used to isolate sections of the roof system. Cutoffs are usually removed before the continuation of work.

Dampproofing: treatment of a surface or structure to resist the passage of water in the absence of hydrostatic pressure.

Dead Level: the term used to describe an absolutely horizontal roof. Zero slope. (See SLOPE.)

Dead Level Asphalt: a roofing asphalt that has a softening point of 140°F (60°C) and that conforms to the requirements of ASTM Standard D 312, Type I.

Dead Loads: non-moving rooftop loads, such as mechanical equipment, air conditioning units, and the roof deck itself.

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

Delamination: separation of the plies in a roof membrane system or separation of laminated layers of insulation.

Dew-Point: the temperature at which water vapor starts to condense in cooling air at the existing atmospheric pressure and vapor content.

Drain: a device that allows for the flow of water from a roof area. (See NRCA Construction Detail **W-2**.)

Dropback: a reduction in the softening point of bitumen that occurs when bitumen is heated in the absence of air. (See SOFTENING POINT DRIFT.)

Edge Sheets: felt strips that are cut to widths narrower than the standard width of the full felt roll. They are used to start the felt-shingling pattern at a roof edge.

Edge Stripping: application of felt strips cut to narrower widths than the normal width of the full felt roll. They are used to cover joints.

Edge Venting: the practice of providing regularly spaced protected openings along a roof perimeter to relieve moisture vapor pressure.

Elastomer: a macromolecular material that returns rapidly to its approximate initial dimensions and shape after substantial deformation by a weak stress and the subsequent release of that stress.

Elastomeric: the term used to describe the elastic, rubber-like properties of a material.

Embedment: (1) the process of pressing a felt, aggregate, fabric, mat, or panel uniformly and completely into hot bitumen or adhesive; (2) the process of placing a material into another material so that it becomes an integral part of the whole material.

Emulsion: the intimate dispersion of an organic material and water achieved by using a chemical or clay emulsifying agent.

Envelope: a continuous felt fold formed by wrapping and securing a portion of a base felt back up and over the felt plies above it. Envelopes help prevent the seepage of bitumen.

Equilibrium Moisture Content: (1) the moisture content of a material stabilized at a given temperature and relative humidity, expressed as percent moisture by weight; (2) the typical moisture content of a material in any given geographical area.

Expansion Joint: a structural separation between two building elements designed to minimize the effect of the stresses and movements of a building's components and to prevent these stresses from splitting or ridging the roof membrane. (See NRCA Construction Detail **C-1**.)

Exposure: (1) the transverse dimension of a roofing element not overlapped by an adjacent element in any roof system. The exposure of any ply in a membrane may be computed by dividing the felt width minus 2 inches by the number of shingled plies; thus, the exposure of a 36 inch wide felt in a shingled, four-ply membrane should be 8-1/2 inches; (2) the time during which a portion of a roofing element is exposed to the weather.

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

Factory Mutual (FM): an organization which classifies roof assemblies for their fire characteristics and wind-uplift resistance for insurance companies in the United States.

Factory Square: 108 square feet (10 square meters) of roofing material.

Felt: a fabric manufactured from vegetable fibers (organic felts), asbestos fibers (asbestos felts), or glass fibers (glass fiber felts). The manufacturing process involves mechanically interlocking the fibers of the particular felt material in the presence of moisture and heat.

Felt Mill Ream: the mass in pounds of 480 square feet of dry, unsaturated felt; also termed "point weight."

Fine Mineral Surfacing: a water-insoluble, inorganic material, more than 50% of which passes through the No. 35 sieve, that may be used on the surface of roofing material.

Fishmouth: (1) a half-cylindrical or half-conical opening formed by an edge wrinkle; (2) in shingles, a half-conical opening formed at a cut edge.

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

Flashing Cement: a trowelable mixture of cutback bitumen and mineral stabilizers, including asbestos or other inorganic fibers.

Flat Asphalt: a roofing asphalt that has a softening point of approximately 170°F (77°C) and that conforms to the requirements of ASTM Standard D 312, Type II.

Flood Coat: the top layer of bitumen into which the aggregate is embedded on an aggregate surfaced built-up roof.

Fluid Applied Elastomer: an elastomeric material, which is fluid at ambient temperature, that dries or cures after application to form a continuous membrane.

Glass Fiber Felt: a felt sheet in which glass fibers are bonded into the felt sheet with resin. They are suitable for impregnation and coating. They are used in the manufacture and coating of bituminous waterproofing materials, roof membranes, and shingles.

Glass Fiber Mat: a thin mat composed of glass fibers with or without a binder.

Glaze Coat:	(1) the top layer of asphalt in a smooth-surface built-up roof assembly; (2) a thin protective coating of bitumen applied to the lower plies or top ply of a built-up roof membrane when application of additional felts or the flood coat and aggregate surfacing are delayed.
Grain:	the weight unit equal to 1/7000 lb.; used in measuring atmospheric moisture content.
Gravel:	coarse, granular aggregate, containing pieces approximately 5/8 inch to 1/2 inch in size and suitable for use in aggregate surfacing on built-up roofs.
Gravel Stop:	a flanged device, frequently metallic, designed to provide a continuous finished edge for roofing materials and to prevent loose aggregate from washing off of the roof.
Headlap:	the minimum distance, measured at 90 degrees to the eaves along the face of a shingle or felt, from the upper edge of the shingle or felt to the nearest exposed surface.
Holiday:	an area where a liquid-applied material is missing.
"Hot Stuff" or "Hot":	the roofer's term for hot bitumen.
Hygroscopic:	the term used to describe a material which attracts, absorbs and retains atmospheric moisture.
Incline:	the slope of a roof expressed either in percent or in the number of vertical units of rise per horizontal unit of run.
Inorganic:	being or composed of matter other than hydrocarbons and their derivatives, or matter that is not of plant or animal origin.
Insulation:	a material applied to reduce the flow of heat.
Knot:	an imperfection or nonhomogeneity in materials used in fabric construction, the presence of which causes surface irregularities.
Live Loads:	moving roof installation equipment, wind, snow, ice or rain.
Manufacturer's Bond:	a security company's guarantee that it will stand behind a manufacturer's liability to finance membrane repairs occasioned by ordinary wear within a period generally limited to 5, 10, 15, or 20 years.
Mastic:	see FLASHING CEMENT or ASPHALT MASTIC.
Membrane:	a flexible or semi-flexible roof covering or waterproofing layer, whose primary function is the exclusion of water.
Mesh:	the square or circular opening of a sieve.
Metal Flashing:	see FLASHING; metal flashing is frequently used as through-wall flashing, cap flashing, counterflashing or gravel stops.
Mineral Fiber Felt:	a felt with mineral wool as its principal component.
Mineral Granules:	opaque, natural, or synthetically colored aggregate commonly used to surface cap sheets, granule-surfaced sheets, and roofing shingles.
Mineral Stabilizer:	a fine, water-insoluble inorganic material, used in a mixture with solid or semi-solid bituminous materials.
Mineral-Surfaced Roofing:	built-up roofing materials whose top ply consists of a granule-surfaced sheet.
Mineral-Surfaced Sheet:	a felt that is coated on one or both sides with asphalt and surfaced with mineral granules.

Mole Run: a meandering ridge in a roof membrane not associated with insulation or deck joints.

Mop-and-Flop: an application procedure in which roofing elements (insulation boards, felt plies, cap sheets, etc.) are initially placed upside down adjacent to their ultimate locations, are coated with adhesive, and are then turned over and applied to the substrate.

Mopping: an application of hot bitumen applied to the substrate or to the felts of a built-up roof membrane with a mop or mechanical applicator.

- **Solid Mopping:** a continuous mopping of a surface, leaving no unmopped areas.
- **Spot Mopping:** a mopping pattern in which hot bitumen is applied in roughly circular areas, leaving a grid of unmopped, perpendicular bands on the roof.
- **Sprinkle Mopping:** a random mopping pattern wherein heated bitumen beads are strewn onto the substrate with a brush or mop.
- **Strip Mopping:** a mopping pattern in which hot bitumen is applied in parallel bands.

Nailing: (1) in the **Exposed Nail Method,** nail heads are exposed to the weather; (2) in the **Concealed Nail Method,** nail heads are concealed from the weather. (See also BLIND NAILING.)

Neoprene: a synthetic rubber (polychloroprene) used in liquid-applied and sheet-applied elastomeric roof membranes or flashings.

Nineteen-Inch Selvage: a prepared roofing sheet with a 17 inch granule-surfaced exposure and a nongranule-surfaced 19 inch selvage edge. This material is sometimes referred to as SIS or as Wide-Selvage Asphalt Roll Roofing Material Surfaced with Mineral Granules.

Organic: being or composed of hydrocarbons or their derivatives, or matter of plant or animal origin.

Perlite: an aggregate used in lightweight insulating concrete and in preformed perlitic insulation boards, formed by heating and expanding siliceous volcanic glass.

Perm: a unit of water vapor transmission defined as 1 grain of water vapor per square foot per hour per inch of mercury pressure difference (1 inch of mercury = 0.491 psi). The formula for perm is:

P = GRAINS OF WATER VAPOR/SQUARE FOOT•HOUR•INCH MERCURY

Permeance: an index of a material's resistance to water vapor transmission. (See PERM.)

Phased Application: the installation of a roof system or waterproofing system during two or more separate time intervals.

Picture Framing: a rectangular pattern of ridges in a roof membrane over insulation or deck joints.

Pitch Pocket: a flanged, open-bottomed, metal container placed around columns or other roof penetrations that is filled with hot bitumen and/or flashing cement to seal the joint. The use of pitch pockets is not recommended by NRCA.

Plastic Cement: see FLASHING CEMENT

Ply: a layer of felt in a built-up roof membrane system. A four-ply membrane system has four plies of felt. The dimension of the exposed surface (the "exposure") of any ply may be computed by dividing the felt width (minus 2 inches) by the number of plies; thus, the exposed surface of a 36 inch wide felt in a four-ply membrane should be 8-1/2 inches. (See EXPOSURE.)

Point Weight: see FELT MILL REAM.

Pond: a roof surface which is incompletely drained.

Positive Drainage: the drainage condition in which consideration has been made for all loading deflections of the deck, and additional roof slope has been provided to ensure complete drainage of the roof area within 24 hours of rainfall precipitation.

Primer: a thin, liquid bitumen applied to a surface to improve the adhesion of subsequent applications of bitumen.

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

Re-entrant Corner: an inside corner of a surface, producing stress concentrations in the roofing or waterproofing membrane.

Reglet: a groove in a wall or other surface adjoining a roof surface for use in the attachment of counterflashing.

Reinforced Membrane: a roofing or waterproofing membrane reinforced with felts, mats, fabrics, or chopped fibers.

Relative Humidity: the ratio of the weight of moisture in a given volume of air-vapor mixture to the saturated (maximum) weight of water vapor at the same temperature, expressed as a percentage. For example, if the weight of the moist air is 1 pound and if the air could hold 2 pounds of water vapor at a given temperature, the relative humidity (RH) is 50%.

Reroofing: the practice of applying new roofing materials over existing roofing materials.

Ridging: an upward, "tenting" displacement of a roof membrane, frequently occurring over insulation joints, deck joints and base sheet edges.

Roll Roofing: the term applied to smooth-surface or mineral-surfaced coated felts.

Roof Assembly: an assembly of interacting roof components (including the roof deck) designed to weatherproof and, normally, to insulate a building's top surface.

Roofer: the trade name for the workman who applies roofing materials.

Roof System: a system of interacting roof components (**NOT** including the roof deck) designed to weatherproof and, normally, to insulate a building's top surface.

Saturated Felt: a felt that has been partially saturated with low softening point bitumen.

Screen: an apparatus with apertures for separating sizes of material.

Seal: (1) a narrow closure strip made of bituminous materials; (2) to secure a roof from the entry of moisture.

Sealant: a mixture of polymers, fillers, and pigments used to fill and seal joints where moderate movement is expected; it cures to a resilient solid.

Selvage: an edge or edging which differs from the main part of (1) a fabric, or (2) granule-surfaced roll roofing material.

Selvage Joint: a lapped joint designed for mineral-surfaced cap sheets. The mineral surfacing is omitted over a small portion of the longitudinal edge of the sheet below in order to obtain better adhesion of the lapped cap sheet surface with the bituminous adhesive.

Shark Fin: an upward-curled felt side lap or end lap.

Shingle: (1) a small unit of prepared roofing material designed to be installed with similar units in overlapping rows on inclines normally exceeding 25%; (2) to cover with shingles; (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 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.

Sieve: an apparatus with apertures for separating sizes of material.

Slag: a hard, air cooled aggregate that is left as a residue from blast furnaces. It is used as a surfacing aggregate and should be surface dry and free of sand, clay, or other foreign substances at the time of application.

Slippage: the relative lateral movement of adjacent components of a built-up roof membrane. It occurs mainly in roof membranes on a slope, sometimes exposing the lower plies to the weather.

Slope: the tangent of the angle between the roof surface and the horizontal. It is measured in inches per foot. The Asphalt Roofing Manufacturers Association (ARMA) ranks slope as follows:

Level Slope .... **up to 1/2 inch per foot.**
Low Slope .... **1/2 inch per foot to 1-1/2 inches per foot.**
Steep Slope .... **over 1-1/2 inches per foot.**

Smooth-Surface Roof: a built-up roof membrane surfaced with a layer of hot-mopped asphalt, cold-applied asphalt-clay emulsion, cold-applied asphalt cutback, or sometimes with an unmopped inorganic felt.

Softening Point: the temperature at which bitumen becomes soft enough to flow. The softening point of asphalt is measured by the "ring-and-ball" test (ASTM Standard D 2398). The softening point of coal tar pitch is measured by the "cube-in-water" test (ASTM Standard D 61).

Softening Point Drift: a change in the softening point of bitumen during storage or application. (See DROPBACK.)

Solid Mopping: see MOPPING.

Special Steep Asphalt: a roofing asphalt that has a softening point of approximately 220°F (104°C) and that conforms to the requirements of ASTM Standard D 312, Type IV.

Split: a separation in roofing material resulting from movement of the substrate. (See CRACK.)

Split Sheet: see NINETEEN-INCH SELVAGE.

Spot Mopping: see MOPPING.

Sprinkle Mopping: see MOPPING.

Square: the term used to describe 100 square feet of roof area.

Stack Vent: a vertical outlet in a built-up roof system designed to relieve any pressure exerted by moisture vapor between the roof membrane and the vapor retarder or deck.

Steep Asphalt: a roofing asphalt that has a softening point of approximately 190°F (88°C) and that conforms to the requirements of ASTM Standard D 312, Type III.

Strawberry: a small bubble or blister in the flood coating of a gravel-surfaced roof membrane.

Strip Mopping: see MOPPING.

Stripping or Strip Flashing: (1) the technique of sealing a joint between metal and the built-up roof membrane with one or two plies of felt and hot-applied or cold-applied bitumen; (2) the technique of taping joints between insulation boards on deck panels.

Substrate: the surface upon which the roofing or waterproofing membrane is applied (i.e., the structural deck or insulation).

Superimposed Loads: loads that are added to existing loads. For example, a large stack of insulation boards placed on top of a structural steel deck.

Tapered Edge Strip: a tapered insulation strip used to (1) elevate the roof at the perimeter and at curbs that extend through the roof; (2) provide a gradual transition from one layer of insulation to another.

Taping: see STRIPPING.

Tar: a brown or black bituminous material, liquid or semi-solid in consistency, in which the predominating constituents are bitumens obtained as condensates in the processing of coal, petroleum, oil-shale, wood, or other organic materials.

Tarred Felt: a felt that has been saturated with refined coal tar.

Test Cut: a sample of the roof membrane, usually 4 inches × 40 inches in size, that is cut from a roof membrane to:

- Determine the weight of the average interply bitumen poundages
- Diagnose the condition of the existing membrane (e.g., to detect leaks or blisters).

NRCA recommends that the test cut procedure **NOT** be used as a means of determining the quality of a roof system.

Thermal Conductance (C): a unit of heat flow that is used for specific thicknesses of material or for materials of combination construction, such as laminated insulation. The formula for thermal conductance is:

$$C = \frac{k}{\text{thickness in inches}}$$

Thermal Conductivity (k): the heat energy that will be transmitted by conduction through one square foot of one inch thick homogeneous material in one hour when there is a difference of 1 degree Fahrenheit perpendicularly across the two surfaces of the material. The formula for thermal conductivity is:

$$k = \text{BTU/SQUARE FOOT/INCH/HOUR/DEGREE FAHRENHEIT}$$

Thermal Insulation: a material applied to reduce the flow of heat.

Thermal Resistance (R): an index of a material's resistance to heat flow; it is the reciprocal of thermal conductivity (k) or thermal conductance (C). The formula for thermal resistance is:

$$R=\frac{1}{C} \text{ or } R=\frac{1}{k} \text{ or } R=\frac{\text{thickness in inches}}{k}$$

Thermal Shock: the stress-producing phenomenon resulting from sudden temperature changes in a roof membrane. (For example, when a rain shower follows brilliant sunshine.)

Through-Wall Flashing: a water-resistant membrane or material assembly extending through a wall and its cavities, positioned to direct any water entering the top of the wall to the exterior.

Underwriters Laboratories (UL): an organization which classifies roof assemblies for their fire characteristics and wind-uplift resistance for insurance companies in the United States.

Vapor Migration: the movement of water vapor from a region of high vapor pressure to a region of lower vapor pressure.

Vapor-Pressure Gradient: a graph, analogous to a temperature gradient, indicating the changes in water vapor pressure at various cross-sectional planes through a roof or wall system.

Vapor Retarder: a material designed to restrict the passage of water vapor through a wall or roof. In the roofing industry, a vapor retarder should have a perm rating of 0.5 or less.

Vent: an opening designed to convey water vapor or other gas from inside a building or a building component to the atmosphere, thereby relieving vapor pressure.

Vermiculite: an aggregate used in lightweight insulating concrete, formed by the heating and consequent expansion of a micaceous mineral.

Water Cutoff: see CUTOFFS.

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