

APPENDIX A  
REFERENCES

GOVERNMENT PUBLICATIONS

Department of the Army

TM 5-805-14	Roofing and Waterproofing
TM 5-617	Inspection, Maintenance and Repair of Roofing Systems
TI 809-01	Load Assumptions for Buildings
TI 809-52	Commentary on Snow Loads
TI 809-29	Structural Considerations for Metal Roofing
TI 809-30	Metal Building Systems
CEGS 02226	Removal and Salvage of Historic Building Materials
CEGS 03300	Cast-In-Place Structural Concrete
CEGS 03410	Precast/Prestressed Concrete Floor and Roof Units
CEGS 03414	Precast Roof Decking
CEGS 03510	Roof Decking, Cast-in-Place Lightweight Concrete
CEGS 03511	Gypsum Plank Decking
CEGS 03340	Precast/Prestressed Concrete Floor and Roof Units
CEGS 05300	Steel Decking
CEGS 06100	Rough Carpentry
CEGS 07220	Roof Insulation
CEGS 07310	Slate Roofing
CEGS 07311	Roofing, Strip Shingles
CEGS 07320	Clay Tile Roofing
CEGS 07412	Non-Structural Metal Roofing

CEGS 07416	Structural Standing Seam Metal Roof (SSSMR) System
CEGS 07510	Built-up Roofing
CEGS 07530	Elastomeric Roofing (EPDM)
CEGS 07548	Polyvinyl Chloride (PVC) Roofing
CEGS 07550 CEGS 07551	Protected Membrane Roofing (PMR) Modified Bitumen Roofing
CEGS 07571	Sprayed Polyurethane Foam (SPF) Roofing
CEGS 07610	Copper Roof System
CEGS 07650	Copper Sheet Metal Flashing
MILHDBK 1008C	Fire Protection for Facility for Engineering Design and Construction

Cold Regions Research & Engineering Laboratory (CRREL)  
72 Lyme Rd., Hanover NH 03755  
(Order Publications from NTIS—[www.dtic.mil/stinet](http://www.dtic.mil/stinet))

MP 1498	(1981) Venting of Built-Up Roofs
MP 2489	(1989) Vapor Retarders for Membrane Roofing Systems
MP 3443	(1994) General Considerations for Roofs
MP 3527	(1994) Ventilating Attics to Minimize Icings at Eaves
MP 3858)	(1996) Snow Guards for Metal Roofs
MP (In Prep)	(1998) Roof Ventilation to Prevent Problematic Icings at Eaves

Construction Engineering Research Laboratories (CERL)  
5285 Port Royal Rd  
Springfield, VA 22161  
(Order Publications from NTIS—[www.dtic.mil/stinet](http://www.dtic.mil/stinet))

M85/05	(1985) Sloped Roof Conversions for Small, Flat-Roofed Buildings
M87-13	Vol. II (1987) Membrane and Flashing Condition Indexes for BURs, Inspection and Distress Manual

M-90/04	(1989) ROOFER: An Engineered Management System (EMS) for Bituminous Built-Up Roofs
FM-93/11	(1993) ROOFER: Membrane and Flashing Condition Indexes for Single-Ply roofs—Inspection and Distress Manual

Air Force Engineering & Services Center  
Tyndall Air Force Base, Florida 32403

ORNL-6520	(1988) Decision Guide for Roof Slope Selection
Instruction 32-1051 (1994)	Roof Systems Management
Eng. Tech Letter 90-1	Built-Up Roof Repair/Replacement Guide Specification
Eng. Tech Letter 90-8	Guide Specific for Ethylene-Propylene Diene Monomer (EPDM) Roofing

National Institute for Standards and Technology (NIST)  
Structures and Materials Division/Center for Building Technology  
Gaithersburg, MD 20899  
(Order Publications from NTIS—[www.dtic.mil/stinet](http://www.dtic.mil/stinet))

NISIR 88-4638	(1991) Performance Approach to the Development of Criteria for Low Sloped Roof Membranes
NBS Report 86-3418	(1986) Performance Criteria for Load-Elongation of Bituminous BUR Membranes; Alternative to the Tensile Strength Criterion
NIST Special Publication 811 (SI)	(1995) Guide for the Use of the International System of Units

Oak Ridge National Laboratories  
PO Box 2008  
Oak Ridge, TN 37831-2008

ORNL CONF 9405206	(1994) Low Slope Reroofing
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**NONGOVERNMENT PUBLICATIONS**

APA—The Engineered Wood Association  
7011 S, 19th St., P. O. Box 11700  
Tacoma, WA 98411-0700

SPE-1025	Guidelines for Proper Installation for APA Rated Sheathing for Roof Applications
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Residential and Commercial Manual

Design/Construction Guide

American National Standards Institute (ANSI)  
11 W. 42nd St. New York, 10036

- |                |  |
|----------------|--|
| ANSI/ASCE-7    | (1995) Minimum Design Loads for Buildings and Other Structures       |
| ANSI/SPRI RP-4 | (1997) Wind Design Standard for Ballasted Single Ply Roofing Systems |

American Society for Testing and Materials (ASTM)  
100 Barr Harbor Drive, W. Conshohockern PA 19428-2959

- |           |                                      |
|-----------|--------------------------------------|
| Manual 18 | (1994) Moisture Control in Buildings |
|-----------|--------------------------------------|

Asphalt Roofing Manufacturers Association  
6000 Executive Blvd., Suite 201  
Rockville, MD 20852-3803

- |             |   |
|-------------|---|
| #105-BUR-82 | (1993) Recommendations Regarding Built-up Roofing Asphalt                           |
| #108-BUR-93 | (1993) Quality Control Guidelines for Application of Built-up Roofing               |
| #109-BUR-88 | (1994) Deck Recommendations for Built-Up Roofing and Modified Bitumen Membranes     |
| #110 RR-96  | (1996) Quality Control Guidelines for Application of Polymer Modified Bitumen Roofs |
| #111-BUR-88 | (1993) Cold Weather Recommendations for Built-Up Roofing                            |
| #115-BUR-93 | (1994) The Effects of Ponding Water   |
| #117-BUR-94 | (1994) Aggregate Retention Enhancement for Built-up Roofing in Extreme Wind Zones   |
| #210-RR-71  | (1993) Color Shading of Asphalt Shingle Roofs                                       |
| #207-RR-85  | (1993) Plain Facts About Buckled Shingles   |
| #209-RR-86  | (1996) Ventilation and Moisture Control for Residential Roofing                     |
| #300 MBS-86 | (1986) Torch Applied Roofing—Do's and Don'ts  |

#301 MBIT-10	(1993) Guide to Preparing Modified Bituminous Roofing Specifications
#302 MBS-88	(1993) Quality Control Recommendations for Polymer Modified Bitumen Roofing
#306-MBS-93	(1993) Guide to Preparing Modified Bituminous Membrane Roofing Specifications
#411-BUR-90	(1990) Built-Up Roofing Design Guide for Building Owners
#421-RR-84	(1997) Residential Asphalt Roofing Manual
#430-MBS-97	(1997) Modified Bitumen—Design Guide for Building Owners
#530-MBS-86	(1986) A Guide to Safety—Torch-on Modified Bitumen Roofing
<p>Cedar Shingle and Shake Bureau 515 116th Ave, N.E., Suite 275 Bellevue, WA 98004-5294 (360) 753-4647 <a href="http://www.cedarbureau.org">www.cedarbureau.org</a></p>	
	Design & Application Manual for New Roof Construction
<p>Copper Development Association 260 Madison Ave New York, NY 10016</p>	
	Copper in Architecture
<p>Factory Mutual System (FM) 1151 Boston-Providence Turnpike Norwood, MA 02063</p>	
FP7825c	(1997) FMRC Approval Guide    Current Listing of Approved Roofing Systems
Loss Prevention Data Sheets	
1-28	(1996) Wind Loads to Roof Systems and Roof Deck Securement
1-29	(1996) Above-Deck Roof Components
1-29	(1988) Tech Advisory Bulletin Safeguarding Torch Applied Roof Installations
1-31	(1992) Metal Roof Systems
1-49	(1985) Perimeter Flashing

2000 International Building Code  
order from ICBO, SBCCI or BOCA

Draft of International Building Code

McGraw Hill Publications  
P. O. Box 545  
Blacklick, OH 43004-0545

ISBN-0-07-024784-6

(1996) Manual of Low Slope Roofing Systems, Griffin & Fricklas

National Roofing Contractors Association (NRCA)  
10255 W. Higgins Rd, Suite 600, Rosemont, IL 60018-5607

(1996) Roofing and Waterproofing Manual 4th Edition

(Annual) Commercial Roofing Materials Guide

(1996) Manual of Inspection and Maintenance of Built-up and  
Modified Bitumen Roof Systems

(1997) Repair Methods for Re-Attaching EPDM Membrane and  
Flashing Experiencing Shrinkage

(1993) Quality Control Guidelines for Application of Built-up  
Roofing

(1997) Repair Manual for Low-Slope Roof Systems

National Tile Roofing Manufacturers Association, Inc.  
P. O. Box 40337  
Eugene, OR 97404

(1998) Concrete and Clay Tile Roof Design Criteria Manual for  
Cold, Snowy Regions

FRSA/NTRMA 07320/1-98

Concrete and Clay Roof Tile Installation Manual  
(Jointly with Florida Roofing, Sheet Metal & Air  
Conditioning Contractors Assn., Inc.)

Oak Ridge National Laboratory (ORNL)  
P. O. Box 2008  
Oak Ridge, TN 37831--2008

CONF-9405206

(1994) Proceedings of the Low Slope Reroofing Workshop

Polyscience Publications, Inc.  
PO Box 148, Morin Heights, PQ  
Canada, J0R 1H0

0-921317-0304

(1980) Roofs—Design, Application, Maintenance

Revere Copper Products, Inc.  
P.O. Box 300  
Rome, NY 13440

(1982) Copper and Common Sense

Roofing Industry Educational Institute (RIEI)  
14 Inverness Dr. E, H-110, Englewood, CO 80112

R-186

(1994) Roof Maintenance

Sheet Metal and Air Conditioning Contractors National Association (SMACNA)  
4201 Lafayette Center Drive  
Chantilly, VA 22021

(1993) Architectural Sheet Metal Manual, 5th Ed.

Standard Practice in Sheet Metal Work (Reprint of 1929 Edition)

Steel Deck Institute  
PO Box 25  
Fox River Grove, IL, 60021

#29

Design Manual for Composite Decks, Form Decks, Roof Decks  
and Cellular Deck Floor Systems with Electrical Distribution

Manual of Construction with Steel Deck

Underwriters Laboratories (UL)  
333 Pfingsten Rd  
Northbrook, IL 60062

Roofing Materials & Systems Directory (Current Date)

Building Materials Directory (Current Date)

Vermont Structural Slate, Inc.  
P. O. Box 98  
Fair Haven, VT 05713

Slate Roofs

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

Clay Roof Tile Manual  
Roofing Details on Tile

APPENDIX B  
BIBLIOGRAPHY**GOVERNMENT PUBLICATIONS**

Cold Regions Research & Engineering  
Laboratory (CRREL)  
72 Lyme Rd., Hanover NH 03755  
(603) 646-4100  
www.crrel.usarmy

Report 76-2 Protected Membrane Roofs in Cold Regions (1974)	Explains PM roof principles and presents performance measurements from 3 PM roofs. Justifies cost premium on much improved performance.
MP 1498 Venting of Built-up Roofing Systems (1984)	Explains why ventilating compact roofing systems accomplishes very little and may do more harm than good.
MP 1509 Can Wet Roof Insulation be Dried Out?(1984)	Quantifies the very slow drying rates of most roof insulations using breather vents and such
MP 2040 Roof Moisture Surveys—Yesterday, Today and Tomorrow (1985)	Overviews nuclear, capacitance and infrared techniques and promotes periodic moisture surveys in conjunction with visual inspections
MP 2489 Vapor Retarders for Membrane Roofing Systems (1988)	Provides a method of deciding if a roof requires a vapor retarder and where it should be placed
MP 2866 New Wetting Curves for Common Roof Insulations (1989)	Quantifies the loss in insulating ability for roof insulations as they become wet.
MP 3233 Standing Seam Metal Roofing Systems in Cold Regions (1990)	Overviews strengths and weaknesses of standing seam metal roofs. Discusses sliding snow, ice damming, electrical heaters.
MP 3441 Installation of a Protected Membrane Roof at the Windiest Place on Earth (1994)	Overviews PM principles and describes how problems with a loose-laid PM were solved by installing a fully-adhered MB membrane. The XEPS insulation was reused.
MP 3443 General Considerations for Roofs	Provides excellent discussion of water shedding and water proof roof designs, especially as related to moisture

MP 3527 Ventilation of attics to minimize Icings at Eaves (1994)	Presents findings from several instrumented attics, before and after retrofits and provides design guidelines for avoiding such problems
MP 3858 Snow Guards for Metal Roofs (1996)	Overviews available types and provides design guidelines.
Videotape—Reroofing with Protected Membranes (1989)	Explains the design and documents the construction of a variety of PMR systems in Alaska.
Freeze-Thaw Durability of Common Roof Insulations	Defines the adverse effect of repeated freezing and thawing on various roof insulation boards
Roof Ventilation to Prevent Problematic Icings at Eaves (1998)	Presents case studies of steep roofs having chronic icings at their eaves which were eliminated by ventilation improvements.
Electric Heating Systems for combating Icing Problems on Metal Roofs (1997)	Presents findings from test installations on several instrumented buildings.
Special Report 95-19 (1995) Roof Blisters—Cause and Cure	Discusses blistering mechanism in BUR and MB
<p>Construction Engineering Research Laboratories (CERL) 1-800-872-2375 (Order Publications from NTIS) 5285 Port Royal Rd Springfield, VA 22161 <a href="http://www.dtic.mil/stinet/">www.dtic.mil/stinet/</a></p>	
M85/05 Sloped-Roof Conversions for Small, Flat Roofed Buildings (1984)	Examines cost-effectiveness of converting flat-roofed buildings to sloped-roof buildings as an alternative to repair or replacement in kind. Actual projects studied. Includes costs.
M86/03 Initial Investigation of Three Uncured Elastomeric Materials used in Military Construction (1986)	CSPE, CPE and PIB are investigated. It was concluded that they should <u>not</u> be used in Corps Projects (at this time).
M86/10 (1986) Investigation of Standing Seam Metal Roofing	Reviews the design and application of SSSMR
M86/14 (1986) Field Test Results of Aluminum Standing Seam Rfg.	Discusses design defects and corrections

M86/21 (1986) Initial Investigation of MB Roofing for use in Military Construction	Lists products and observations on performance
M87/04 Experimental PVC Roofing Field Performance	This work set the basis for the Corps CEGS on PVC
M87-13: ROOFER :Membrane and Flashing Condition indexes for BURs (1987)	Details on inspection of BUR systems using ROOFER procedures
M90/04 ROOFER: and Engineered Management System for BURs (1989)	Gives background on a roof management program for BUR and Single Ply
M90/09 Long Term Field Test Results of Experimental DPDM and PUF Roofing (1990)	Documents a seven year field test program
M93/05 Three Year Field Test Summary for Experimental Modified Bituminous Roofing	Results of three modified bituminous systems at Fort Polk, LA
FM 92/05 Cleaning Aged EPDM Rubber Roofing Membrane Material for Patching (1992)	Describes cleaning techniques and a droplet test for cleanliness
FM 93/11 ROOFER: Membrane and Flashing Condition Indexes for Single-Ply roofs—inspection and Distress Manual (1993)	Details on inspection of Single Ply roofing systems using ROOFER procedures
Corps of Engineers— Ft. Belvoir <a href="http://www.usacpw.belvoir.army.mil/librarie/riss/riss/m-gen.htm">www.usacpw.belvoir.army.mil/librarie/riss/riss/m-gen.htm</a>	
Corps of Engineers-Huntsville <a href="http://www.hnd.usace.army.mil/techinfo/">www.hnd.usace.army.mil/techinfo/</a>	
Air Force Engineering & Services Center Tyndall Air Force Base, Florida 32403	
Air Force Civil Engineer Support Agency Field Guides: Single-Ply Roofing Systems; Pitched Roofing Systems; BUR Systems.	Three pocket-sized booklets with color photographs of roofing defects and discussion of problems. Also includes inspection check sheets.

Department of the Interior

BUREC Technical Service Center  
Material Engineering and Research Group  
PO Box 25007, Code D-8180  
Denver Federal Center  
Denver, CO 80225

R-94-18 Maintenance and Repair of Sprayed Polyurethane Foam Roofing. (1994)	Contains Introduction to foa systems, materials, coatings, defects, inspection and repair
EPA Energy Star Cool Roofs Program <a href="http://www.eetd.lbl.gov/CoolRoof">www.eetd.lbl.gov/CoolRoof</a>	Information of High Albedo Roofs, results on many tested materials.
National Institute for Standards and Technology (NIST) (Order publications from NIST) <a href="http://.DTIC/mil/stinet">http://.DTIC/mil/stinet</a> Building Science Series	
#3 Wind Loads on Buildings (1970)	Covers proceedings of technical meeting concerning wind loads of buildings
#9 Thermal Shock Resistance for BURs (1967)	The resistance of BURs to thermally induced forces is discussed
#23 Hail Resistance of Roofing Products	Discusses hail test with synthetic hailstones. Most prepared roofings suffer damage when stones >37 mm (1-1/2 in.) dia. are used. Solidly supported systems are better than soft substrates. Aggregate surfacing is beneficial.
#37 Effects of Moisture on the Heat Transfer Performance of Insulated Flat Roof Constructions (1971)	A solution to the problem of unwanted moisture in the thermal insulation of flat roofs was found. The best insulation and moisture performance was obtained by utilizing the heat of the summer sun to vaporize and transfer to the room beneath any free moisture contained within the construction.
#55 Preliminary Performance Criteria for BUR (1974)	Develops a performance approach based upon testing of successful BUR membranes. Recommends levels of performance for nine attributes including low temperature tensile strength.
#92 Viscosities of Roofing Asphalts at Application Temperatures (1976)	Indicates how fluidity of asphalt can relate to good handling as observed by experienced contractors. This report lead to the establishment of EVT.
#123 Effect of Moisture on the Thermal Conductance of Roofing	Five types of rigid board insulations with BURs had moisture induced into the roof specimens.

Systems (1980)	Measurements were taken of moisture gain and thermal conductivity.
#167 Interim Criteria for Polymer Modified Bituminous Roofing Membrane Materials (1989)	Results of a study for the selection of polymer-modified bituminous materials. Dimensional stability, fire, flow resistance, hail impact, moisture content and absorption, pliability, strain energy, uplift resistance and weathering resistance (sun exposure) are identified
#169 Strength and Creep Rupture Properties of Adhesive Bonded EPDM Joints Stressed in Peel (1990)	Discusses the major defect in EPDM—field seams. Cure time and level of cleanliness have the greatest effect on joint strength, while the thickness of the adhesive and the mechanical load have the greatest effect on a joint's creep rupture time to failure
#175 Performance of Tape-Bonded Seams of EPDM Membranes: Comparison of the Peel Creep Rupture Response of the Tape-Bonded and Liquid Adhesive Bonded Systems (1996)	Continues the work of BSS #167 and #169. The industry has gradually shifted from neoprene-based adhesives to butyl-based adhesives to primer and tape systems. This paper concludes that the tape systems are at least as good as the earlier adhesive systems.
NBSIR 85-3239 Roof Management Programs (1985)	Three general types of management programs are identified and discussed: total management, new construction, and maintenance management. Reference is made to USAF Manual 91-36, which includes chapters on general information, data base, rating the serviceability of existing roofs and alternatives, repair procedures, design and construction management.
NISTIR 88-4008 Corrosion of Metallic Fasteners in Low Sloped Roofs: A Review of the Available Information and Identification of Research Needs(1989)	The potential for corrosion-induced problems is of concern. Mechanical fasteners have gained acceptance for fastening components to roof decks. Three main areas are addressed: the field performance of fastener systems; fastener system materials and the possibility of corrosion; and evaluation techniques for corrosion resistance.
NISTIR 89-4155 Report of Roof Inspection—Characterization of Newly Fabricated Adhesive Bonded Seams at an Army Facility (1991)	Specimens of EPDM field seams were analyzed for peel strength and surface condition. Voids and release agent may contribute to low peel strength.
NISTIR 4504 A Field Study of the Performance of EPDM Roofing at	About 1/3 of the roofs surveyed had minor defects which were readily repairable, but which had gone

Air Force Facilities (1991)	without repair. This confirms a key concern expressed by field personnel that they had lacked the ability to perform routine maintenance.
NISTIR 4638 A Performance Approach to the Development of Criteria for Low-Sloped Roof Membranes (1991)	Continues the Work of BSS #167 and includes progress of an international task force on roofing performance (CIB/RILEM)
NBS 231 Solar Heating, Radiative Cooling and Thermal Movement / Their effects on BUR (1961)	Twenty-five different BUR specimens were subjected to natural solar heating and night-time cooling. The data indicates that the temperature attained in a roof membrane is influenced by the absorptance and emmissivity of the surface, as well as the properties of the substrate. Insulated roofings may be heated to as much as 44°C (80°F) above ambient due to solar heating and 11°C (20°F) below ambient due to radiative cooling. Thermal expansion data is presented.
NBS 473 Lab/Field Comparisons of BUR membranes (1961)	Field Specimens tend to have thinner moppings and better thermal shock resistance
NBS 965 Effects of Moisture in BUR—State of the Art Literature Survey (1978)	A literature review of the effects of moisture on BUR, including quantitative data on permeability, absorption, tensile strength and fungus attack resistance
NBS 1135 Cooling of Bitumen during Construction of BUR systems—a Mathematical Model (1981)	Provides a model of how bitumens cool, which will help in the development of better application guidelines
NBSIR 76-987 Effect of Insulation on the Surface Temperature of Roof Membranes	This paper, published after the oil embargo of 1972-73, resolved the issue of whether membrane roofing would fail prematurely due to excessive thermal load on highly insulated membranes. It found that after about the equivalent of 25 mm (1 in.) of insulation the temperatures only increased slightly with increased R value.
NBSIR 86-3418 Strain Energy of Bituminous BUR Membranes: An Alternative to the Tensile Strength Criterion (1986)	This document proposed a minimum strain energy of 13 N•m/m (3 lbf•in/in) @ -18°C (0°F)
NBS Report 10950 Slippage of BUR Membranes—Causes and Prevention (1972)	Identified major reasons why BURs can slip: wrong asphalt for slope, asphalt degraded by overheating, roof lacking nailers to back-nail the felts, excessive

NBS Report M-89 Effects of Thermal Shrinkage of BUR	<p>gravity force for the slope, hot climate, use of coated sheets and/or phased construction. All-ply constructions without a coated base sheet were less likely to slip. Excessive interply bitumen (likely due to asphalt too cool when applied) was a major factor, and this observation led to the development of the EVT concept.</p> <p>Gives insight into why BURs shrink. Anchorage to the substrate to avoid shear planes is important. Ratchet effect with organic materials show that they contract when the roof is cooling and the interply bitumen is still relatively fluid. However, when felts take up moisture and try to expand, the bitumen is stiff and resists expansion. Results of this cyclic effect is non-restorable shrinkage. This effect is far less significant on glass fiber felts.</p>
NBS Report 86-3418 Performance Criteria for Load Elongation of Bituminous BUR membranes; Alternative to the Tensile Strength Criterion (1986)	<p>Modified bituminous roofs differ from BUR. Specimens were tested in tension to determine load elongation properties and to measure strain energy. As an alternative to the conventional BUR criterion for a minimum tensile strength of 35 kN/m (200 lbf), it was recommended that the strain energy should be a minimum of 13 Nm/m (3 lbf) when tested at -18°C (0°F) in the weakest direction.</p>
NBS Report 9381 Exposure of New Roofing Systems (1966)	<p>Provided excellent insight into the first generation of new roofing systems.</p>
NBS Technical Note 972 Elastomeric Roofing: A Survey (1978)	<p>Good insight into the second generation of single ply systems including PVC, Hypalon® and EPDM. Guidelines for selection and application and a summary of references is included.</p>
NBS Technical Note 778 Guidelines for Selection of and Use of Foam Polyurethane Roofing Systems	<p>Provides for the selection and use of SPF and suggests performance specifications for foam and protective coatings. Most of the guidelines are still valid today. Use in conjunction with ASTM D-5469 Application of New Spray-Applied Polyurethane Foam and Coated Roofing Systems.</p>
CIB/RILEM Joint Report Elastomeric, Thermoplastic and MB Roofing Technical Report (1986)	<p>Since the 1970's, a phenomenal proliferation of materials, composites and systems employing elastomers, thermoplastics and MBs has occurred. It was agreed that criteria, test methods and standards could be developed. (See following report)</p>
CIB-Rilem Joint Report Performance Testing of Roofing	<p>This report gave recommendations for a test protocol comprising a set of performance test methods for</p>

Membrane Materials,  
Recommendations of the  
Committee (1988)

characterizing and evaluating sheet roof membrane materials. Four test parameters were concentrated on: puncture testing; tear resistance, cyclic fatigue and thermal analysis.

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(615) 576-5454  
[www.ornl.gov/roofs&walls](http://www.ornl.gov/roofs&walls)

Conf 9405206 Low Slope Roofing  
Workshop (1994)

Collection of papers relating to reroofing and re-cover issues.

Conf 9610200 Sustainable Low-  
Slope Roofing Workshop (1996)

Collection of papers on durability and recyclability

ORNL 89-SD350/1 Moisture  
Control Handbook — New, Low-  
rise Residential  
Construction(1989)

Discusses designs for various climate situations

### **NONGOVERNMENT PUBLICATIONS**

Arizona Roofing Contractors Association  
Concrete Tile Roof Specifications  
(1998)

Covers Tile Installations in the Western U.S. Directed towards cement tile, but applicable to clay as well

APA—The Engineered Wood Association  
7011 S. 19th St., P.O. Box 11700  
Tacoma, WA 98411-0700  
(253 )565-6600

Guidelines for Proper Installation  
of APA Rated Sheathing for Roof  
Applications  
Residential and Commercial  
Manual

Provides checklist for deck preinspection, panel application and fastening hints

Comprehensive guide to panel construction systems for both residential and commercial/industrial buildings

American National Standards Institute  
(ANSI)  
11 W. 42nd St. New York, 10036  
(212) 642-4900  
[www.ansi.org](http://www.ansi.org)

ANSI/ASCE 7-95 Minimum Design Loads for Buildings and Other Structures (1996)

Provides wind, snow ice and seismic maps and other information to be used by building designers

ANSI/SPRI RP-4 Wind Design Standard for Ballasted Single Ply Roofing Systems (1998)

Updated to be consistent with ANSI/ASCE-7-95. Provides design information on ballasted single-ply roofs.

American Society of Civil Engineers  
Book Orders A 803, PO Box 831  
Somerset, NJ 08875-0831  
(800)-548-2723  
www.asce.org

Guide to the use of the Wind Load Provisions of ASCE 7-95

Written by Texas Tech. University to assist readers of ASCE-7-95

American Society of Heating, Refrigerating & Air Conditioning Engineers (ASHRAE)  
1791 Tullie Circle, NE  
Atlanta, GA 30329  
(404) 636-8400

Handbook of Fundamentals

Voluminous reference book includes chapters on psychrometrics and condensation, steam tables, thermal insulation calculations and resistance; climate data.

Proceedings on Thermal Performance of Exterior Envelopes, PMRs

A Water-Ballasted Life-time Energy Saving Roof System, Economic Projections

American Society for Testing and Materials (ASTM)  
100 Barr Harbor Drive, W. Conshohocken  
PA 19428-2959  
(610) 832-9500  
www.astm.org

STP 603 Roofing Systems (1977)

Eight papers, including cold process BUR and moisture in PMR insulation

STP 790 Single-ply Roofing Technology (1982)

Seven papers including wind effects on ballasted and spot attached systems. Also EPDM seam adhesion

STP 959 (1987)	Nine papers including heat transfer through mechanically fastened single plies; MB testing; cold adhesives
STP 1088 Roofing Research & Standards Development (1990)	Fourteen papers-Includes paper on EPDM adhesives, comparing open time. Adhesive thickness and surface cleanliness on peel strength; PVC roofing; testing
Moisture Control in Buildings Manual 18	Comprehensive overview of issues and data related to moisture control in buildings. Ch. 16 covers roofing.
<p>Asphalt Roofing Manufacturers Association 4041 Powder Mill Road, Suite 404 Calverton, MD 20705-3106 <a href="http://www.asphaltroofing.org">www.asphaltroofing.org</a></p>	
<p>Butterworth Architecture 80 Montvale Ave Stoneham, MA 02180</p>	
Problems in Roof Design (1991)	Textbook by H. McCampbell, listing types of roofing (mostly west coast design), avoiding failures, details that work.
<p>Cedar Shingle and Shake Bureau 515 116th Ave, N.E., Suite 275 Bellevue, WA 98004-5294 (800) 843-3578 <a href="http://www.cedarbureau.org">www.cedarbureau.org</a></p>	
Design & Application Manual for New Roof Construction	General Design and Application Details using Plywood and OSB, Specification Guidelines
<p>Construction Specification Institute (CSI) 601 Madison St. Alexandria, VA 22314 (703)684-0300 <a href="http://www.csinet.org">www.csinet.org</a></p>	
<p>Copper Development Association 260 Madison Ave New York, NY 10016 (212) 251-7220 <a href="http://www.copper.org">www.copper.org</a></p>	<p>6-part video series for architects: Copper in Architecture, Standing seam Roofs, Batten Seam Roofs, Flat Seam and Shingle Roofs, Horizontal Seam Roofs and Gutters, Flashing and Roof Details</p>
Copper in Architecture Manual	3-ring Binder with fundamentals, and details. Also contains 6-floppy disc with details and specifications

Council of Forest Industries of British  
Columbia  
1500/1055 West Hastings St.  
Vancouver, Canada V6E 2H1  
(604) 684-0211  
[www.cofi.org/wrcla](http://www.cofi.org/wrcla)

Western Red Cedar Shingles and Shakes Used in Heavy Snowfall Areas	Number of recommendations on location of stacks, ventilation of roof system, layers of shingles or shakes
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Factory Mutual System (FM)  
1151 Boston-Providence Turnpike  
Norwood, MA 02063

P7825c Approval Guide Building Materials (Annual)	Lists Approved Materials and Systems
Approval Standard 4435 for Roof Flashing	Booklet describing basis for listings of Flashing Materials
Approval Standard 4450 Class 1 Insulated Steel Deck Roofs (1989)	Booklet describing basis for listings including fire, wind, heat damage and fasteners
Approval Standard 4451 for Steel Roof Decking (1996)	Booklet describing basis for listings, including wind, welds, corrosion
Approval Standard 4454 for Lightweight Insulating Concrete Roof Deck	Booklet describing basis for listings when using Lightweight Insulating Concrete
Approval Standard 4470 Class 1 Roof Covers (1986)	Booklet describing basis for listings including fire, wind, corrosion of fasteners, hail, leakage
Approval Standard 4471 Class 1 Panel Roofs (1995) (1994)	Defines criteria for acceptance of metal and plastic panel roofs, including fire, wind, foot traffic, hail damage resistance and water leakage resistance.
1-7 Wind Forces on Buildings and Other Structures	Data sheet with wind maps and procedures for estimating uplift forces
1-22 Maximum Foreseeable Loss Fire Walls	Use of fire walls in construction
1-28 Wind Loads to Roof Systems and Roof Deck	Data sheet on roofing materials installation

## Securement

1-28/1-29R Roof Systems	Data sheet on roofing procedures
1-29 Above Deck Roof Components	Vapor retarders, insulation, singleply and BUR
1-29* Safeguarding Torch-Applied Roof Installations	Safety procedures
1-29* PVC Roof Coverings	
1-31 Metal Roof Systems (1996)	Recover of and Recover by metal roofing
1-47S.1 Hail Damage (1985) 1-49 Perimeter Flashing (1985)	Recommendations to minimize hail damage Both BUR and single ply details are provided, including installation of edge nailers
1-52 Field Uplift Tests (1986)	Data sheet on evaluating wind damaged roofing using tripod or suction panel apparatus.
1-54 Roof Loads for New Construction (1994)	Snow and rain loads and roof drainage

Florida Roofing, Sheet Metal And Air  
Conditioning Contractors Association, Inc.  
PO Drawer 4850  
Winter Park, FL 32792  
(407)671-3772

Concrete and Clay Roof Tile Installation Manual (2nd Ed) (Jointly with National Tile Roofing Manufacturers Association)	Covers direct deck installations, battens, mortar and adhesive-set and execution using tile roofing.
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2000 International Building Code  
order from ICBO, SBCCI or BOCA

New code intended to replace Uniform, Basic and Standard Codes.

McGraw Hill Publications  
PO Box 545  
Blacklick, OH 43004-0545

Manual of Low Slope Roofing  
Systems (1996)

Means, R.S Co.  
100 Construction Plaza  
Kingston, MA 02364  
(617) 685-7880

Text Book by C.W. Griffin and R.L. Fricklas covering the roof as a system, drainage, decks, thermal insulation, vapor control, fire and wind resistance, BUR, MB, Elastomeric and Thermoplastic systems,

Flashings, PMRs, SPF, metal, inspections, reroofing, specifications and warranties.

Roofing-Design Criteria Options,  
Selection

Estimating Guides

Text Book by R. D. Herbert, listing types of roofing, avoidance of failure, accessories, maintenance, warranties, codes, system selection and estimating. Several different guides available for construction estimating

Metal Building Manufacturers Association  
(MBMA)  
1300 Sumner Ave  
Cleveland, OH 44115-2561  
(216) 241-7333

Midwest Roofing Contractors Association  
(MRCA)  
4840 W. 15Th St., Ste 1000  
Lawrence, KS 66049  
(913)843-7555  
[www.mrca.org](http://www.mrca.org)

Safety In Torch Welding (1986)

National Tile Roofing Manufacturers  
Association, Inc. (NTRMA)  
PO Box 40337  
Eugene, OR 97404  
(541) 689-0366  
[www.ntrma.com](http://www.ntrma.com)

Concrete and Clay Tile Roof  
Design Criteria Manual for Cold,  
Snowy Regions

National Roofing Contractors Association  
10255 W. Higgins Rd, Ste 600  
Rosemont, IL 60018-5607  
(847) 299-9070  
[www.nrca@roofonline.org](mailto:www.nrca@roofonline.org)

Commercial Roofing Guide  
(Updated annually)

Directory of materials manufacturers, including membranes, adhesives, coatings, metals, insulations. Also includes analysis of manufacturer warranties

Residential Roofing Guide

Directory of materials, manufacturers for steep roofing

Conferences on Roofing  
Technology

Periodic publication of proceedings of joint conferences  
between NRCA, NIST and other sponsors

North American Insulation Manufacturing  
Association (NAIMA)  
44 Canal Center Plaza, Suite 310  
Alexandria, VA 22314  
(703) 684-0084

NAIMA 202-96 Standard for  
Flexible Fiber Glass Insulation  
Used in Metal Buildings

Gives guidance on R-values of compressible glass  
fiber insulation in service and in identification of  
products.

Polyscience Publications, Inc.  
PO Box 148, Morin Heights, PQ  
Canada, J0R 1H0

Roofs—Design, Application,  
Maintenance

Text Book by M.C. Baker, physics of roofing, basic  
principles, materials that every designer should know.

Reston Publishing Co., Inc.  
Reston, VA (Prentice-Hall)

Roofing Systems: Materials and  
Application

Text Book by John Watson, Historical usage, physical  
properties, substrate preparation, specs and  
installation methods, with emphasis on steep roofing

Revere Copper Products, Inc.  
PO Box 300  
Rome, NY 13440  
(800) 448-1776

Copper and Common Sense

Compact but highly regarded manual on copper roof  
design and detailing

Roofing Industry Educ. Institute (RIEI)  
14 Inverness Dr. E, H-110, Englewood,  
CO 80112  
(303) 790-7200  
[www.riei.org](http://www.riei.org)

Conducts training seminars on flat and steep roofing.  
Course manuals available for purchase, as well as  
other training aids.

Sheet Metal and Air Conditioning  
Contractors Nat'l. Assoc. (SMACNA)  
4201 Lafayette Center Drive  
Chantilly, VA 22021  
(703) 803-2989  
[www.smacna.org](http://www.smacna.org)

1929 Standard Practice in Sheet Metal Work	Very useful reference in historical restoration of metalwork
Sheet Membrane and Component Suppliers to the Commercial Roofing Industry (SPRI) 200 Reservoir St., Ste 309A Needham, MA 02194 (781) 444-0242 www.spri.org	
ANSI/SPRI RP-4-1997 Wind Design Standard for Ballasted Single-ply Roofing Systems	Provides reference information on wind loads, edge securement, ballast type and quantity, as well as height/parapet recommendations.
Wind Design Guide for Edge Systems used with Low Slope Roofing Systems	Reference material on edge materials used with low slope roofing systems including securement of the substrate, holding power of the edge detail and materials specifications.
Steel Deck Institute PO Box 25 Fox River Grove, IL, 60021 (847) 462-1930 www.sdi.org	
# 29 Design Manual for Composite Decks, Form Decks, Roof Decks, and Cellular Deck Floor Systems with Electrical Distribution	Covers ribbed steel roof deck construction of varying configurations used for the support of roofing materials, design live load and SDI constructions loads.
Manual of Construction with Steel Deck	Intended as an aid and general guide for the proper erection of steel decks.
Underwriters Laboratories (UL) 333 Pfingsten Rd Northbrook, IL 60062	
Building Materials Directory	Lists non-roofing constructions (i.e. construction joints)
Roofing Materials and Systems Directory	Lists approved materials and systems for external fire and under-deck fire resistance, as well as wind uplift ratings
Fire Resistance Directory	Lists Time-Temperature ratings.
UL 55A Materials for BUR	Describes felts & bitumen

Coverings (1985)

UL 55B Class C Asphalt Organic-Felt Sheet Roofing and Shingles (1983)

Properties of organic felts and shingles

UL580 Tests for Wind-Uplift Resistance of Roof Assemblies (1980)

Test Equipment and Procedures

UL 790 Tests for Fire Resistance of Roof Covering Materials (1983)

Class A,B,C test protocol for external fire

UL 2218 (1996) Impact Resistance of Prepared Roof Coverings

Impact procedure with steel ball impacts at room temperature

UL 1256 Fire Test of Roof Deck Constructions (1985)

Steiner Tunnel procedure for under-deck fire spread

Western States Roofing Contractors Association (WSRCA)  
8000 Airport Blvd. Suite 412  
Burlingame, CA 94010  
(800)725-0333

Roofing Details

Contains "Western" details for commercial roofing, for example uninsulated roofs and walls. Also contains details for flashing tile roofs.

APPENDIX C.  
ACRONYMS

ANSI	American National Standards Institute
APA	The Engineered Wood Association
APO	Alpha-Polyolefin (Polymer used in MB Systems)
APP	Atactic (or Amorphic) Polypropylene ( Used in MB)
ARMA	Asphalt Roofing Manufacturers Association
ASCE	American Society of Civil Engineers
ASTM	American Society for Testing and Materials
BOCA	Building Officials and Code Administrators (Basic Building Code)
BUR	Built-up Roofing
CDA	Copper Development Association
CFC	Chlorofluorocarbon (Blowing Agent)
CPE	Chlorinated Polyethylene (Single Ply Polymer)
CSPE	Chlorosulfonated Polyethylene (Hypalon®)
ECO	Polyepichlorohydrin Rubber
EPDM	Ethylene Propylene Diene Monomer (or "m" class polymer)
EPS	Expanded Polystyrene
ETD	Equivalent Temperature Difference (ASHRAE)
EVT	Equiviscous Temperature
FM	Factory Mutual System
FMRC	Factory Mutual Research Corporation
FR	Fire-retarded
HCFC	Hydrogenated Chlorofluorocarbon (Blowing Agent)
HVAC	Heating, Ventilation, Air-conditioning

ICBO	International Congress of Building Officials (Uniform Building Code)
IPP	Isotactic Polypropylene
KEE	Ketone Ethylene Ester (Single Ply Polymer)
MB	(Polymer-) Modified Bitumen
MEPS	Molded, Expanded Polystyrene (Foam)
MRCA	Midwest Roofing Contractors Association
MSDS	Material Safety Data Sheets
NRCA	National Roofing Contractors Association
O&M	Operations & Maintenance Manual
ORNL	Oak Ridge National Laboratory
PIB	Polyisobutylene (Single Ply Polymer)
PMR	Protected Membrane Roof (System)
PVC	Poly(vinyl) Chloride (Single Ply Polymer)
PVDF	Polyvinylidene (di) Fluoride (Kynar 500®; Hylar 5000®)
RIEI	The Roofing Industry Educational Institute
ROOFER	Corps of Engineer Maintenance Data-Base Management System
SBA	Systems Builders Association (Formerly MBDA)
SBC	Standard Building Code (See SBCCI)
SBCCI	Southern Building Code Congress International, Inc. (Standard Building Code)
SBS	Styrene (or Sequenced) Butadiene Styrene
SDI	Steel Deck Institute
SMACNA	Sheet Metal and Air Conditioning Contractors National Association
SPF	Sprayed Polyurethane Foam
SPFD	Spray Polyurethane Foam Division (of SPI)

SPI	Society of the Plastics Industry
SPRI	Single Ply Roofing Institute
SPUF	Sprayed Polyurethane Foam
SSSMR	Structural Standing Seam Metal Roofing
TCS	Terne-Coated Stainless Steel
Tg	Glass Transition Temperature
TPO	Thermoplastic Polyolefin
UBC	Uniform Building Code (See ICBO)
UL	Underwriters Laboratories
UV	Ultraviolet Light
WSRCA	Western States Roofing Contractors Association
XEPS	Extruded (expanded) Polystyrene Foam

## APPENDIX D

## GLOSSARY OF ROOFING RELATED TERMS

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

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

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

Asphalt—A dark brown to black cementitious material whose predominating constituents are bitumens that occur in nature or are obtained in petroleum processing.

Asphalt felt—An asphalt-saturated felt.

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.*

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

Backup plate—A rigid plate to support an end lap to provide uniform compression.

Backnailing—*blind* (i.e., concealed by overlapping felt) nailing of roofing felts to a substrate in addition to hot-mopping to prevent slippage.

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

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

Batten—Raised rib, in a metal roof, or a separate part or formed portion in a metal roofing panel.

Beaufort scale—A scale in which the force of the wind is indicated by numbers from 0 to 12. No.7 is "near gale" at 52-61 km/h (32-38 m.p.h.). No. 9 is "strong gale" at 76-87 km/h (47-54 m.p.h.).

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

Bituminous emulsion—A suspension of minute globules of bituminous material in water or in an aqueous solution.

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

Blanket insulation—Fiberglass insulation in roll form, often installed between metal roof panels and the supporting purlins.

Blister—An enclosed pocket of air-water vapor, trapped between membrane plies or between membrane and substrate.

Blister (Polyurethane Foam)—Undesirable rounded delamination of the surface of a polyurethane foam whose boundaries may be either more or less sharply defined.

**Block copolymer**—An essentially linear copolymer in which there are repeated sequences of polymeric segments of different chemical structure.

**Block or board thermal insulation**—Rigid or semi-rigid thermal insulation preformed into rectangular units.

**Blocking**—(1) wood built into a roofing system above the deck and below the membrane and flashing to (a) stiffen the deck around an opening, (b) act as a stop for insulation, (c) serve as a nailer for attachment of the membrane or flashing. (2) Wood cross-members installed between rafters or joists to provide support at cross-joints between deck panels. (3) Cohesion or adhesion between similar or dissimilar materials in roll or sheet form that may interfere with the satisfactory and efficient use of the material.

**Blocking, wood**—Treated wood members designed to help prevent movement of insulation.

**Blowing agent**—A compounding ingredient used to produce gas by chemical or thermal action, or both, in manufacture of hollow or cellular articles.

**Blueberry**—A small bubble or blister in the flood coating of a gravel-surfaced membrane.

**Bodied solvent adhesive**—An adhesive consisting of a solution of the membrane compound in solvent used in the seaming of membranes.

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

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

**Breaking strain**—% elongation at which a sheet or other tested component ruptures under tensile force.

**Breaking stress**—Stress (in force per linear or area units) at which sheet, or other tested component, ruptures under tensile force.

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

**Brooming**—Embedding a ply by using a broom to smooth it out and ensure contact with the adhesive under the ply.

**Btuh**—Btu per hour.

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

**Built-up roofing (BUR)**—A continuous, semi-flexible 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).

**Bull**—Roofer's term for flashing or plastic cement.

**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 machine with two or more rolls, operating at selected surface speeds and controlled temperatures, for sheeting, laminating, skim coating (topping) and a friction coating to a controlled thickness or surface characteristic, or both.

**Camber**—A predetermined curvature designed into a structural member to offset the anticipated deflection under design load.

**Canopy**—Any overhanging or projecting roof structure with the extreme end usually unsupported.

**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.

**Capflashing**—See Flashing.

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

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

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

**Cavity Wall**—A wall built of hollow masonry units arranged to provide a continuous internal air space.

**Centistoke**—unit measurement of viscosity-i.e., resistance to flow.  $1 \text{ cS} = 1 \times 10^{-6} \text{ m}^2/\text{s}$ .

**Chain scission**—Breaking of chemical bonds between carbon atoms by UV photo-oxidation, a reversal of the asphalt-blowing polymerization process that produces long chainlike hydrocarbon chains, resulting in embrittlement and cracking.

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

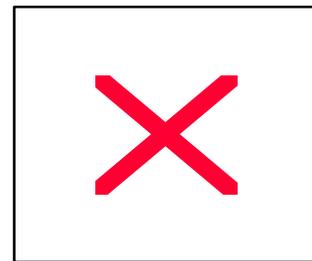
**Chalking**—A powdery residue on the surface of a material resulting from degradation or migration of an ingredient, or both.

**Channel mopping**—See Strip mopping under Mopping.

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

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

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



**Coefficient of thermal expansion**—The change in length per unit of length for a unit change in temperature. (Thus the coefficient per °F must be multiplied by 1.8 for the coefficient per °C.)

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

**Coal tar felt**—A felt saturated with refined coal tar.

**Coal tar pitch**—Dark brown to black, solid cementitious material obtained as residue in the partial evaporation or distillation of coal tar.

**Coated fabric**—Fabrics impregnated and/or coated with a plastic material in the form of a solution, dispersion hot melt, or powder. (The term also applies to materials resulting from the application of a preformed film to a fabric by means of calendaring.)

**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.

Coating weight—Weight of coating on surface (both sides), usually expressed in ounces per sq. ft. or grams per sq. meter.

Coil coating—The application of an organic finish to a coil of metal using a continuous process.

Cold flow—Slow deformation, under gravitational force, at or below room temperature. (See Creep)

Cold process roofing—A continuous, semi-flexible 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)

Condensation polymerization—Polymerization in which monomers are linked together with the splitting off of water or other simple molecules.

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.  $C=(W/m^2 \cdot K)$   $C=(Btu/h \cdot ft^2 \cdot ^\circ F)$ .

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

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.  $k=(W/m \cdot K)$   $k=(Btu/h \cdot ft^2 \cdot ^\circ F)$ .

Coping—A covering on top of a wall exposed to the weather, usually sloped to carry off water.

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

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

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

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

Cream Time—This is the time, measured in seconds at a given temperature, when the "A" and "B" components of a polyurethane foam compound will begin to expand after being mixed through the spray gun.

Creep—The dimensional change with time of a material under load, following the initial instantaneous elastic deformation. Creep at room temperature is sometimes called cold flow.

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.*

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

Cross-linking—A general term referring to the formation of chemical bonds between polymeric chains to yield an insoluble, three dimensional polymeric structure. Cross-linking of rubbers is vulcanization, qv.

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

Cure—To change the properties of a polymeric system into a more stable, usable condition by the use of heat, radiation, or reaction with

chemical additives.

*NOTE: Cure may be accomplished, for example, by removal of solvent or cross-linking.*

Curing—See Vulcanizations.

Curled felt—BUR membrane defect characterized by a continuous, open longitudinal seal with top felt rolled back from underlying felt.

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, 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 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.

Degree-days—The difference between a reference temperature (usually 18°C [65°F]) and the mean temperature for the day times 24 hours times the number of days in the period. Degree-days are used to compare the severity of cold or heat during the heating or cooling season.

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

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.

Depth of measurement—The maximum thickness of a roof system upon which a given moisture survey method is effective.

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

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

Double pour—Doubling of flood-coat, graveling-in operation, to provide additional waterproofing integrity for a BUR membrane.

Downspout—A conduit used to carry water from the gutter of a building to the ground or storm drain.

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

Duckboard—A boardwalk or slatted flooring laid on a wet, muddy or cold surface.

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

Eave height—The vertical dimension from finished floor to the eave.

Edge 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. (It is of doubtful efficacy.)

Efflorescence—A deposit or encrustation of soluble salts, generally white and most commonly consisting of calcium sulfate, 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.

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

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

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

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

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

**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.

**EIP (Elastoplastic)**—pertaining to polymeric materials, including thermoplastic and elastomeric categories.

**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**—A synthetic rubber that includes two epichlorohydrin-based elastomers of saturated high molecular weight, aliphatic polyethers with chloro-methyl side chains. The two types include a homopolymer (CO) and a copolymer of epichlorohydrin 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. This rubber offers excellent oil resistance.

**Equilibrium moisture content**—(1) 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.

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

**EVT (Equiviscous Temperature)**—Temperature at which the viscosity of an asphalt is appropriate for application. Viscosity units are generally expressed in centipoise or centistokes. Tolerance on EVT is usually  $\pm 1400$  ( $\pm 25^\circ\text{F}$ ).

**Exotherm**—Heat generated in a chemical reaction.

**Expansion joint**—A structural separation between two building elements that allows free movement (expansion or contraction) between 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 914 mm (36 in.) wide felt in a shingled, four ply membrane should be 216 mm (8-1/2 in.); (2) The time during which a portion of a roofing element is exposed to the weather.

**Extra steep asphalt**—See Super Steep Asphalt.

**Extractables**—Components or substances removable from a solid or liquid mixture by means of an appropriate solvent.

**Extruder**—A machine with a driven screw that forces ductile or semi-soft solids through a die opening of appropriate shape to produce continuous film, strip, or tubing.

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

**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”.

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

**Fallback**—Reduction in bitumen softening point, sometimes caused by refluxing or overheating in a relatively closed container.

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

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

**Felt mill ream**—The mass in pounds of 480 ft<sup>2</sup> of dry, unsaturated felt, also termed “point weight.”

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

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

**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.

**Filler strip**—See Closure Strip.

**Film**—Sheeting having nominal thickness not greater than (0.25 mm) 10 mils.

**Fin**—A sharp, raised edge capable of damaging a roof membrane.

**Fine mineral surfacing**—Water insoluble inorganic material, more than 50% of which passes the 500 micrometer (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 counter-flashing shields the upper edges of the base flashing.

**Flashing cement**—A trowelable mixture of cutback bitumen, mineral stabilizers and fibers.

**Flash point**—Temperature at which a test flame ignites vapor above a liquid surface.

**Flat asphalt**—A roofing asphalt conforming to the requirements of Specification D312, Type II.

**Fleece**—Term used to describe mats or felts of usually nonwoven fibers.

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

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

**Fluorocarbon films**—Substituted ethylene polymers, featuring outstanding formability, heat resistance, color retention, and resistance to solvents and chalking.

Framed opening—Frame work (headers and jambs) and flashing which surround an opening in the wall or roof of a building; usually for field-installed accessories such as overhead doors or powered roof exhausters.

“Free carbon” in tars—The hydrocarbon fraction precipitated from a tar by dilution with carbon disulfide.

Friability—The tendency of a material or product to crumble or break into small pieces easily.

Gable roof—A ridged roof that terminates in gables.

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

Galvanic cell—A cell in which chemical change is the source of electrical energy. It usually consists of two dissimilar conductors in contact with each other and an electrolyte.

Galvanized steel—Steel coated with zinc for corrosion resistance.

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

Glass mat—A thin mat of glass fibers with or without a binder.

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.

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.

Gloss—Subjective term describing the relative amount and nature of mirror-like reflection from a surface

Grain—Weight unit equal to 1/7000 lb, used in measuring atmospheric water vapor content.

Granule—See Mineral Granules.

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

Gravel stop—Flanged device, usually metallic, designed to prevent loose aggregate from washing off the roof and to provide a continuous finished edge for the roofing.

Green building technology—Utilizing technology to reduce impact on the earth. Includes recyclability, reduction in carbon dioxide, ozone or other atmospheric pollutants, and reduction of urban heat islands.

Grout—Mixture of cement, sand, and water used to fill cracks and cavities. Often used under base plates or leveling plates to obtain uniform bearing surfaces.

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

Haunch—The deepened portion of a column or rafter, designed to accommodate the higher bending moments at such points. (Usually occurs at connection of column and rafter.)

Header—A horizontal framing structural member of a door, window, or other framed opening.

Headlap—The minimum distances 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.

Heat capacity—The amount of energy required to raise the temperature of a unit substance 1°F (or 1°C).

Heat seaming—The process of joining two or more thermoplastic films or sheets by heating areas in contact with each other to the temperature at which fusion occurs. The process is usually aided by a controlled pressure. In

dielectric seaming, the heat is induced within films by means of radio frequency waves.

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

Hip roof—A roof which rises by inclined planes from all four sides on the building. The line where two adjacent sloping sides of a roof meet is called the Hip.

Homopolymer—A natural or synthetic high polymer derived from a single monomer.

Holiday—An area where a liquid applied material is missing, a void.

Hot-dip metallic coating—Adherent protective coating applied by immersing steel in a molten bath of coating material.

Hood—Cover, usually light gage metal, over piping or other rooftop equipment.

“Hot stuff” or “hot”—A roofer’s term for hot bitumen.

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

Humidity test—A test involving exposure of specimens at controlled levels of humidity and temperature.

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<sub>4</sub>, ethylene, butadiene), liquid (hexene, benzene), or solid (Natural rubber, naphthalene, cispolybutadiene).

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—Comprising matter other than hydrocarbons and their derivatives, or matter not of plant or animal origin.

Insulation—See Thermal Insulation.

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

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

Isoboard—Abridgement of polyisocyanurate foam insulation board.

Joist — Any of the small timbers or metal beams arranged parallel from wall to wall to support a floor, ceiling or roof of a building.

Kesternich test—Simulates acid rain conditions by subjecting samples to a sulfur dioxide atmosphere as well as condensing moisture.

Kick-out (Elbow)—(Turn-Out) A lower downspout section used to direct water away from a wall.

Laitance — An accumulation of finer particles on the surface of fresh concrete due to an upward movement of water (as when excessive mixing water is used).

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

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

Layer (Plywood)—A layer is a single veneer ply or two or more plies laminated with parallel grain

direction. Two or more plies laminated with grain direction parallel is a "parallel laminated layer".

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.

Live load—Live load means all loads including snow, exerted on a roof except dead, wind, and lateral loads.

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

Macromolecule—A large molecule in which there is a large number of one or several relatively simple chemical units, each consisting of several atoms bonded together.

Masonry—Anything constructed of materials such as bricks, concrete blocks, ceramic blocks, and concrete.

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

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

Memory—Tendency of a material to regain a previous configuration—notably, the tendency of glass-fiber felts not to lie flat on their substrate after unrolling; the retraction of single-ply roll goods which were stretched during production or winding.

Mer—The repeating structural unit of any high polymer.

Mesh—The square opening of a sieve.

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

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

Mineral Granules—Natural or synthetic aggregate, ranging in size from 500 $\mu$ m (1 $\mu$ m =

10<sup>-6</sup>m) to 1/4 in. diameter, used to surface BUR or modified bitumen cap sheets, asphalt shingles, and some cold process membranes.

Model Codes—Codes established to provide uniformity in regulations pertaining to building construction.

Examples:

Uniform Building Code published by ICBO

National Building Code by BOCA

Standard Building Code by SBCCI

International Building Code (New)

Modulus of elasticity—The ratio of stress (nominal) to corresponding strain below the proportional limit of a material, expressed in force per unit area based on the minimum initial cross sectional area.

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

Moisture contour map—A map with lines connecting continuous levels of moisture. When drawn by computer the wettest areas are often indicated by darkest symbols and the driest areas left blank.

Mole run—A meandering ridge in a membrane not associated with insulation or deck joints.

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

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

from a broom or mop in a random pattern.

**Mud cracking**—Surface cracking resembling a dried mud flat.

**Nail-type concrete anchor**—A hammer-driven fastener with spiral or annular rings that provides pullout strength.

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

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

**Needle punched**—A mechanical entanglement of dry laid (usually cross-lapped, carded staple fiber) webs where barbed needles achieve, in multiple punches, mechanical bonding.

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

**Neutral sealants**—Acid-free and amine-free sealants.

**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.

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

**Nonwoven fabric**—A structure produced by bonding or interlocking of fibers (or both) by mechanical, thermal or solvent means (or combinations thereof).

**Off-ratio mix**—When the mixture of isocyanate and resin does not conform to the manufacturer's recommended mixing ratio. The acceptable ratio for most systems is when the

two components are combined in equal volumes.

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

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

**One-on-one**—See Phased Application.

**Organic, adj.**—Composed of hydrocarbons or their derivatives, or matter of plant or animal origin.

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

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

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

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

**Parapet**—Portion of wall above the roof line.

**Pascal**—SI unit of measure for force per unit area ( $N/m^2$ ).

**Pea gravel**—Small gravel with a diameter approaching that of a pea. Size roughly defined by ASTM D448, Number 7 or smaller.

**Peak**—The uppermost point of a gable.

**Penetration**—The consistency of a bituminous material expressed as the distance in tenths of a millimetre (0.1 mm) that a standard needle or

cone vertically penetrates a sample of material under specified conditions of loading, time, and temperature.

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

Percent water by volume—

$$= \frac{\text{Volume of Water in Sample}}{\text{Volume of Sample}} \times 100$$

Percent water by weight—

$$= \frac{\text{Sample Weight Wet-Sample Weight Dry}}{\text{Sample Weight Dry}} \times 100$$

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

Perm—(vapor transmission) Unit to measure water vapor transmission—one grain of water vapor per square foot per hour per inch of mercury pressure difference. 1 Perm = 1 grain/h•ft<sup>2</sup>•in. Hg = 5.74 x 10<sup>-11</sup> kg/Pa•s•m<sup>2</sup>.

Permeability—(1) The capacity of a porous medium to conduct or transmit fluids; (2) The amount of liquid moving through a barrier in a unit time, unit area and unit pressure gradient not normalized for but directly related to thickness; (3) The product of vapor permeance and thickness (for thin films, ASTM E96—over 3.2 mm (1/8 in.), ASTM C355). Usually reported in perm inches or grain/h•ft<sup>2</sup>•in. Hg per inch of thickness. 1 perm inch = 1.46 x 10<sup>-12</sup> kg/Pa•s•m.

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

Petroleum pitch—A dark brown to black, predominantly aromatic, solid cementitious material obtained by the processing of petroleum, petroleum fractions, or petroleum residuals.

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.

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

Picture framing—A rectangular pattern of ridges in a membrane over insulation or deck joints.

Pig spout—A sheet metal flashing designed to direct the flow of water out through the face of the gutter rather than through a downspout.

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 container placed around a column or other roof penetration and filled with hot bitumen, flashing cement or pourable sealer.

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

Plastic cement—See Flashing Cement.

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

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

Plastisols—Mixtures of resins and plasticizers that can be cast or converted to continuous films

by the application of heat.

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

**Ply (Plywood)**—A single veneer lamina in a glued plywood panel.

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

**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.

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

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

**Polyisocyanurate**—Thermoset polymer formed by polymerization of isocyanate; rigid foam insulation meeting ASTM C1289; a thermal insulation similar in appearance to polyurethane foam, but with improved fire resistance or rating.

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

**Polyols**—A polyhydric alcohol, i.e., one containing three or more hydroxyl groups.

**Polypropylene**  $(C_3H_5)_n$ —A synthetic thermoplastic polymer, with a molecular weight of 40,000 or more.

**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.

**Pond**—A roof area that retains water instead of draining after rainfall.

**Ponding**—Water in low or irregular roof areas that remains longer than 48 hours after the cessation of rainfall.

**Pot Life**—The working time once a product has been reacted (catalyzed).

**Pre-painted coil**—Coil steel which receives a paint coating prior to the forming operation.

**Press brake**—A machine used in cold-forming metal sheet or strip into desired cross-section.

**Prestressed concrete**—Concrete in which the reinforcing cables, wires, or rods in the concrete are tensioned before there is load on the member, holding the concrete in compression for greater strength.

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

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

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

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

down roof assembly).

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

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

Racking—To stretch or strain by force, such as by the thermal or wind action.

Raggle—See Reglet.

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

Rake angle—Angle fastened to purlins at rake for attachment of endwall panels.

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

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

Reentrant corner—An inside corner of a surface, where stress concentrations may occur.

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.

Relative saturation—

$$= \frac{\text{Volume of Water in Sample}}{\text{Maximum volume of water sample could hold}} \times 100$$

Remedial roofing—The repair of selected isolated portions of the roof system to return the roof to uniform condition. This normally involves the removal of wet materials along with correction of the original cause of the problem.

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

Resistance, thermal—See Thermal Resistance.

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

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

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

Ridging—An upward, tenting displacement of a membrane, frequently over an insulation joint.

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

Roll roofing—Coated felts, either smooth or mineral surfaced.

Roof cement—See Flashing Cement.

Roof covering—The exposed exterior roof skin.

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

Roof jack—An accessory used to cover pipes (such as vents or flues) that penetrate the roof panel.

Roof overhang—A roof extension beyond the endwall/sidewall of a building.

Roof seamer—Machine that crimps panels together or that welds laps of E/P systems using

heat, solvent or dielectric energy.

**Roof slope**—The angle a roof surface makes with the horizontal, measured in the number of inches of vertical rise in a horizontal length of 12 inches. (Or as a ratio such as 1:48, or as a per cent.)

**Roofing system**—An assembly of interacting components designed to weatherproof, and normally to insulate, a building's top surface.

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

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

**Saddle**—A small structure that helps to channel surface water to drains. Frequently located in a valley, a saddle is often constructed like a small hip roof or like a pyramid with a diamond-shaped base (also see Cricket).

**Sandwich panel**—A panel assembly used as covering; consists of an insulating core material with inner and outer skins.

**Scarf**—To scrap or abrade a surface to remove degraded or wet polyurethane foam.

**Scupper**—Channel through parapet, designed for peripheral drainage of the roof, usually a safety overflow to limit accumulation of ponded rainwater caused by clogged drains.

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

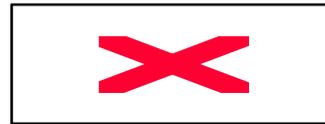
**Sealant**—Any material used to close up cracks or joints to protect against leaks. Lap sealant is applied to exposed lap edges in E/P systems.

**Sealing washer**—A metal-backed rubber washer assembled on a screw to prevent water from

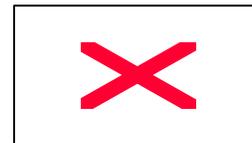
migrating through the screw hole.

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

**Self-drilling screw**—A fastener that drills and taps its own hole, used as a fastener for attaching panels to purlins and girts.



**Self-tapping screw**—A fastener that forms receiving threads when turned into a previously drilled hole. It is for attaching panels to purlins and girts and for connecting trim and flashing.



**Selvage**—An edge or edging which differs from the main part of: (1) a fabric, or (2) granule surfaced roll roofing.

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

**Shark fin**—Curled felt projecting upward through the flood coat and aggregate of a BUR membrane.

**Shear**—The force tending to make two contacting parts slide upon each other in opposite directions parallel to their plane of contact.

**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.

Shelf life—Maximum safe time to store a fluid construction material before use.

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

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

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

Sidelap—The continuous overlap of closures along the side of a panel.

Sieve—An apparatus with square apertures for separating sizes of material.

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

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

Siphon break—A small groove to arrest the capillary action of two adjacent surfaces.

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

Slab—A semi-finished steel product, intermediate between ingot and plate, with the width at least twice the thickness.

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

Slope—Tangent of the angle between the roof surface and the horizontal plane, expressed as a

percentage, or in inches of rise per foot of horizontal distance. (See also Incline)

Smooth surfaced roof—A roof membrane without mineral aggregate surfacing.

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

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

Softening point drift—Change in softening point during storage or application. (See also Fallback)

Solid mopping—See Mopping.

Sprinkle mopping—See Mopping.

Spud—To remove the roofing aggregate and most of the bituminous top coating by scraping and chipping.

Spudder—Heavy steel implement with a dull, bevel-edged blade for removing embedded aggregate from a BUR membrane surface.

Spunbonded—A generic name for nonwoven fabrics formed directly from polymer chips, spun into continuous filaments which are laid down and bonded continuously, without an intermediate step.

Spunlaced—A hydroentangled nonwoven fabric whereby a dry laid staple fabric is mechanically bonded by water jet which entangles the individual fibers.

Square—A roof area of 9.29 m<sup>2</sup> (100 ft<sup>2</sup>), or enough material to cover 9.29 m<sup>2</sup> of deck.

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

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

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

**Standing water test**—Evaluations in which test panels are submerged in aqueous solutions and alternately dried in air.

**Starting platform**—A movable platform used to support a seaming machine as it begins to roll-seal a metal seam.

**Steep asphalt**—A relatively viscous roofing asphalt conforming to the requirements of Specification D312, Type III.

**Strain**—Deformation under stress.

**Strawberry**—See Blueberry.

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

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

**Stress relaxation**—The time-dependent change in the stress resulting from 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.

**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 reinforcing scrim.

**Strippable films**—Added protection sometimes applied to continuous strip in coil coating process. Applied after prime and topcoats to resist damage prior to and during erection.

**Stripping**—Strip flashing: (1) The technique of sealing a joint between metal and bituminous 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.

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

**Substrate**—Surface upon which a roof component is placed (structural deck or insulation).

**Super-steep asphalt**—A high viscosity roofing asphalt conforming to the requirements of Specification D312, Type IV.

**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.

**Surfactants**—Surface active agents that reduce surface tension when dissolved in water or water solutions, or reduce interfacial tension between two liquids, or between a liquid and a solid.

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

**Tack-free**—A film is considered tack-free when the finger, with a slight pressure, will not leave a mark. The surface will not be sticky.

**Tapered edge strip**—A tapered insulation strip used to elevate the roofing at the perimeter and at penetrations of the roof.

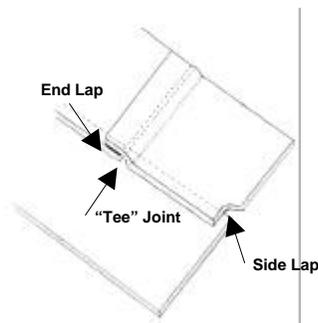
**Tar boils**—Bubbles of moisture vapor encased in a thin film of bitumen, also known as blueberry, blackberry, etc.

**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.

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

**Tee joint**—the condition created by the overlapping intersection of three or four sheets in the membrane.



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

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

**Therm**—A unit of heat commonly used by utilities, equivalent to 100,000 BTU =  $1.05 \times 10^6$  joules.

**Thermal block**—A spacer of low thermal conductance material, designed to prevent formation of a thermal bridge.

**Thermal bridge**—Interruption of a layer of thermal insulation by a material of high thermal conductivity (e.g. metal).

**Thermal conductance (C)**—The rate of heat flow through a material whose surfaces have stated a temperature differential  $\text{Btu} \cdot \text{in.} / \text{h} \cdot \text{ft}^2 \cdot ^\circ\text{F}$  ( $\text{W} / \text{m}^2 \cdot ^\circ\text{C}$ ).

**Thermal conductivity (k)**—The rate of heat flow

through a stated thickness of material with a stated temperature differential  $\text{Btu} / \text{h} \cdot \text{ft}^2 \cdot ^\circ\text{F}$  ( $\text{W} / \text{m}^2 \cdot ^\circ\text{C}$ ).

**Thermal insulation**—A material designed to reduce the conductive heat flow.

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

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

**Thermogram**—A visible light record of the display of an infrared camera system via a Polaroid print, 35 mm film, or videotape.

**Thermography**—A technique for producing heat pictures from the invisible radiant energy emitted from stationary or moving objects at any distance and without in any way influencing the temperature of the objects under view. The electronic generation and display of a visible image of an infrared spectrum.

**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 in 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.

**Thermoset**—A material that will undergo (or has undergone) a chemical reaction by the action of heat, catalysts, ultraviolet light, etc., leading to a relatively infusible state.

**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 to the exterior.

**Toggle bolt**—A two-piece assembly consisting of

a threaded bolt and an expanding clip that can fit through a drilled bolt hole, then spring outward to provide anchorage from the blind side.

Trim—The light gauge metal used in the finish of a building, especially around openings and at intersections of surfaces. Often referred to as flashing.

Tuck pointing—The filling in with fresh mortar of cutout or defective mortar joints in masonry.

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

Ultimate elongation—The elongation of a stretched specimen at the time of break. Usually reported as percent of the original length. Also called breaking strain.

Unsupported sheeting—A polymer sheeting one or more plies thick without a reinforcing fabric layer or scrim.

Uplift—Wind load on a building which causes a load in the upward direction. (See Suction)

Valley gutter—A channel used to carry off water at the intersection of two sloping roof planes.

Vapor barrier—See Vapor Retarder.

Vapor migration—The flow of water vapor from a region of high vapor pressure to a region of lower vapor pressure.

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

Vapor retarder—A material that resists the flow of water vapor.

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

Ventilator—An accessory usually used on the roof that allows air to pass through.

Vermiculite—An aggregate used in lightweight

insulating concrete, formed by heating and expanding a micaceous mineral.

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

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

Vulcanization—An irreversible process during which a rubber compound, through a change in its chemical structure, e.g., cross-linking, 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.

Warp—In textiles, the lengthwise yarns in a woven fabric.

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  $\text{g}/\text{h}\cdot\text{m}^2$  (grains/ $\text{h}\cdot\text{ft}^2$ ).  $1 \text{ grain}/\text{h}\cdot\text{ft}^2 = 0.697 \text{ g}/\text{h}\cdot\text{m}^2$ .

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

Weatherometer—An instrument used to subject specimens to accelerated weathering conditions, e.g., rich UV source and water spray.

Wicking—The process of moisture movement by capillary action as contrasted to movement of water vapor.

Yield strength—(1) The longitudinal stress a material can bear before plastic deformation (i.e., elongation under constant stress); (2) The stress at which a material exhibits a specified reduction in the constant stress/strain ratio is the elastic range.

Yield strength—The stress at which a material exhibits a specified deviation from proportionality of stress and strain.

APPENDIX E  
METRIC PRACTIC GUIDE FOR ROOFING INDUSTRY  
Conversion Factors

Property	to Convert from	Symbol	to	Symbol	Multiply by	Remarks
Application rate	U.S. gallon per square	gal (U.S.)/ 100 ft <sup>2</sup>	litre per square metre	litre/m <sup>2</sup>	0.4075	= 0.4075 mm thick
	U.K. gallon per square	gal (U.K.)/ 100 ft <sup>2</sup>	litre per square metre	litre/m <sup>2</sup>	0.4893	= 0.4893 mm thick
Area	square inch	in. <sup>2</sup>	square millimetre	mm <sup>2</sup>	645.2	1 000 000 mm <sup>2</sup> = 1 m <sup>2</sup>
	square foot square	ft <sup>2</sup> 100 ft <sup>2</sup>	square metre square metre	m <sup>2</sup> m <sup>2</sup>	0.092 90 9.290	
Breaking Strength	pound force per inch width	lbf/in.	kilonewton per metre width	kN/m	0.175	
Coverage	square foot per U.S. gallon	ft <sup>2</sup> /gal	square metre per litre	m <sup>2</sup> /litre	0.024 54	
	square foot per U.K. gallon	ft <sup>2</sup> /gal	square metre per litre	m <sup>2</sup> /litre	0.020 44	
Density, or mass per unit volume	pound per cubic foot	lb/ft <sup>3</sup>	kilogram per cubic metre	kg/m <sup>3</sup>	16.02	water = 1000 kg/m <sup>3</sup>
Energy or work	kilowatt-hour British thermal unit	kWh Btu	megajoule joule	MJ J	3.600* 1055	J=W*s = N*m
Flow, or volume per unit time	U.S. gallon per minute	gpm	cubic centimetre per second	cm <sup>3</sup> /s	63.09	or 0.0631litre/s
	U.K. gallon per minute	gpm	cubic centimetre per second	cm <sup>3</sup> /s	75.77	or 0.0758litre/s
Force	pound force	lbf	newton	N	4.448	
	kilogram force	kgf	newton	N	9.807	N = kg*m/s <sup>2</sup>
Heat flow	thermal conductance, C	btu/ft <sup>2</sup> *oF	watt per square metre kelvin	W/m <sup>2</sup> *K	5.678	
	thermal conductivity, k	btu*in./ft <sup>2</sup> *oF	watt per metre kelvin	W/m*K	0.1442	

Incline	inch per foot	in./ft	percent	%	8.333	3 in./ft = 25%
Length, width, thickness	mil	0.001 in.	micrometre	µm	25.40*	1000 µm = 1mm
	inch (up to ~48 in.)	in.	millimetre	mm	25.40*	1000 mm=1m
	foot (~4 ft and above)	ft	metre	m	0.3048*	
Mass (weight)	ounce	oz	gram	g	28.35	1000 g = 1 kg
	pound	lb	kilogram	kg	0.4536	1000 kg = 1 Mg
	short ton	2000 lb	megagram	Mg	0.9072	
Mass per unit area	pound per square foot	lb/ft <sup>2</sup>	kilogram per square metre	kg/m <sup>2</sup>	4.882	
	pound per 100 square foot (roofing square)	lb/sq	kilogram per square metre	kg/m <sup>2</sup>	488.2	
	pound per square foot	lb/ft <sup>2</sup>	gram per square metre	g/m <sup>2</sup>	4882	
	pound per square	lb/100 ft <sup>2</sup>	gram per square metre	g/m <sup>2</sup>	48.82	
	ounce per square yard	oz/yd <sup>2</sup>	gram per square metre	g/m <sup>2</sup>	33.91	
Permeability at 23°C	perm inch	grain*in./ft <sup>2</sup> *h*in. Hg	nanogram/pascal second metre	ng/Pa*s*m	1.459	ng = 10 <sup>-12</sup> kg
Permeance at 23°C	perm	grain/ft <sup>2</sup> *h*in. Hg	nanogram/pascal second square metre	ng/Pa*s*m <sup>2</sup>	57.45	1 grain = 64.8 mg
Power	horsepower	hp	watt	W	746	W = N*m/s + J/s
Pressure or stress	pound force per square inch	lb/in. <sup>2</sup> or psi	kilopascal	kPa	6.895	Pa = N/m <sup>2</sup>
	pound force per square foot	lb/ft <sup>2</sup> or psf	pascal	Pa	47.88	
Temperature	degree Fahrenheit	°F	degree Celsius	°C	(t <sub>c</sub> -32)/1.8*	32°F = 0°C
	degree Celsius	°C	kelvin	K	t <sub>c</sub> +273.15*	273.15 K = 0°C
Thread count (fabric)	threads per inch width	threads/in.	threads per centimetre width	ftreads/cm	0.394	
Velocity (speed)	foot per minute	ft/min or fpm	metre per second	m/s	0.005 080*	
	mile per hour	mile/h or mph	kilometre per hour	km/h	1.609	
Volume	U.S. gallon	gal (U.S.)	cubic metre	m <sup>3</sup>	0.003 785	or 3.785 litres
	U.K. gallon	gal (U.K.)	cubic metre	m <sup>3</sup>	0.004 546	or 4.546 litres
	cubic foot	ft <sup>3</sup>	cubic metre	m <sup>3</sup>	0.028 32	
	cubic yard	yd <sup>3</sup>	cubic metre	m <sup>3</sup>	0.764 6	