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Roofing Maintenance Management System

ROOFER: An Engineered Management System (EMS) for Bituminous Built-Up Roofs

by
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This report gives instructions for using ROOFER, an engineered management system for bituminous built-up roofs that is designed to help military installations make the best use of roof maintenance and repair (M&R) funds.

This system includes procedures for dividing roofs into manageable sections; collecting and maintaining inventory information, surveying, rating, and evaluating roof condition; and determining general M&R needs and priorities.

The overall roof condition rating procedure is based on the Roof Condition Index, which is composed of separate condition indexes for the membrane, flashing, and insulation.

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This system includes procedures for dividing roofs into manageable sections; collecting and maintaining inventory information, surveying, rating, and evaluating roof condition; and determining general M&R needs and priorities.

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FOREWORD

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COL Carl O. Magnell is Commander and Director of USACERL, and Dr. L. R. Shaffer is Technical Director.

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ROOFER: AN ENGINEERED MANAGEMENT SYSTEM (EMS) FOR BITUMINOUS BUILT-UP ROOFS

1 INTRODUCTION

Background

Each of the U.S. armed services branches has a very large inventory of roofs with bituminous built-up membranes. Roof repairs and reconstruction are steadily increasing as the roofs approach the end of their service lives, making it increasingly important to better manage maintenance funds. Currently, there is need for a systematic procedure to determine priorities and select repair strategies that will ensure a maximum return on investment.

In response to this problem, the U.S. Army Construction Engineering Research Laboratory (USACERL), with the assistance of the U.S. Army Cold Regions Research and Engineering Laboratory (USACRREL) and the U.S. Army Engineering and Housing Support Center (USAEHSC), has developed ROOFER, a roofing maintenance management system. ROOFER provides military installations with a practical decision-making procedure to identify problems and select maintenance and repair strategies for roofs with bituminous membranes.

Objective

This report describes ROOFER, a maintenance management system for bituminous built-up roofs designed to make the best use of maintenance and repair (M&R) funds.

Organization of Report

Chapter 2 discusses the process of dividing the roof network into manageable sections and the procedure for collecting and managing roof inventory information. Chapter 3 summarizes the visual inspection procedure. A complete description of the visual inspection procedure can be found in *Membrane and Flashing Condition Indexes for Built-Up Roofs, Volume II: Inspection and Distress Manual.*[1] This field-validated procedure is used to determine the severity of existing membrane and flashing distresses and to compute the membrane condition index (MCI) and flashing condition index (FCI). These indexes measure the component's functional condition, M&R requirements, and waterproof integrity. Chapter 4 contains roof moisture detection procedures and a means for computing the insulation condition index (ICI). Chapter 5 discusses the strategies for maintenance and repair based on the Roof Condition Index (RCI), which is computed from the three individual indexes (i.e., MCI, FCI, and ICI).

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[1]M. Y. Shahin, D. M. Bailey, and D. E. Brotherson, *Membrane and Flashing Condition Indexes for Built-Up Roofs, Volume II: Inspection and Distress Manual,* Technical Report M-87/13 (U.S. Army Construction Engineering Research Laboratory [USACERL], September 1987).

Scope

Although ROOFER is designed for maintenance management of bituminous built-up roofs, it is adaptable to all types of low-slope roofing systems. This flexibility will allow these other roofing systems to be incorporated into ROOFER in the future.

Mode of Technology Transfer

More information about the ROOFER Engineered Management System and Micro ROOFER, including fact sheets, technical reports, software links, and support points of contact, may be found by a search of ERDC/CERL's Publications or Products/Capabilities web pages starting at http://www.cecer.army.mil/td/tips/.

[Original text revised 18 December 2003 by Gordon L. Cohen, editor, CEERD-II-P.]

[2]Technical Manual (TM) 5-617, *Facilities Engineering Inspection, Maintenance, and Repair of Roofing Systems* (Draft).

2 INVENTORY AND DATA MANAGEMENT PROCEDURE

The roof inventory is the foundation of ROOFER. It provides the information needed by engineering personnel to select repair techniques and determine the suitability of replacement systems. A well-maintained inventory will also provide a structural history of each roof and a record of roof performance that can be used to determine which roof system is most suitable for use on a particular building type or occupancy. The inventory data and condition evaluation data (discussed in Chapters 3, 4, and 5) are used to determine maintenance and repair strategies.

Roof Network Identification

A roof network, as defined for the ROOFER system, consists of all the low-slope roofs maintained by an installation. This network is generally divided into the following manageable components:

Building

A building consists of one distinct structure that may include several wings or sections, but generally has one building number or designation. Buildings connected by covered walks or enclosed passageways should be considered separately unless they are designated by the same building number. Building complexes with only one building number or designation should be given subdesignations for easier identification.

Roof Section

A roof section is a roof, or part of a roof, that is identifiable as a separate entity. The section is distinct in that it may represent one level of a building's roof having many levels. A section may also be part of a very large roof that is physically divided by firewalls, expansion joints, area dividers, or some other identifiable boundary. For smaller buildings, the roof section may be the entire roof.

Dividing the roof of a building into sections provides a better means of evaluating the condition and determining Maintenance, Repair, and Replacement (MRR) needs. For example, a roof section that is in poor condition would not detract from the condition assessment of a roof section in good condition on the same building, and a condition evaluation indicating replacement of a section would not signal replacement of the entire roof.

Guidelines for Section Identification

A section is generally delineated by:

- firewalls, expansion joints, or area dividers
- different roof levels
- areas that were built at different times
- areas having different roofing systems, different amounts of roof traffic and/or rooftop equipment, or radically different occupancies below the roof.

A building's roof sections are assigned letter designations (A, B, C, D...).

If a roof is physically divided into many small areas, it may be possible to combine several such areas into one section (e.g., all the canopies over entrances may be grouped into one section provided they are of similar age and construction). However, if areas have different structural systems, roof systems, or environments below the roof (i.e., canopies, freezers, or unheated warehouses), they should be treated as individual sections. Large areas without obvious delineations can be arbitrarily divided into areas of 25,000 to 40,000 sq ft.*

Recordkeeping System

The information needed to successfully manage a roof network must be stored in a way that makes the data accessible and usable. The manual system described in this report affords easy conversion to a computerized system. Once stored, the information about each building and roof section can be used to develop reports that are needed to effectively manage large networks of building roofs or individual roof projects. Figure 1 shows an example of a filing sequence for a typical recordkeeping system. The file should contain a Building Folder for each building and a Roof Section Folder for each roof section on the building.

Building Folder

The Building Folder should contain a completed Building Identification Sheet (Figure 2) which includes a building roof plan. The building roof plan should show overall dimensions and identify each roof section. It should be drawn to a scale that will fit in the space provided on the sheet. For large buildings, a scale of 1 in. = 30 ft or 1 in. = 60 ft will probably be required to show the entire roof. Contract drawings, specifications, and as-built drawings for any work done on the building should also be kept in the building folder, or if they are kept elsewhere, their location should be stated in the folder.

Roof Section Folder

A Roof Section Folder should be established for each roof section containing a completed Roof Section Identification Sheet (Figure 3), and a Roof Inspection Worksheet (Figure 4). A roof section plan should be drawn to scale on the Roof Inspection Worksheet. The plan should show all physical features including perimeter conditions (roof edge, expansion joint, parapet wall, etc.), rooftop equipment, projections through the roof, roof drains, walkways, sign supports, and piping. The standard symbols shown in Figure 5 should be used to identify these items whenever possible.

A master Roof Inspection Worksheet with an unmarked roof section plan should be kept in each folder. Copies of the Roof Inspection Worksheets (discussed in Chapter 3) are used to conduct condition evaluation inspections. They are filled out and stored in the Roof Section Folder. Roof distresses or defects identified during the inspections are noted on the plan for future reference and to help determine maintenance and repair needs.

A blank Roof Inspection Worksheet is included in Appendix A of this report.

Inventory Data Collection

The information on the Building and Roof Section Identification Sheets can come from a variety of sources. At installations with complete building records, most of the information can be taken from

*Metric conversion factors are on page 55.

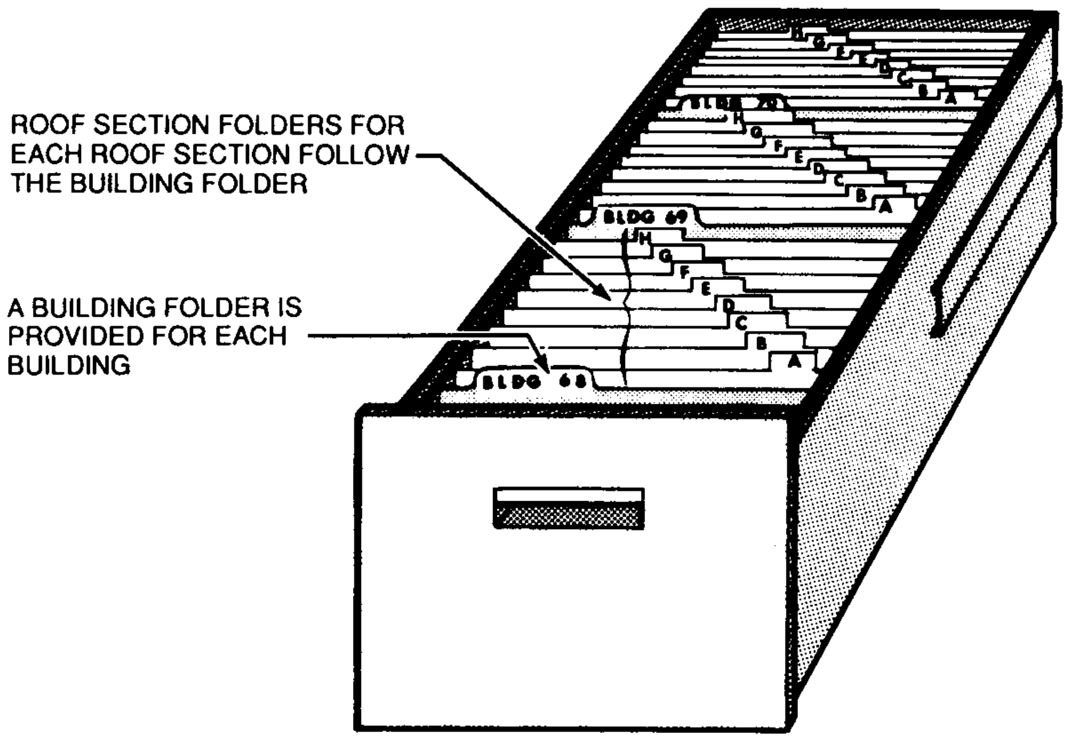


Figure 1. Example of a manual recordkeeping system.

as-built drawings, record drawings, and specifications. Because these drawings and specifications often do not show actual conditions, all data should be verified during the visual inspection. Core samples taken for the purpose of verifying wet insulation (Chapter 4) should be used to determine the components of the roof sections.

It is important that the collected information be as complete as possible. Missing data will make analysis and planning difficult. Although this phase does require some investment of time and effort, it needs to be done only once and then updated when changes to the roof system occur.

Building Identification Sheet

The Building Identification Sheet (Figure 2) is kept in the Building Folder and gives general information including building name, number, location, and occupancy. The Building Identification Sheet also lists each roof section and its area, and the date of original construction of the building. Although some of the information is not directly related to the roofing system, it does provide essential data for managing the network.

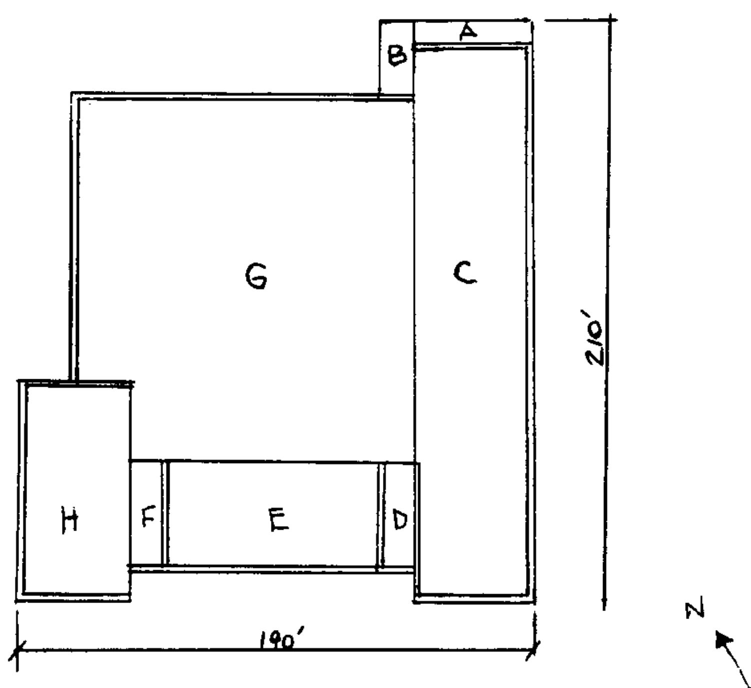
BUILDING IDENTIFICATION		AGENCY/INST. NO.: 9 9 9 9 9
DATE: 4 / 25 / 1987	AGENCY/INST.: FT. JONES	
BUILDING NAME: TROOP TRAINING		
BUILDING NUMBER: 68	DESIGN CATEGORY CODE 1 1 7 1 2 0	
TYPE CONST. P	FACILITY NUMBER 0 0 0 6 8	
LOCATION: 1206 THUNDERBIRD AVE		
USE: CLASSROOM TRAINING		YEAR BUILT: 1968

ROOF SECTIONS:

A	436	SF	F	418	SF	K		SF
B	352	SF	G	16,800	SF	L		SF
C	7843	SF	H	3128	SF	M		SF
D	418	SF	I		SF	N		SF
E	3128	SF	J		SF	O		SF

REMARKS:

MAJOR RENOVATION 10-85
- REPLACED WINDOWS
- STEEL SIDING ON EXTERIOR



BUILDING ROOF PLAN SCALE: 1" = 60'

Figure 2. Completed Building Identification Sheet.

ROOF SECTION IDENTIFICATION		AGENCY/INST.: FT. JONES	
DATE: MAY / 1987	BLDG NO: 68	SECTION ID: 6	AREA: 16,800 SF
OCCUPANCY:	YEAR ORIG CONST:		YEAR LAST REPLACED: 1978

10 GENERAL

11 PERIMETER:

PARAPET	243 LF	AREA DIVIDER	___ LF
ROOF EDGE	161 LF	ADJ. WALL	___ LF
EXP. JOINT	124 LF	OTHER	___ LF

12 ACCESS: ADJACENT ROOF SECTION F

20 STRUCTURAL FRAME

21 TYPE: CONCRETE - BEAMS

30 ROOF DECK

31 TYPE: CONCRETE, STD. CAST-IN-PLACE

32 DESIGN LOAD:
LIVE 25 PSF
DEAD 50 PSF

33 SLOPE: 1/8 IN 12

34 DRAINAGE: INTERIOR DRAINS

40 VAPOR RETARDER

41 TYPE: LAMINATED FELTS

50 INSULATION

51 TYPE: PERLITE AND POLYURETHANE BOARDS

52 PHYSICAL PROPERTIES:

	BOARD STOCK	FILLS
THICKNESS (in.)	3	___
NO. OF LAYERS	2	___
TAPERED	N	___

53 R-VALUE: 15

54 ATTACHMENT: ADHESIVE - HOT

60 MEMBRANE

61 PRODUCT:

PROTECTED MEMBRANE N (Y/N)

MANUFACTURER CELOTEX
SPECIFCATION NO. ___

DESCRIPTION BASE SHEET + 3 PLIES
WARRANTY N (Y/N)
EXP. DATE ___

62 TYPE: BUILT-UP ASPHALT

63 ATTACHMENT:

64 REINFORCEMENT: GLASS FELTS

65 SURFACING: CRUSHED STONE

66 WALKWAYS: WOOD DUCK BOARDS

70 FLASHING

71 BASE FLASHING: MINERAL SURFACED ORGANIC

72 FLASHING ADHESIVE: COLD MASTIC

73 COUNTERFLASHING: METAL

74 FLASHING TYPES: PARAPET, EXP. JT., PLUMBING VENT, PIPE SUPPORTS - WOOD BLOCKS, PITCH PAN

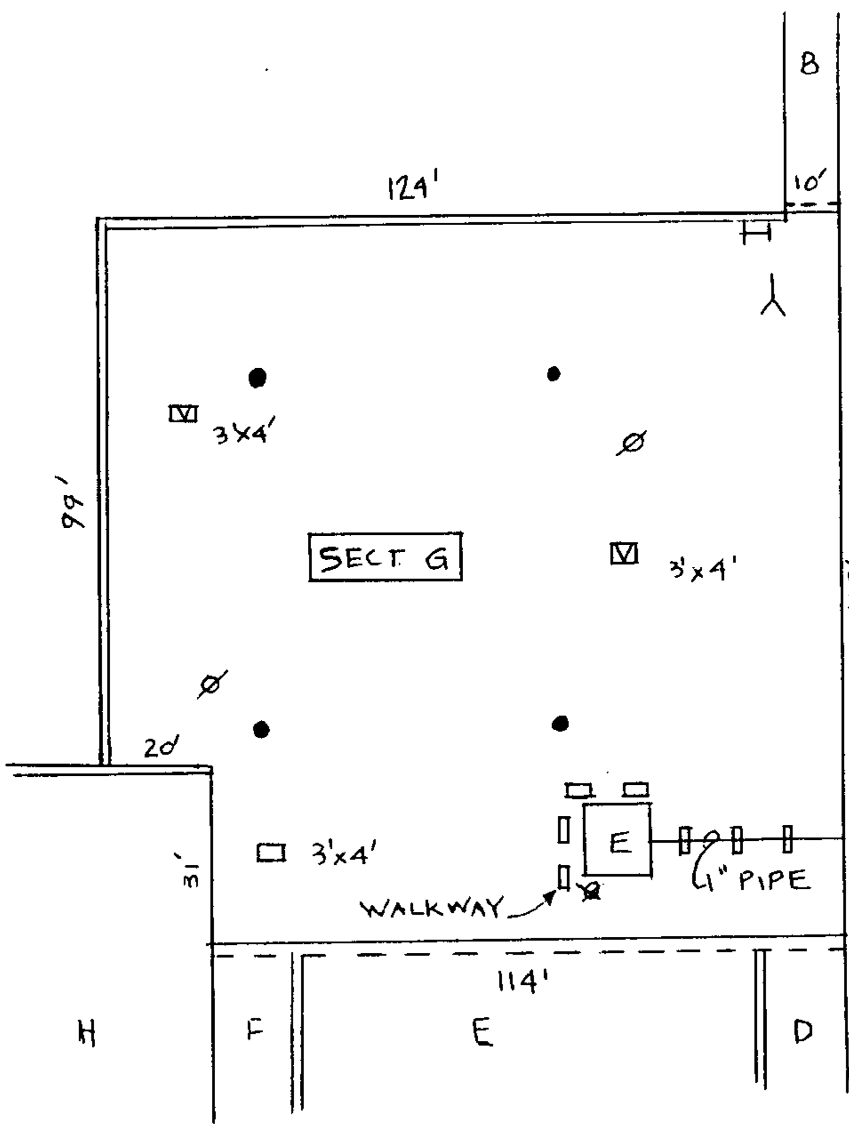
80 REMARKS:

Figure 3. Completed Roof Section Identification Sheet.

ROOF INSPECTION WORKSHEET	AGENCY/INST.: FT. JONES		
BUILDING 68	PER. FLASHING 527 LF	DATE	
SECTION 6	CURB FLASHING 36 LF	NAME	

BF-BASE FLASH	PP-PITCH PANS	SP-SPLITS	PA-PATCHING
MC-METAL CAP	DR-DRAIN & SC	HL-HOLES	DV-DEBRIS & VEG
EM-EMBEDD MET	BL-BLISTERS	SR-SURF DET	EQ-EQ SUPPORT
FP-FLASHED PEN	RG-RIDGES	SL-SLIPPAGE	PD-PONDING

ID #	DIS	SEV	DEF	QTY



SCALE: 1" = 30'

NORTH

Figure 4. Roof Inspection Worksheet with Roof Section Plan.

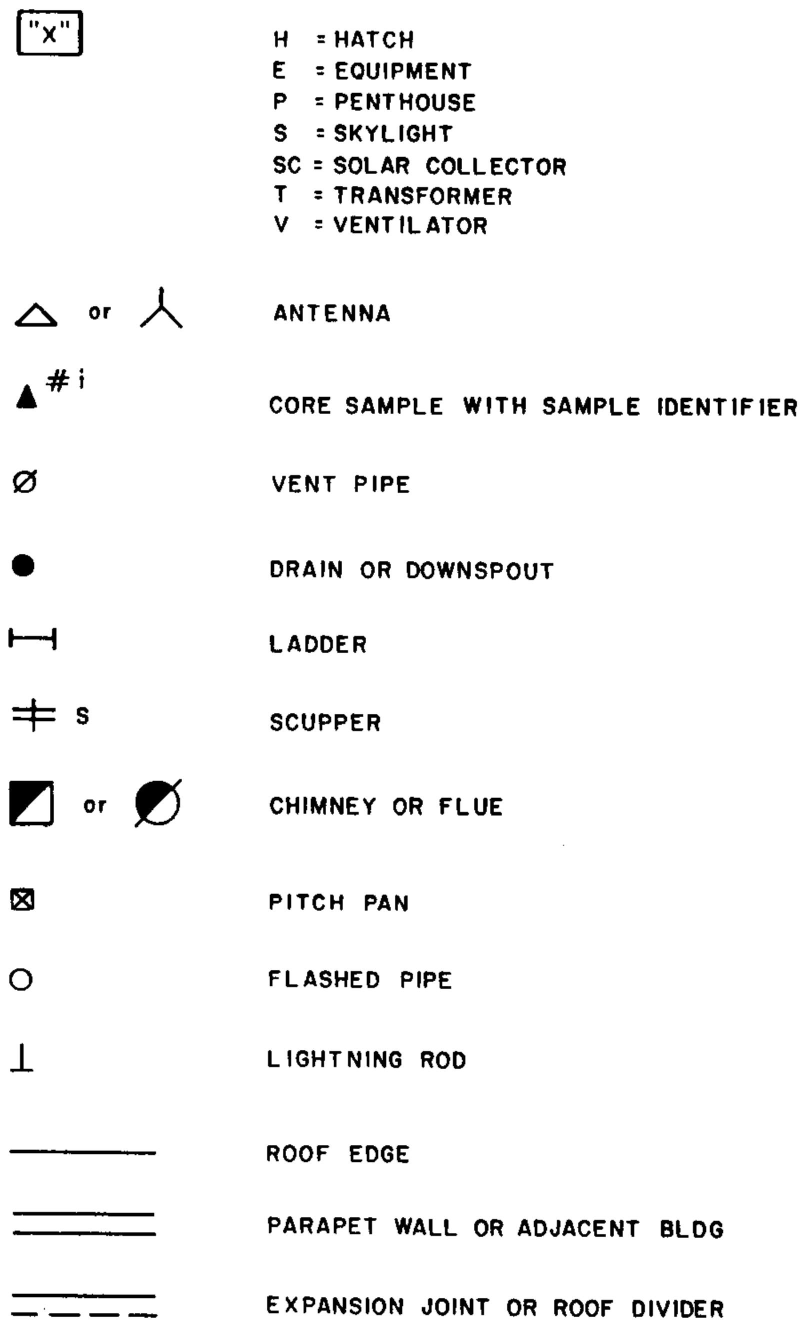


Figure 5. Symbols to be used on roof section plans.

Roof Section Identification Sheet

The Roof Section Identification Sheet (Figure 3) is completed for each roof section listed on the Building Identification Sheet and is kept in the corresponding Roof Section Folder. The sheet has eight major divisions and organizes the section data.

Roof Section Identification Worksheet

The three-page Roof Section Identification Worksheet (Figure 6) simplifies the task of collecting the necessary data and ensures uniformity in reporting terminology. Most of the items are self-explanatory and the collection process only requires checking-off items pertaining to the roof section. Much of the data can be obtained from specifications, drawings, core cuts, and visual inspection. Some guidance is provided below. The information from these worksheets is transferred to the Roof Section Identification Sheet.

Descriptions of the collected inventory data follow:

General

Section 11 - Perimeter. The length (in feet) of the perimeter of the roof section categorized into the listed construction "edges."

Section 12 - Access. The method used to gain access to the roof. Note whether the ladder is inside or outside the building and if it is permanently attached to the building. If it is not, a portable ladder will be necessary for inspection. If access is from an adjacent roof section, identify the section.

Structural Frame

Section 21 - Type. The structural framing system which supports the roof section.

Roof Deck

Section 31 - Deck Type. The roof deck construction supporting the roofing system.

Section 32 - Design Load. The live and dead loads for the roof section. This information can usually be found on the building's structural drawings. Check in the general notes or in a special note on the Roof Framing Plan.

Section 33 - Slope. The predominate slope of the roof section. The roof plan will generally indicate the slope (e.g., 1/4 in. in 12 in.). If the slope is not noted on the roof plan, the section drawings may indicate the slope. Measure the major slope if it cannot be found on the roof plan or section drawings.

Section 34 - Drainage. The existing means of removing rainwater from the roof section. Check the roof section for interior drains, gutters, and downspouts. Determine whether leaders and downspouts are connected to the scuppers. Check for overflow scuppers which control the height of ponded water and prevent overloading of the structure. ROOF EDGE indicates that the roof water flows over the building edge to the ground or to a lower roof area without gutters or scuppers.

ROOF SECTION IDENTIFICATION WORKSHEET		AGENCY/INST.: FT. JONES	
DATE: MAY / 1987	BLDG NO: 68	SECTION ID: G	AREA: 16,800 SF
OCCUPANCY: OFFICE	YEAR ORIG CONST: ____		YEAR LAST REPLACED: 1978

10 GENERAL

11 PERIMETER:

PARAPET	243 LF	EXP. JOINT	124 LF	ADJ. WALL	____ LF
ROOF EDGE	161 LF	AREA DIVIDER	____ LF	OTHER	____ LF

12 ACCESS (check one):

INTERNAL LADDER
__ Permanent
__ Temporary

EXTERNAL LADDER
__ Permanent
__ Temporary

__ PENTHOUSE
X ACCESSED FROM ADJACENT ROOF SECT (Sec. ID F)

20 STRUCTURAL FRAME

21 TYPE (check one):

STEEL
__ Beams, Girders, Cols.
__ Long Sp Deck, Beams
__ Trusses
__ Bar Joists With Beams and Cols.
__ Bar Joists With Bearing Walls
__ Bar Joists With Combination

CONCRETE
X Beams
__ Flat Slab

WOOD
__ Laminated Beams
__ Trusses
__ Joists
__ Panels

SPECIAL
__ Dome
__ Space Frame

__ UNKNOWN

30 ROOF DECK

31 TYPE (check one):

NONCOMBUSTIBLE

__STEEL

CONCRETE, STD.
Precast
X Cast-In-Place

GYPSUM
__ Fiberboard Form
__ Fiberglass Form
__ Gypsum Form
__ Precast

CONCRETE, L.W.
__ Precast
__ Cast-In-Place
__ Vermiculite
__ Cellular
__ Perlite

CEMENT FIBER
__ Bulb-Tees
__ Clipped

COMBUSTIBLE

__ WOOD BOARDS

__ PLYWOOD

__ WOOD FIBER

32 DESIGN LOAD:

LIVE 25 PSF
DEAD 50 PSF
__ UNKNOWN

33 SLOPE: 1/8 **IN 12**

34 DRAINAGE (check all):

X INTERIOR DRAINS
__ GUTTERS & DOWNSPOUTS
__ SCUPPERS
__ ADJACENT ROOF SECTION
__ SCUPPERS W/LEADERS AND DOWNSPOUTS
__ OVERFLOW SCUPPERS
__ ROOF EDGE

40 VAPOR RETARDER

41 TYPE (check one):

__ NONE
__ ALUMINUM FOIL
__ POLYETHYLENE
__ COATED ROLL ROOFING
__ LAMINATED ASPH/KRAFT
X LAMINATED FELTS
__ PVC
__ VINYL
__ UNKNOWN

Figure 6. Completed Roof Section Identification Worksheet.

50 INSULATION

51 TYPE (check all):

- __ NONE
- __ WOOD FIBERBOARD
- __ GLASS FIBER
- X PERLITE
- X POLYURETHANE/BOARD
- __ EXPANDED POLYSTY.
- __ EXTRUDED POLYSTY.
- __ FOAMGLASS
- __ PHENOLIC
- __ POLYISOCYANURATE
- __ CORK
- __ FOAMED IN PLACE/PUF

INSULATING FILLS
- __ Vermiculite
- __ Perlite
- __ Cellular
- __ Gypsum
- __ Lwt. Concrete
- __ Fill Type Unknown

__ UNKNOWN

52 PHYSICAL PROPERTIES: __ N/A (No Insul.)

BOARD STOCK

TOTAL THICKNESS 3 INCHES

NO. OF LAYERS 2

TAPERED N (Y/N)

FOAMED IN PLACE AND INS. FILLS

TOTAL THICKNESS ______ INCHES

TAPERED ______ (Y/N)

53 R-VALUE (total): ______ __ UNKNOWN __ N/A (No Insul.)

54 ATTACHMENT (board stock only)(check all):

- __ MECHANICAL
- __ LOOSE LAID
- X ADHESIVE-HOT
- __ ADHESIVE-COLD
- __ UNKNOWN

60 MEMBRANE

61 PRODUCT: __ UNKNOWN

MANUFACTURER CELOTEX

SPECIFICATION NO. ______

PROTECTED MEMBRANE N (Y/N)

DESCRIPTION BASE SHEET + 3 PLY

WARRANTY N (Y/N) EXP DATE __

62 TYPE (check one):

BIT. BUILT-UP
- X Asphalt
- __ Coal Tar Pitch
- __ Cold Process\ Emulsion
- __ Cold Process\ Cutback
- __ Bit. Type Unknown

MODIFIED BITUMEN
- __ SBS
- __ APP
- __ Modifier Unknown

ROLL ROOFING
- __ Org./Min. Surface
- __ Glass/Min. Surface
- __ Smooth

SINGLE-PLY
- __ EPDM
- __ CPE
- __ CSPE
- __ PIB
- __ PVC
- __ Butyl
- __ Neoprene
- __ Nitrile
- __ Type Unknown

LIQUID APPLIED
- __ Neoprene/Hypalon
- __ Acrylic Elastomer
- __ Butyl
- __ Polysulfide
- __ Urethane
- __ Silicone
- __ Type Unknown

PUF WITH COATING
- __ Silicone
- __ Urethane
- __ Catal. Urethane
- __ Acrylic
- __ Coating Unknown

63 ATTACHMENT (for Single-Ply only)(check one):

- __ FULLY ADHERED
- __ LOOSE/BALLASTED
- __ PLATE/DISK/PARTIALLY ADHERED

MECH. FASTENERS
- __ Penetrating
- __ NonPenetrating

64 REINFORCEMENT (check one):

BIT. BUILT-UP
- __ Organic Felt
- X Glass Felt
- __ Asbestos Felt
- __ Felt Type Unknown

MODIFIED BITUMEN & SINGLE-PLY
- __ Polyester, Woven
- __ Polyester, Nonwoven
- __ Glass
- __ Asbestos
- __ Fleece, Synthetic
- __ Felt
- __ Laminate Backer
- __ Polyethylene
- __ Reinforcement Unknown
- __ No Reinforcement

Figure 6. (Cont'd)

65 SURFACING (check one):

AGGREGATE
__ River Gravel
X Crushed Stone
__ Slag
__ Pea Gravel
__ Volcanic Rock
__ Marble Chip
__ Limestone
__ Aluminum Granule
__ Mineral Granule
__ Agg. Unknown

SMOOTH
__ Cutback
__ Emulsion
__ Hot Asphalt
__ Bit. Type Unknown

__ REFLECTIVE

__ ELASTOMERIC

__ METAL SKIN

__ MINERAL SURF. CAP

__ LATEX COATING

PAVERS
__ Concrete
__ Composite

__ OTHER

__ NONE

66 WALKWAYS (check all):

__ ASPHALT PLANK

__ CONCRETE PAVERS

X WOOD DUCK BOARDS

__ MINERAL SURFACED FELTS

__ RUBBER MAT

__ OTHER

__ NONE

70 FLASHING

71 BASE FLASHING (check all):

MINERAL SURFACED
X Organic
__ Glass
__ Fabric Unknown

__ REINFORCED ASBESTOS

__ FIBERGLASS

__ COTTON

__ BURLAP

MODIFIED BITUMEN
__ Granule Surface
__ Foil Surface
__ Smooth Surface

__ VINYL

__ PVC

__ NEOPRENE

__ EPDM

__ PVC COVERED METAL

__ METAL

__ CPE

__ CSPE

__ NONE

__ UNKNOWN

72 FLASHING ADHESIVE (check one):

__ HOT MOPPED

X COLD MASTIC

__ TORCH APPLIED

__ UNKNOWN

73 COUNTERFLASHING (check all):

X METAL

__ BITUMINOUS

__ FLEXIBLE

__ NONE

74 FLASHING TYPES (check all):

ROOF EDGE
__ Embedded Edge Met.
__ Metal Cap Flash.

X WALL/PARAPET

__ COPING

__ AREA DIVIDER

EXPANSION JOINT
__ Metal Cover
X Flexible Cover

__ ROOF PENETRATION

__ ROOF RELIEF VENT

X PLUMBING VENT

EQUIPMENT SUPPORT
__ Structural Frame
__ Curbs
__ Conduit
__ Wood Sleepers
__ None (unflashed)

X PITCH PAN

PIPE SUPPORTS
X Wood Blocks
__ Rollers

80 REMARKS

Figure 6. (Cont'd)

Vapor Retarder

Section 41 - Type. The material type used in reducing vapor transmission through the roofing system (sometimes referred to as vapor barrier). This information can usually be found in the specifications or on construction drawings. If needed, determine the presence and type of vapor retarder from core cuts.

Insulation

Section 51 - Type. Type(s) of insulation used in the roofing system.

Section 52 - Physical Properties. The total thickness and number of layers of insulation. Also indicate if the insulation system is tapered. Core samples are the best means of determining insulation type and thickness. Check specifications or contracts for information concerning whether insulation was tapered to provide slope, and if multiple layers were used.

Section 53 - R-value. The total R-value (thermal resistance) of the insulation. Check specifications, manufacturer's information, or use industry accepted values.

Section 54 - Attachment. The method used for attachment of the roof insulation. This information should be in the specifications. The insulation on roofs installed before 1982 was frequently attached with mechanical fasteners on the perimeter of steel decks and adhesive on the field of the roof. Enter all methods if more than one method was used. Single-ply ballasted systems are generally installed with the insulation loose-laid.

Membrane

Section 61 - Product. The manufacturer, product description and specification of the roof membrane. Construction drawings or contractor submittals are the only reliable source for this information. Also indicate if the roof assembly is a protected membrane (insulation on top of membrane).

Section 62 - Type. The type of material used as the membrane. The contract specifications or shop drawing file will be the best sources for this data. For built-up roofs, a simple method for determining bitumen type is described in Appendix B.

Section 63 - Attachment. The method of membrane attachment (for single-ply membranes only). The contract specifications or shop drawings are the best sources for this information.

Section 64 - Reinforcement. Type of fabric or reinforcement used in the membrane. Contract specifications and manufacturer's literature are the best sources for this information.

Section 65 - Surfacing. Type of surfacing on the membrane providing protection or ballast. Visual observations or the contract specifications are the best sources for this information. If more than one surfacing appears on the roof section, consider dividing it into multiple sections.

Section 66 - Walkways. Type(s) of walkways used on the roof section. Check the roof section plan to be sure they are shown.

Flashing

Section 71 - Base Flashing. Types of base flashing that are present. The contract specifications or contractor's submittals and visual observation are the best sources for this information.

Section 72 - Flashing Adhesive. The adhesive used to apply the base flashing. The contract specifications should provide this information.

Section 73 - Counterflashing. Types of counterflashing present on the roof section. The contract specification, contractor shop drawings, and visual observation are the best sources for this information.

Section 74 - Flashing Types. Types of flashing details existing on the roof section. There will normally be several flashing types on every roof. Check off all types that are present. Check the roof section plan to be sure that all of the existing flashing, especially penetrations, pitch pans, and pipe supports are shown.

Remarks

Additional information that will be useful to the planners in scheduling maintenance or replacement. If the roof system was placed over an existing roof, it should be stated in this section.

3 VISUAL INSPECTION AND EVALUATION PROCEDURE

The visual roof condition evaluation procedure is the critical component of ROOFER. The data obtained during the procedure is combined with the insulation inspection data (Chapter 4) to provide an overall assessment of the roof condition and determine MRR requirements. This chapter briefly explains the visual inspection procedure and the methods used to calculate the membrane and flashing condition indexes (MCI and FCI). A complete description of the visual inspection procedure can be found in USACERL Technical Report M-87/13[3] which provides the necessary guidance to perform the inspections and is the standardized reference for distress/defect identification.

Membrane and Flashing Condition Ratings

The membrane and flashing components are rated separately by direct measurement of the distresses found in each component. Treating each component separately provides a more accurate assessment of component condition, needed repair, and waterproof integrity. MCI and FCI ratings are numerical indicators based on a scale of 1 to 100. The scale and associated ratings are shown in Figure 7.

Inspection Procedure

The inspection and recording can be accomplished by one individual. However, for safety reasons, a second individual should assist the inspector. During initial implementation, a third team member can help develop the roof section plan and take core samples. Each roof section is carefully inspected, and flashing and membrane distresses are recorded on a Roof Inspection Worksheet (Figure 8). The total perimeter flashing length should be determined and recorded in the space provided in the heading. The curb flashing, which includes the length of the base flashing on all curbed projections such as equipment supports, should also be determined and recorded in the heading. The problems are identified by distress type, severity level, specific defect, and quantity. A description of the blister distress and specific defects is shown in Figure 9. Similar detailed descriptions for all other membrane and flashing distresses are presented in USACERL Technical Report M-87/13[4]. Figure 10 contains an abbreviated list of identifiers for all the distresses/defects associated with the ROOFER inspection process. The list can be attached to the bottom of a long clipboard for ready reference by the inspector to identify specific defects in each distress category (i.e., Base Flashing - High - Holes, splits, and tears, would be identified as BF-H-1 on the Roof Inspection Worksheet). If a roof moisture survey of the insulation (see Chapter 4) was completed before the visual inspection, mark the core sample locations at this time.

As part of the visual inspection, a survey of the interior and exterior conditions should be performed. The inspector shall complete the reverse side of the Roof Inspection Worksheet (Figure 11) and record in the "remarks" section any additional comments that would alert the manager of problems that should be further investigated and corrected.

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[3]M. Y. Shahin, D. M. Bailey, and D. E. Brotherson.
[4]M. Y. Shahin, D. M. Bailey, and D. E. Brotherson.

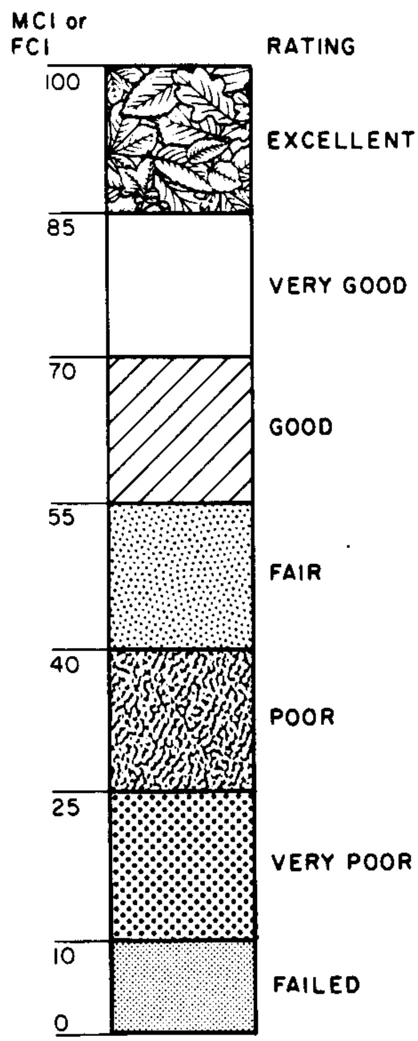


Figure 7. MCI and FCI and ratings.

Calculating the MCI and FCI from Inspection Results

The MCI and FCI of a roof section is determined from the information recorded on the Roof Inspection Worksheet. The calculations are completed on the Roof Section Rating Form (Figure 12) using the following five step procedure (also shown in Figure 13):

Step 1

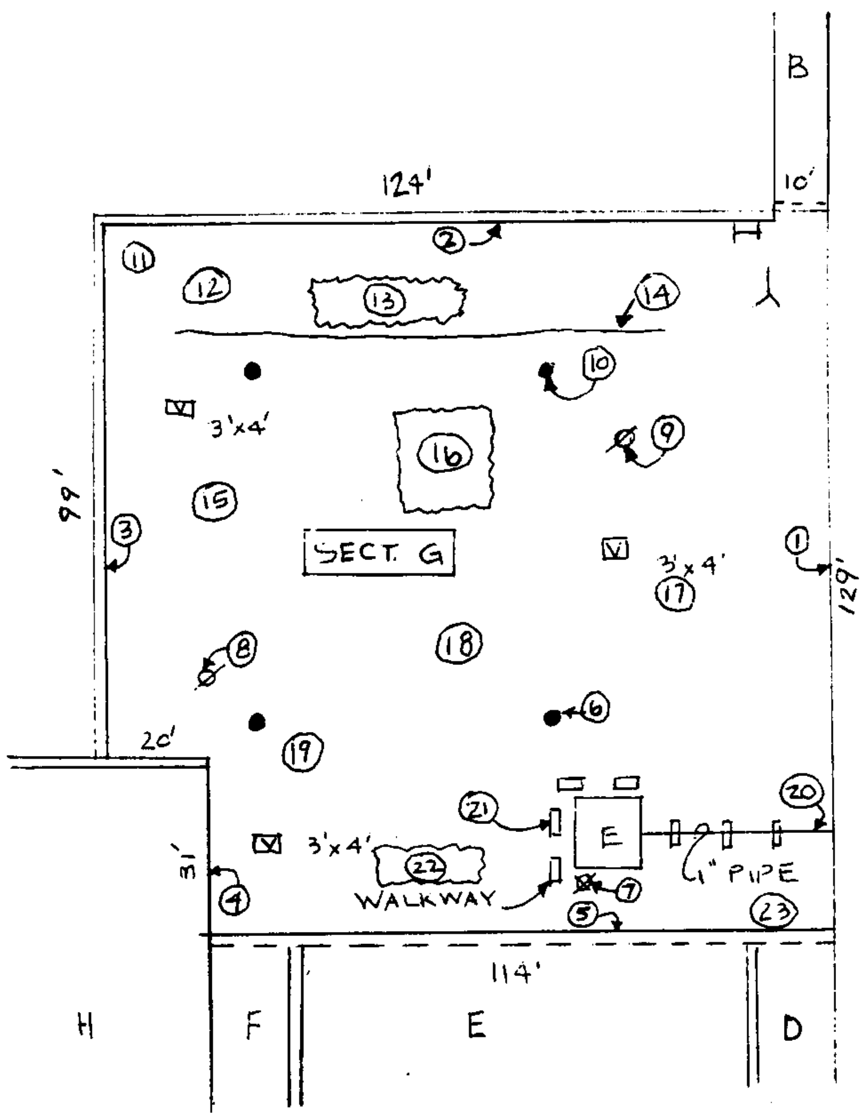
Transfer the quantities for each combination of distress type and severity level to the Roof Section Rating Form.

ROOF INSPECTION WORKSHEET | **AGENCY/INST.:** FT. JONES

BUILDING 68 **PER. FLASHING** 527 **LF** **DATE** MAY 19, 1987

SECTION G **CURB FLASHING** 36 **LF** **NAME** R. SMITH

BF-BASE FLASH
MC-METAL CAP
EM-EMBEDD MET
FP-FLASHED PEN
PP-PITCH PANS
DR-DRAIN & SC
BL-BLISTERS
RG-RIDGES
SP-SPLITS
HL-HOLES
SR-SURF DET
SL-SLIPPAGE
PA-PATCHING
DV-DEBRIS & VEG
EQ-EQ SUPPORT
PD-PONDING



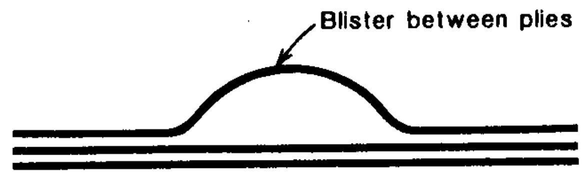
ID #	DIS	SEV	DEF	QTY
1	BF	L	1	130
2	BF	L	1	123
3	MC	H	2	10
4	BF	M	2	31
5	MC	L	2	5
6	DR	L	1	1
7	PP	H	4	1
8	FP	H	2	1
9	FP	H	4	1
10	DR	H	3	1
11	BL	L	1	4
12	PA	M	1	10
13	PA	M	1	24
14	SP	H	1	123
15	PD	L	1	20
16	SR	M	1	400
17	BL	M	1	6
18	BL	L	1	12
19	HL	H	1	1
20	EQ	M	1	3
21	SR	L	4	8
22	DV	M	3	30
23	SR	M	1	120

SCALE: 1" = 30'

NORTH

Figure 8. Completed Roof Inspection Worksheet.

BLISTERS



Graphic Representation of Blister

Description: Blisters are round or elongated raised areas of the membrane which are filled with air.

Note: Blisters and ridges are difficult to differentiate at the low and medium severity levels. The rating error will be insignificant because of the similarity in the deduct curves. At high severity, however, it is important to distinguish between the two distresses due to their different leak potentials.

Severity Levels:

Low:

1. The raised areas are noticeable by vision or feel. The surfacing is still in place and the felts are not exposed.

Medium:

1. The felts are exposed or show deterioration.

High:

1. The blisters are broken.

Measurement:

1. Measure the length and width of the blister in lineal feet and calculate the area (length times width). If the distance between individual blisters is less than 5 ft, measure the entire affected area in sq ft.
2. When large quantities of this problem are present (especially on large roofs), the representative sampling technique can be used.

Density:

$$\frac{A}{B} \times 100 = \text{Problem Density}$$

where A = total area of membrane blisters (sq ft)
B = total area of roof section being rated (sq ft)

Note: The problem density is calculated for each existing severity level.

Causes: Blisters are caused by voids or lack of attachment within the membrane. Moisture and gasses within the void greatly increases the potential for growth.

Figure 9. Example description of blister distress.

FLASHING DISTRESSES/DEFECTS

BF-LOW
1. Loss surface-NO DET
2. < 6" high
3. Permanent repairs

BF-MED
1. Slip, wrink, loose
2. Loss surface-DET
3. Grease-NO DET
4. Temp. repairs

BF-HIGH
1. Holes, splits, tears
2. Gap-top, side
3. Grease-DET

MC-LOW
1. Paint,light corrosion
2. Cap deformed
3. CtrFl deformed
4. CtrFl sealed to base

MC-MED
1. Holes-vert surface
2. Cap loose, jts open
3. Sealant bad
4. CtrFl loose
5. CtrFl not over BaseFl

MC-HIGH
1. Cap/CtrFl missing
2. Holes-hor surface
3. Jt.Cov missing

EM-LOW
1. Exists

EM-MED
1. Joints exist
2. Nails backing out
3. Corrosion
4. Loose-NO DET

EM-HIGH
1. Felts missing
2. Splits at joints
3. Holes in metal
4. Loose-deteriorated felts
5. Holes-interior gutter

FP-LOW
1. Sleeve deformed
2. < 6"

FP-MED
1. Felt exposed
2. Top not sealed
3. Sleeve open, no umbrella
4. Metal corrosion

FP-HIGH
1. No strip felt
2. Sleeve cracked
3. No sleeve
4. No seal at membrane

PP-LOW
1. Exist

PP-HIGH
1. Corrosion
2. Seal below rim
3. Felts-DET
4. Seal cracked, separated

DR-LOW
1. Bitumen Flow-NO CLOG

DR-MED
1. Felt exposed
2. Strainer broken
3. Scupper corroded

DR-HIGH
1. Felt-DET
2. Ring loose/missing
3. Clogged
4. Scupper metal has hole

MEMBRANE DISTRESSES/DEFECTS

BL-LOW
1. Visible-NOT BARE

BL-MED
1. Felts exposed

BL-HIGH
1. Felts broken

RG-LOW
1. Visible-NOT BARE

RG-MED
1. Felts exposed

RG-HIGH
1. Break at top
2. Top felt deteriorated

SP-HIGH
1. Open split

HL-HIGH
1. Hole in membrane

SR-LOW
1. Poor aggregate embedment
2. Open laps, fishmouths
3. Alligatoring starting
4. Walkways-cracked,blister

SR-MED
1. Flood coat exposed
2. MC-felt exposed
3. SM-no coating
4. SM-alligatoring to felt

SR-HIGH
1. Felts exposed
2. MS-felt deteriorated
3. SM-alligatoring thru felt
4. Walkway membrane torn

SL-LOW
1. Exists < 2"

SL-HIGH
1. Exists >2"

PA-LOW
1. Visible

PA-MED
1. Not equal to existing

PA-HIGH
1. Other distress in patch

DV-MED
1. Material on roof
2. Solvent/oil/grease-NO DET
3. Vegetation-NO PENETRATION

DV-HIGH
1. Solvent/oil/grease-DET
2. Roots in felts

EQ-LOW
1. Exists

EQ-MED
1. Movement of support-NO DAM
2. Bolts-SEALED

EQ-HIGH
1. Movement of support-DAMAGE
2. Bolts-NOT SEALED

PD-LOW
1. Exists or evidence

INSULATION DISTRESS/DEFECT

INS-HIGH
1. Wet insulation

Figure 10. List of distress/defect identifiers.

Step 2

Total the quantities for each distress/severity level combination, calculate the density values, and determine the Deduct Values (DV) from the Deduct Value Curves. Appendix C contains Deduct Value Curves for the 16 distress types.

Step 3

Treating the flashing and membrane distresses separately, list the individual deduct values for each component (flashing and membrane) in descending order and compute the sum of the deduct values (SDV) and the number of deducts greater than 1 (q), as shown on page 30. Determine the corresponding Corrected Deduct Values (CDV) from the Corrected Deduct Value Curves (Appendix C). (Note: different Corrected Deduct Value Curves are used for the membrane and the flashing.) The CDV of maximum value should be used to compute the condition index.

ROOF INSPECTION WORKSHEET - COMMENTS

INSTRUCTIONS: Circle response, i.e., Y = yes, N = no or U = unknown or not observed. If Y (yes), circle the type of problem.

A. EVALUATION OF INTERIOR CONDITIONS

1. Does the roof leak? Describe: Yes, NE corner of Room 54 — (Y) N U

2. Are there water stains on: — (Y) N U
   a. walls (c) deck e. structural elements
   b. ceilings d. floor f. other: ______

3. Do structural elements show any of the following: — (Y) N U
   (a) cracks d. alteration g. physical damage
   b. splits e. rotting h. insect damage
   c. spalling f. settlement i. other: ______

4. Does the underside of the deck show any of the following: — (Y) N U
   a. rusting (c) spalling e. sagging
   b. rotting d. cracks f. other ______

B. EVALUATION OF EXTERIOR CONDITIONS

1. Do the exterior walls shown any of the following: — Y (N)
   a. cracks c. spalling e. water stains
   b. rusting d. movement f. other: ______

2. Does the fascia or soffit show any of the following: — (Y) N
   a. cracks c. spalling e. water stains
   b. rusting (d) peeling f. other: ______

3. Do the gutters or downspouts show any of the following: — Y (N)
   a. loose c. missing e. clogged
   b. damaged d. disconnect f. other: ______

C. EVALUATION OF ROOFTOP CONDITIONS

1. Is there any unauthorized, unnecessary, or improperly installed equipment on the roof? — (Y) N
   a. equipment (c) antennas e. cables
   b. signs d. platforms f. other: ______

2. Do adjacent parapet walls show any of the following: — Y (N)
   a. cracks c. cap cracked e. sealant
   b. spalling d. cap missing f. other: ______

D. REMARKS: ______

Figure 11. Reverse side of the Roof Inspection Worksheet.

ROOF SECTION RATING FORM

BUILDING 68	SECTION G	DATE 21 MAY 87	CALC. BY D.B
PER. FLASHING 527 LF CURB FLASHING 36 LF	FLASHING TOTAL 563 LF	AREA 16,800 SF	CHKD. BY R.D

FLASHING

DISTRESS TYPES

BF - BASE FLASH
MC - METAL CAP
EM - EMBEDDED MET
FP - FLASHED PEN
PP - PITCH PANS
DR - DRAIN & SCUPPER

TYP	SV	QUANTITIES	TOT	DEN	DV
BF	L	130 + 123	253	45	17
MC	H	10	10	1.8	13
BF	M	31	31	5.5	13
MC	L	5	5	0.89	2
DR	L	1	1	0.18	1
PP	H	1	1	0.18	9
FP	H	1 + 1	2	0.36	11
DR	H	1	1	0.18	21
CORRECTED DEDUCT VALUE (CDV)					33

FCI = 100 - CDV = 67

FLASHING RATING = GOOD

MEMBRANE

DISTRESS TYPES

BL - BLISTERS
RG - RIDGES
SP - SPLITS
HL - HOLES
SR - SURF DET
SL - SLIPPAGE
PA - PATCHING
DV - DEBRIS & VEG
EQ - EQU SUPPORTS
PD - PONDING

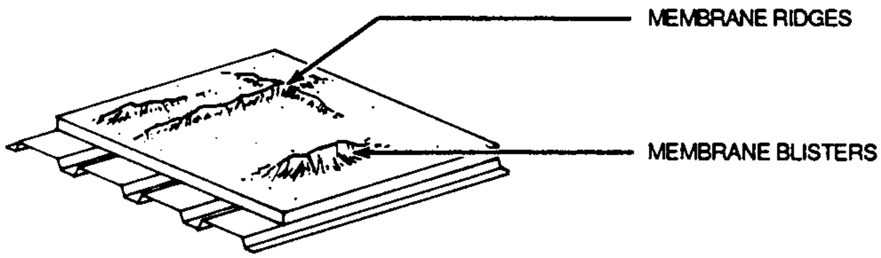
TYP	SV	QUANTITIES	TOT	DEN	DV
BL	L	4 + 12	16	0.10	3
PA	M	10 + 24	34	0.20	7
SP	H	123	123	0.73	65
PD	L	20	20	0.12	3
SR	M	400 + 120	520	3.1	14
BL	M	6	6	0.036	2
HL	H	1	1	0.006	5
EQ	M	3	3	0.018	3
SR	L	8	8	0.048	2
DV	M	30	30	0.18	2
CORRECTED DEDUCT VALUE (CDV)					65

MCI = 100 - CDV = 35

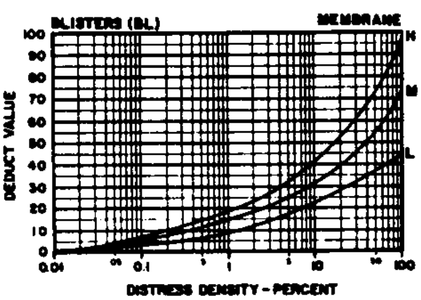
MEMBRANE RATING = POOR

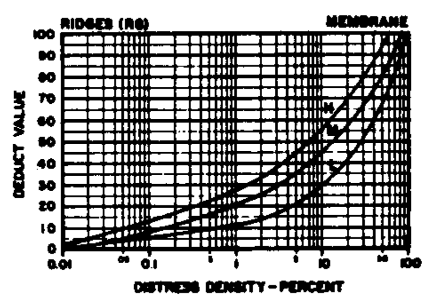
Figure 12. Completed Roof Section Rating Form.

STEP 1. INSPECT ROOF. DETERMINE DISTRESS TYPES AND SEVERITY LEVELS; DETERMINE QUANTITIES AND CALCULATE DENSITIES.

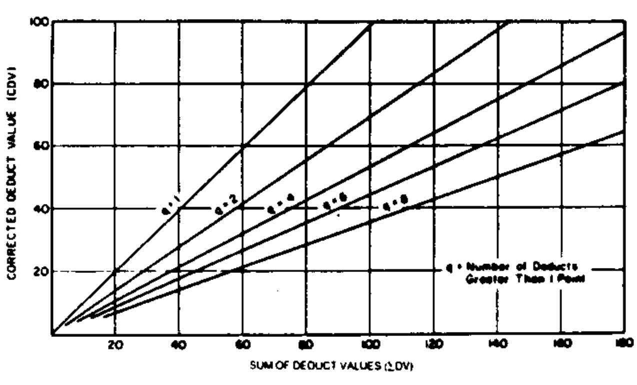


STEP 2. DETERMINE DEDUCT VALUES.





STEP 3. COMPUTE CORRECTED DEDUCT VALUE.



STEP 4. COMPUTE MEMBRANE CONDITION INDEX (MCI). = 100-CDV

STEP 5. DETERMINE MEMBRANE CONDITION RATING.

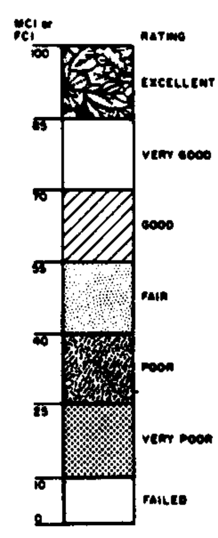


Figure 13. Steps for calculating MCI and FCI for a roof section.

Flashing

(Distress data from the Completed Roof Section Rating Form [Figure 12])

DV	SDV	q	$CDV_{flashing}$
21	21	1	21
17	38	2	24
13	51	3	28
13	64	4	32
11	75	5	33
9	84	6	33
2	86	7	32
1	87	7	31

Maximum $CDV_{flashing} = 33$

Membrane

(Distress data from the Completed Roof Section Rating Form [Figure 12])

DV	SDV	q	$CDV_{membrane}$
65	65	1	65
14	79	2	55
7	86	3	53
5	91	4	48
3	94	5	47
3	97	6	43
3	100	7	40
2	102	8	37
2	104	9	38
2	106	10	38

Maximum $CDV_{membrane} = 65$

Step 4

Calculate the condition indexes using the following equations:

$$FCI = 100 - \text{Max. CDV}_{\text{(flashing)}} \quad \text{[Eq 1]}$$

$$MCI = 100 - \text{Max. CDV}_{\text{(membrane)}} \quad \text{[Eq 2]}$$

Step 5

Determine the corresponding descriptive condition ratings from Figure 7 for both indexes.

Use information from the Roof Inspection Worksheet to complete the heading section of the Roof Section Rating Form. Building, section, and agency/installation data is essential to provide continuity in the various forms. File the completed Roof Section Rating Form in the corresponding Roof Section Folder.

4 INSULATION INSPECTION AND EVALUATION PROCEDURE

A complete evaluation of an insulated roofing system requires that the insulation be inspected to determine if it contains moisture. This chapter describes the effects of wet insulation, the insulation condition rating procedure, moisture detection methods, and the determination of the Insulation Condition Index (ICI).

Insulation Condition Rating

The insulation condition rating is based on the Insulation Condition Index (ICI). The ICI, a numerical indicator between 0 and 100, reflects the condition of the insulation in terms of its ability to perform its function and the level of needed repair. Insulation with an ICI of 100 is in excellent condition.

Effects of Wet Insulation

Insulation is a common component of many low-slope roofing systems. Defects in the membrane and/or flashing components can provide paths for water to enter and wet the insulation. Moisture in the insulation can also be caused by condensation. Moisture reduces the R-value of the insulation and may also reduce the bond between it and the membrane. Roofs with wet insulation are more prone to blow off or split. Water in insulation adds to the weight the structural system must resist and may also promote corrosion of fasteners or metal decks, rotting of wood decks and nailers, and deterioration of cementitious deck materials.

Roof Moisture Detection

Rooftop conditions that could suggest wet insulation include spongy areas, depressions in the roof surface, vegetation growing through the membrane, and leaks that continue to drip long after the source of water has been removed from the roof.

Detecting wet insulation and determining the extent of the wet area can be done using a nondestructive moisture detection technique such as infrared (IR) scans, nuclear meter, or capacitance meter. The results of a moisture survey using any of these techniques must always be verified by core sampling.[5]

Infrared Scanning

IR scanning systems detect the temperature differences that occur on a roof above areas of wet and dry insulation. IR roof scans should be performed at night and can either be accomplished on the roof or from the air. When surveying only a few roofs in an area, on-the-roof scans may be more cost

[5] W. Tobiasson and C. Korhonen, *Roof Moisture Surveys: Yesterday, Today and Tomorrow*, CRREL Miscellaneous Paper 2040 (U.S. Army Cold Regions Research and Engineering Laboratory [CRREL], September 1985).

effective than aerial scans. In many instances, however, an aerial IR scan is more cost effective because all the insulated roofing systems of most military installations can be surveyed in a few hours.[6]

A thermal image (thermogram) of a roof taken during an on-the-roof survey is shown in Figure 14. The bright thermal anomalies indicate where insulation is wet. Figure 15 is a conventional photograph of the same roof. The thermogram in Figure 16 was taken from an Army helicopter about 500 ft above a roof. Bright areas denote potentially wet areas of insulation as well as areas having hot rooftop equipment or exhaust coming from roof vents.

Aerial scans are usually done from a helicopter but can also be done using a fixed-wing aircraft. The thermal images taken from the air are recorded on film or videotape for subsequent review and analysis. Later, the areas that appear to contain wet insulation may be marked on airphotos (Figure 17).

Nuclear Meter

Nuclear meters detect moisture by measuring the increased number of hydrogen atoms that occur in areas of wet insulation. Readings are taken on a grid pattern (the grid is normally 5 ft by 5 ft) established on the roof. The differences in the meter readings are analyzed and interpreted, and a moisture contour map of the roof is drawn to delineate potentially wet areas. Computers are often used to analyze the data and develop the contour map, greatly reducing the time involved.

Capacitance Meter

Capacitance meters measure the differences that occur in dielectric properties between areas of wet and dry insulation. Capacitance meter readings are also taken on a grid pattern that is normally 5 ft by 5 ft. The differences in the meter readings are analyzed and interpreted, and a moisture contour map is drawn.

Core Sampling and Determining Moisture Content

After the moisture detection work is completed, the areas of potentially wet insulation are plotted on the roof section plan of a Roof Inspection Worksheet (Figure 18). The areas of potentially wet insulation are shown by hatchmarks.

Since the moisture detection techniques discussed above provide only relative results, core samples from the roof system must be taken and analyzed to determine the amount of moisture actually present in the insulation.

Proposed core sample locations are selected for areas of potentially wet insulation and marked on the Roof Inspection Worksheet as triangles. Usually, a core sample should be taken for each potentially wet area. However, when small areas are found near a large area, one core sample can be assumed to represent those areas as well. One additional core sample is always taken in a dry area as well, to verify that it is indeed dry and not just less wet. The core sample locations can be very critical. A core sample taken at a presumably wet location on the roof section could easily indicate

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[6]W. Tobiasson, *Aerial Roof Moisture Surveys*, CRREL Miscellaneous Paper 2022 (CRREL, August 1985); W. Tobiasson, *A Method for Conducting Airborn Infrared Roof Moisture Surveys*, CRREL Miscellaneous Paper 2436 (CRREL, April 1988).

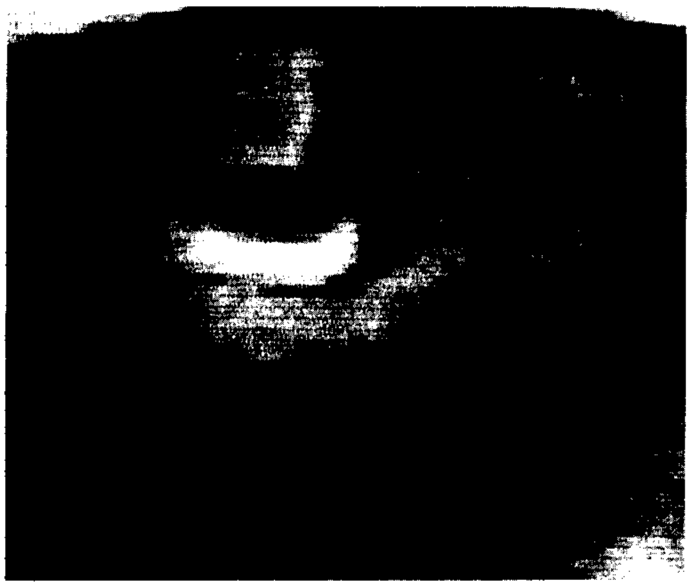


Figure 14. Typical infrared photo.

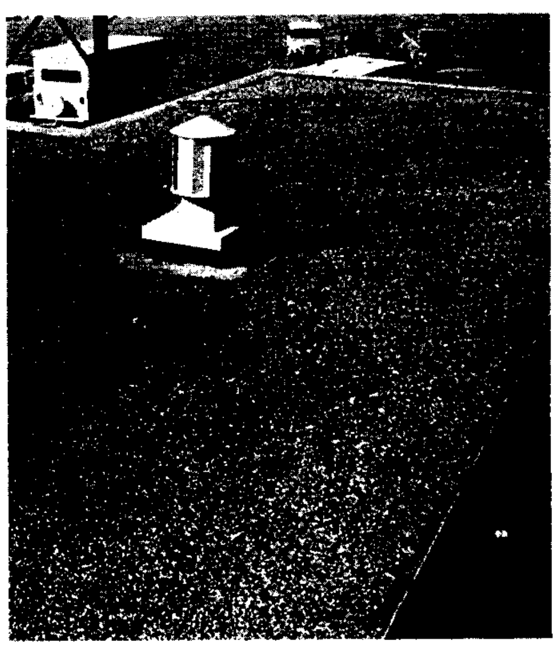


Figure 15. Conventional photo of roof in Figure 14.

Figure 16. Aerial thermogram of a roof.

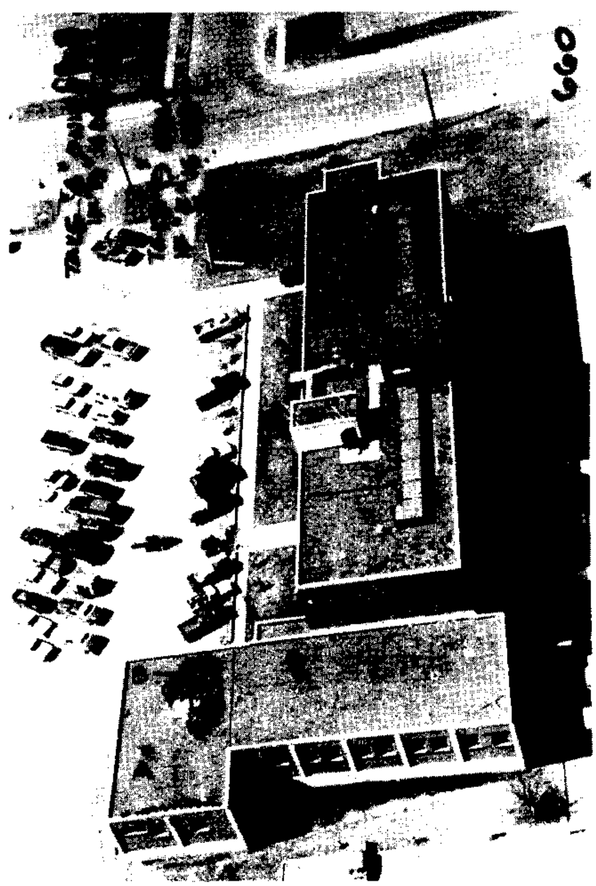


Figure 17. Airphoto marked to show potential areas of wet insulation.

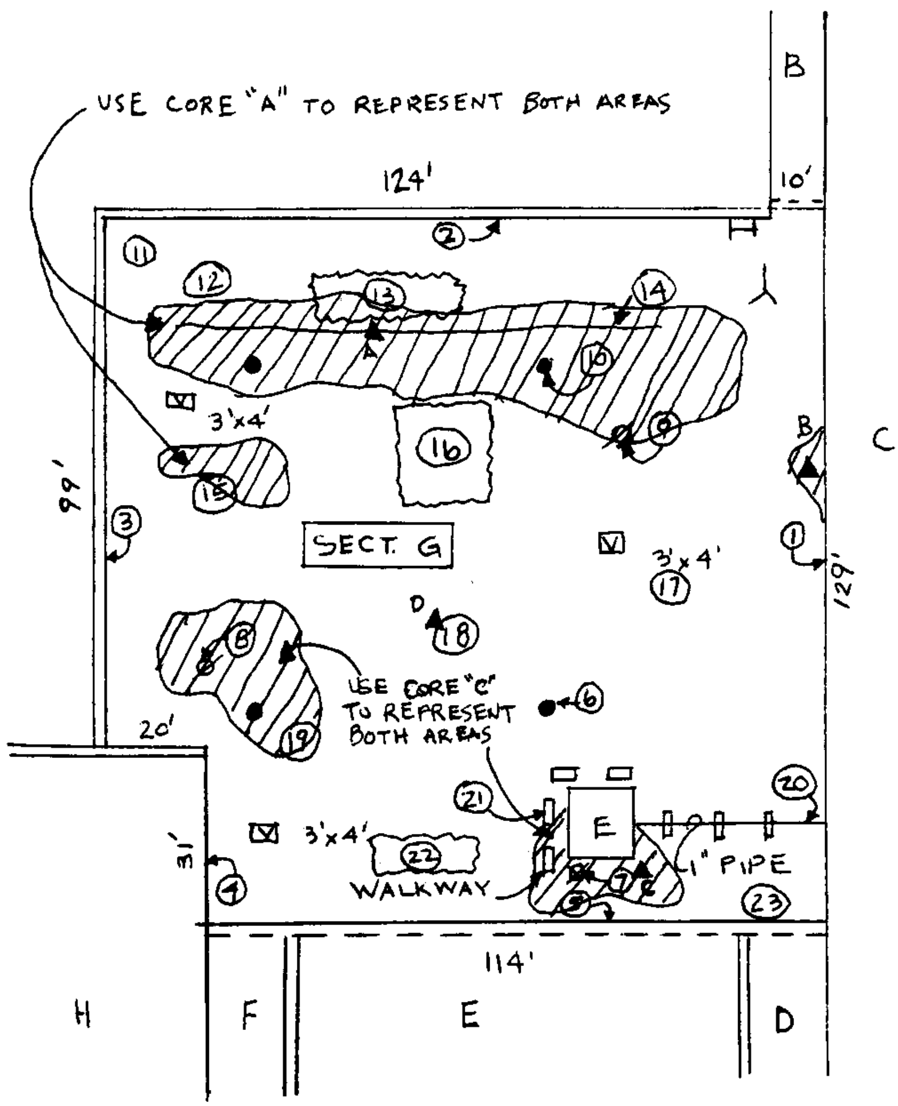
ROOF INSPECTION WORKSHEET | **AGENCY/INST.:** FT. JONES

BUILDING 68 **PER. FLASHING** 527 **LF** **DATE** MAY 24 1987

SECTION 6 **CURB FLASHING** 36 **LF** **NAME** G. Wienke

BF-BASE FLASH	PP-PITCH PANS	SP-SPLITS	PA-PATCHING
MC-METAL CAP	DR-DRAIN & SC	HL-HOLES	DV-DEBRIS & VEG
EM-EMBEDD MET	BL-BLISTERS	SR-SURF DET	EQ-EQ SUPPORT
FP-FLASHED PEN	RG-RIDGES	SL-SLIPPAGE	PD-PONDING

ID #	DIS	SEV	DEF	QTY



SCALE: 1" = 30'

NORTH

Figure 18. **Potentially wet areas and core sample locations mapped onto Roof Inspection Worksheet.**

dry conditions if it is taken on the wrong side of the wet-dry line. Dimensions for the core sample locations are not necessary if an on-the-roof IR survey was made and the potentially wet areas were outlined by spray painting.

Core samples are obtained by cutting and removing plugs of the roof insulation and membrane. The void must then be filled with a combination of spacer plugs and mastic, and the roof membrane patched. From each core sample, each type of insulation is separated and placed into sealed plastic bags or other containers and taken to a laboratory for analysis. The amount of moisture is determined by weighing the sample before and after a period of oven drying at 120 °F. The ratio of the weight of water lost during drying to the weight of the dry sample represents the moisture content of the sample expressed as a "percent of dry weight." It is not unusual to have moisture contents in excess of 100 percent of dry weight, especially in wet cellular plastic insulation materials.

Insulation Severity Factors

Moisture affects the performance of roof insulation in varying degrees depending on the type of insulation. The Insulation Severity Factor (ISF) is a measure of the adverse effect of moisture on the thermal performance of an insulation. Curves that relate the ISF for various types of insulating materials to their moisture contents are presented in Figures 19 and 20. For example, fiberboard, with a moisture content of 20 percent has an ISF of 0.7. The same ISF is reached in urethane insulation at a moisture content of 305 percent and in 1 PCF polystyrene at a moisture content of 440 percent.

Calculating the Insulation Condition Index

The Insulation Condition Index (ICI) for a roof section is calculated on the ICI Calculation Sheet (Figure 21) using the following three steps:

Step 1

Determine the moisture content and insulation severity factors of each area of potentially wet insulation. Section 1 of the ICI Calculation Sheet provides space where the moisture content of the samples can be calculated. Values entered in this section are determined in the laboratory. The notes in the headings of the columns show how the values are calculated. When more than one type of insulation is present, a moisture content calculation (percent of dry weight) is performed for each type of insulation. The ISF for each type of wet insulation in each core sample is determined from Figures 19 and 20.

Step 2

Determine the average ISF for the wet insulation. Section 2 of the ICI Calculation Sheet provides space for this computation. The largest ISF for each core sample is used in the calculation. The total wet area represented by the core is determined and multiplied by its ISF. This is repeated for all core samples, and the values are summed. The sum is entered in Box D of the calculation sheet (Figure 21). The total area of wet insulation is determined and entered in Box C.

The average ISF is calculated by dividing the value in Box D by the value in Box C.

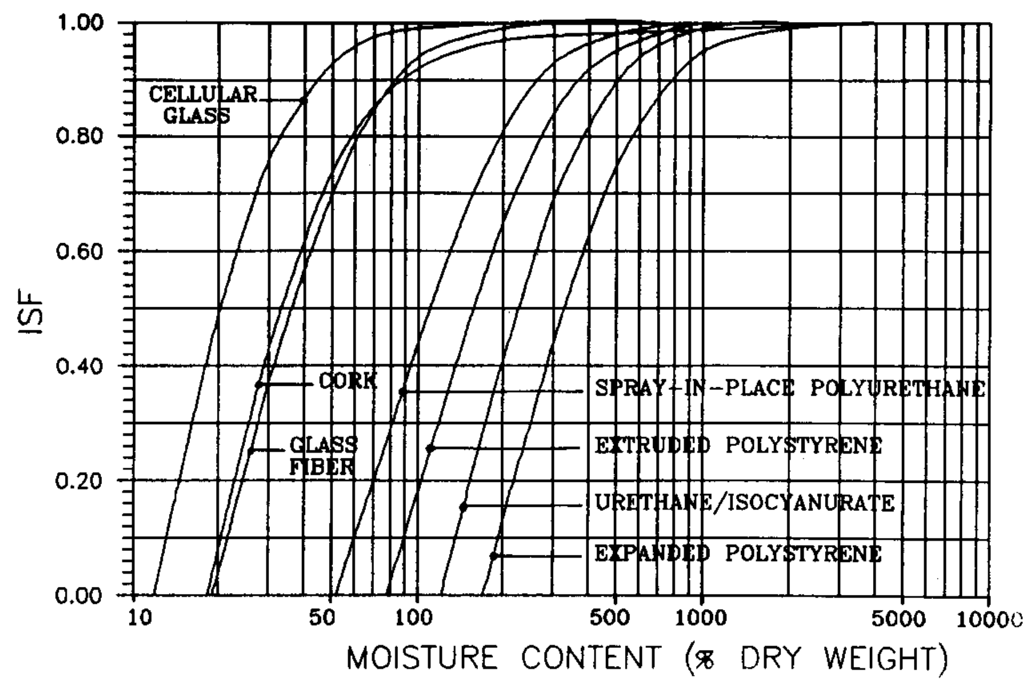


Figure 19. **Insulation severity factor (ISF) vs moisture content for cellular glass, cork, glass fiber, polyurethane, polystyrene, and polyisocyanurate insulation.**

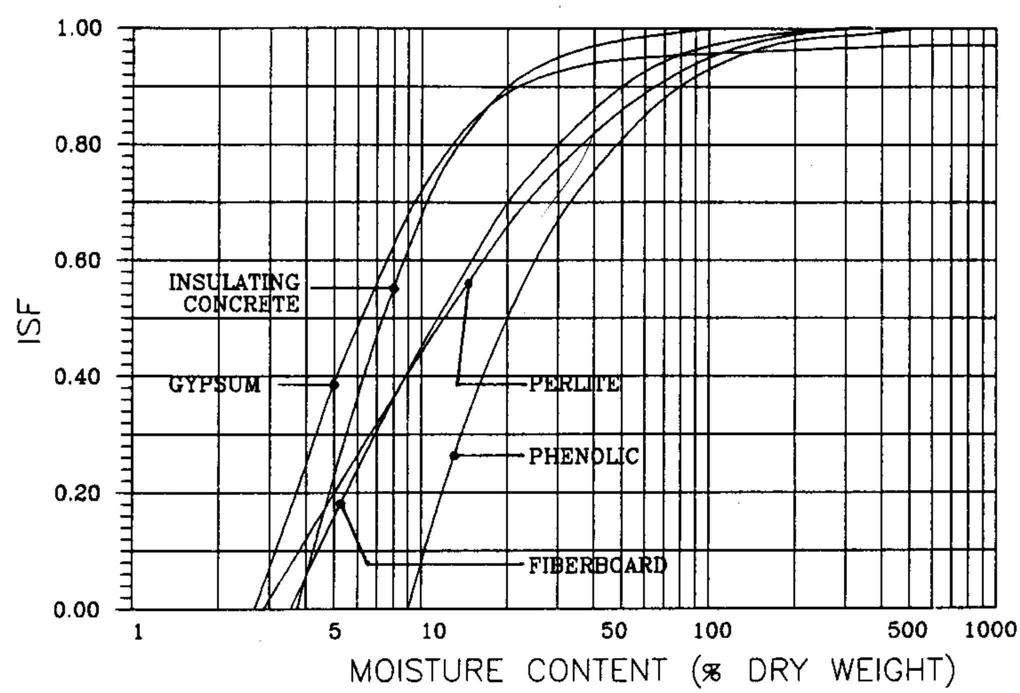


Figure 20. **ISF vs moisture content for phenolic, insulating concrete, gypsum, perlite, and fiberboard insulation.**

ICI CALCULATION SHEET	AGENCY/INST.: FT. JONES		
DATE: 5/25/1987	BLDG. NO.: 68	SECTION: 6	AREA: 16,800 SF
MC CALC. BY: J. WILLIAMS		ISF & ICI CALC. BY: W. KEMP	

1. DETERMINATION OF MOISTURE CONTENT AND INDIVIDUAL ISF OF CORE SAMPLES

CORE	INSULATION TYPE	THICK	A TARE WT	B WET+ TARE	C DRY+ TARE	D WET (B-A)	E DRY (C-A)	F WATER (D-E)	%WATER (F/E) X 100	ISF
A	URETHANE	2	8.80	19.90	12.50	11.10	3.70	7.40	200	0.41
A	PERLITE	1	8.76	34.89	16.21	26.13	7.45	18.68	250	0.99
B	URETHANE	2	8.82	12.84	12.47	4.02	3.65	0.37	10	0
B	PERLITE	1	8.73	16.27	16.05	7.54	7.32	0.22	3	0
C	URETHANE	2	8.75	23.95	12.90	15.20	4.15	11.05	266	0.60
C	PERLITE	1	8.82	33.17	16.20	24.35	7.38	16.97	230	0.99

2. DETERMINATION OF AVERAGE ISF

CORE	ISF (A)	WET AREA (B)	(A) X (B)
A	0.99	2064	2043
B	0	DRY	0
C	0.99	812	804
TOTALS		(C) 2876	(D) 2847
AVERAGE ISF (D)/(C)			0.99

3. DETERMINATION OF ICI

PROBLEM DENSITY: 17.1 %

(TOTAL WET AREA / TOTAL AREA) X 100

IDV: 70

WAF: 8

ICI: 23

100 - [(IDV + WAF) X AVERAGE ISF]

RATING: VERY POOR

1. DETERMINE THE ISF FOR EACH COMPONENT OF COMPOSITE INSULATION;
FOR EACH CORE USE THE LARGEST ISF WHEN DETERMINING THE AVERAGE ISF.

2. DO NOT INCLUDE ANY AREAS THAT HAVE AN ISF OF ZERO

3. ROUND ICI TO NEAREST WHOLE NUMBER.

WET AREA FACTOR (WAF)

WET AREAS	WAF
1	0
2	4
3	6
4	8
5 OR MORE	10

INSULATION CONDITION RATING

ICI		
86 - 100	EXCELLENT
71 - 85	VERY GOOD
56 - 70	GOOD
41 - 55	FAIR
26 - 40	POOR
11 - 25	VERY POOR
0 - 10	FAILED

Figure 21. Completed ICI Calculation Sheet.

Step 3

Determine the ICI for the roof section. Section 3 of the ICI Calculation Sheet provides space for the calculation. The problem density is determined using the following equation:

$$\text{Problem Density} = \frac{(C) \times 100}{\text{Area}} \qquad \text{[Eq 3]}$$

where C = Total area of wet insulation

Area = Total area of roof section being rated.

The Insulation Deduct Value (IDV) is then determined from Figure 22 and the ICI is calculated using the following equation:

$$ICI = 100 - [(IDV + WAF) \times ISF_{Ave}] \qquad \text{[Eq 4]}$$

where IDV = Insulation Deduct Value from Figure 22

WAF = Wet Area Factor, (use the following to adjust the index to account for the number of wet areas present*)

No. of wet areas	1	2	3	4	5 or more
WAF	0	4	6	8	10

ISF_{Ave} = The Average Insulation Severity Factor determined from Step 2

The insulation condition rating is then selected from the table at the bottom of the calculation sheet (Figure 21). In the example shown, the ICI is 23 (rounded to the nearest whole number), and the rating is "very poor."

Looking at the computation, one can see that a roof section with 17.1 percent wet insulation would be "very poor" in terms of the ability of the insulation to perform. If the wet insulation were all located in one contiguous area, then the WAF would be "0" and the ICI would increase to 31 and the roof section would be rated as "poor" with regard to insulation.

*This is the actual number of separate wet areas or potentially wet areas on the roof section and not necessarily the number of core samples used to represent these wet areas. For the example shown in Figure 18, the number of wet areas is four. The core location B found the potential wet area to be dry.

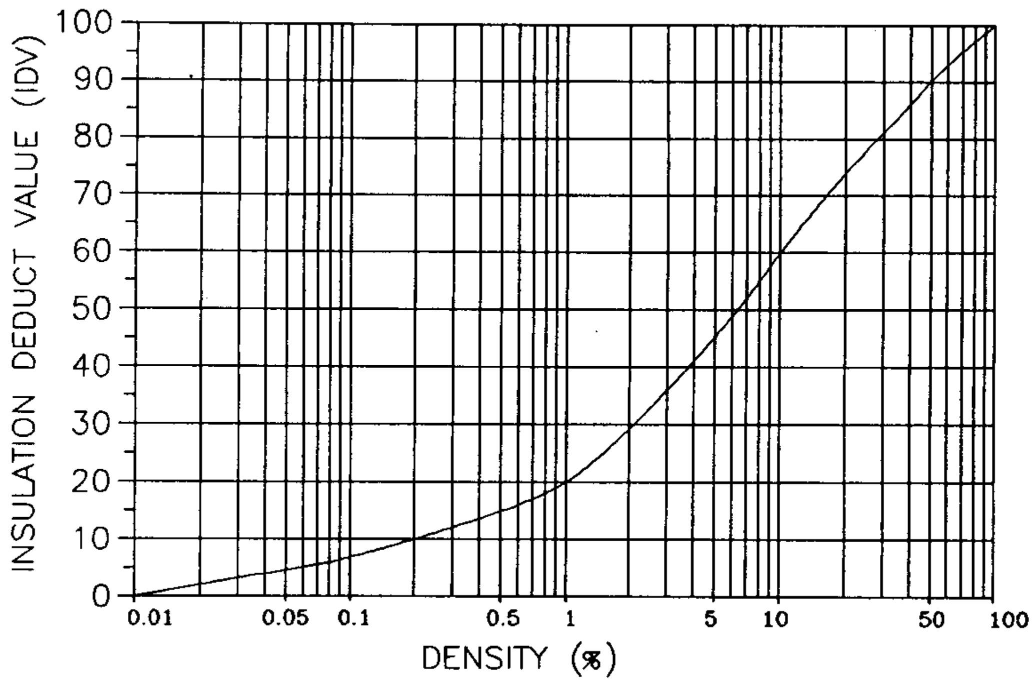


Figure 22. Insulation deduct value (IDV) vs problem density.

5 ROOF CONDITION EVALUATION AND MAINTENANCE, REPAIR, AND REPLACEMENT (MRR) PROCEDURES

The membrane, flashing, and insulation condition indexes, in total, provide an assessment of the condition of a roof section. By combining these three indexes, a roof condition index (RCI) is produced. This single index is useful for evaluating the overall condition of a roof section and for comparing conditions between roof sections. The RCI allows the user to rank individual roof sections in accordance with their ability to perform.

The three component indexes (FCI, MCI, and ICI) have a direct relationship to determining the needs for MRR of the various roof sections. The RCI similarly provides an overall indication of MRR needs for the entire roof network. This chapter will describe the method used to develop the relationship between the RCI and the three component indexes. It will also illustrate how MRR alternatives can be determined for the individual roof sections.

Roof Condition Index Calculation

Each individual index (MCI, FCI, ICI) reflects the component's ability to provide its intended service and indicates MRR needs. Since the components must interact to function as a roof system, they are dependent on each other. This relationship is defined for roof sections with insulation by the following equation:

$$\text{RCI} = (0.7 \times \text{lowest condition index}) + (0.15 \times \text{Sum of remaining condition indexes}) \qquad \text{[Eq 5]}$$

If a nondestructive moisture survey of an insulated roof section has not been conducted, an ICI of 100 is assumed. In this case, the RCI may not be an accurate index.

If the roof section has no insulation, the RCI is determined by the following equation:

$$\text{RCI} = (0.7 \times \text{Lowest condition index}) + (0.3 \times \text{Remaining condition index}) \qquad \text{[Eq 6]}$$

The above equations give the greatest weight to the component with the lowest condition index and then modify it by adding "value" from the remaining indexes.

The following examples illustrate how this relationship works:

Example 1: FCI = 67; MCI = 35; ICI = 23

$$\begin{aligned} \text{RCI} &= (0.7 \times 23) + 0.15\,(67 + 35) \\ &= 16 + 15 \\ &= 31 \end{aligned}$$

Example 2: FCI = 67; MCI = 35 ; ICI = 100

$$\begin{aligned} \text{RCI} &= (0.7 \times 35) + 0.15\,(67 + 100) \\ &= 25 + 25 \\ &= 50 \end{aligned}$$

Example 3: FCI = 67; MCI = 35; no insulation

$$\begin{aligned} RCI &= (0.7 \times 35) + (0.3 \times 67) \\ &= 25 + 20 \\ &= 45 \end{aligned}$$

The flashings for the roof section represented in example 1 are in good condition (FCI = 67). However, when the FCI is combined with an MCI of 35 and an ICI of 23, the RCI is 31, indicating that replacement of the roofing system is probable (Table 1). In example 2, the FCI and MCI are the same as in example 1, but the ICI is 100 (no wet insulation), resulting in an RCI of 50 and indicating that major repairs are needed. If, for this same roof section, there was no insulation present in the roofing system (example 3), the RCI would equal 45.

The RCI calculation sheet (Figure 23) is used to determine the RCI for a roof section. The completed sheet is kept in the roof section folder with other inspection and calculation sheets.

Roof Evaluation Procedure

The evaluation of a building's roof system is made on a section by section basis. Each roof section represents an area uniform in construction and subjected to the same conditions. Each section is unique and should be treated as a unit that can be replaced without affecting adjacent roof areas.

For evaluating a roof section, its overall condition and rate of deterioration must be defined to provide a means of estimating its expected service life.

Overall Condition

The RCI of a roof section describes the overall condition of the section and, as discussed above, combines the condition indexes of the flashing, membrane, and insulation to give the user an indication of the level of repair needed. The RCI, alone, cannot be used to determine detailed MRR requirements for a roof section. However, the RCI does provide a means for comparing the overall needs of many roof sections and aids in developing short- and long-term MRR plans for the roof network.

Table 1

MRR Recommendations

RCI	Corrective Action
86 - 100	Routine Maintenance
71 - 85	Minor Repairs Needed
56 - 70	Moderate Repairs Needed
41 - 55	Major Repairs Needed
26 - 40	Replacement Probable
11 - 25	Replacement Needed
1 - 10	Replacement Critical

RCI CALCULATION SHEET	AGENCY/INST.: FORT JONES		
DATE: JUN / 1 / 1987	BLDG NO: 68	SECTION ID: 6	AREA: 16,800 SF

ROOF SECTION WITH INSULATION:

	VALUE	LOWEST	OTHER
MCI	35		35
FCI	67		67
ICI	23	23	
	TOTAL	23	102
		X 0.70	X 0.15
		(A) 16.1	(B) 15.3
		(A+B) RCI	31

RATING: REPLACEMENT PROBABLE

ROOF SECTION WITHOUT INSULATION:

	VALUE	LOWEST	OTHER
MCI			
FCI			
	TOTAL		
		X 0.70	X 0.30
		(A)	(B)
		(A+B) RCI	

RATING: ____________________

MRR RECOMMENDATIONS

86	- 100	ROUTINE MAINTENANCE
71	- 85	MINOR REPAIRS NEEDED
56	- 70	MODERATE REPAIRS NEEDED
41	- 55	MAJOR REPAIRS NEEDED
26	- 40	REPLACEMENT PROBABLE
11	- 25	REPLACEMENT NEEDED
0	- 10	REPLACEMENT CRITICAL

Figure 23. Completed RCI Calculation Sheet.

Rate of Deterioration

The roof on a building begins deteriorating shortly after it is applied and continues deteriorating until it is replaced. The rate of deterioration is governed by a complex relationship between the physical characteristics of the roofing material, the natural environment, and the level of maintenance and repair being performed. It is also influenced by the design of the building, the use or misuse of the roof surface, and unusual weather phenomena such as windstorms or hailstorms.

Although poorly designed and constructed roofs have been known to fail in less than 2 years, and other roofs have lasted for 30 years or more, the design life of a built-up roof is generally considered by the roofing industry to be 20 years. For the ROOFER system, a 20-year life has been established as "normal." This assumes that after 20 years the RCI will be in the "Replacement Probable" range (26-40). A "normal" deterioration curve, with the RCI set equal to 33 (center of "Replacement Probable" band) and the age equal to 20, is shown in Figure 24. Data taken at three Army installations on a variety of built-up roof systems of different ages confirm the shape of this curve.

Determination of Deterioration Curve, Expected Life (EL) and Remaining Service Life (RSL)

The deterioration rate and expected life for roof sections may vary greatly from that of a theoretically defined "normal" 20-year roof, depending on the previously mentioned factors. A series of curves were developed which represent roof section deteriorating at rates different from the "normal" 20-year roof (Figure 24). The curves falling below the "normal" curve represent roof sections deteriorating at a faster rate and predicted to fail before 20 years. The curves above the "normal" curve are performing better than a 20-year roof.

The predicted deterioration curve for a roof section having an RCI at a given age can be determined using this family of curves. As an example, the deterioration curve for a roof section with RCI equal to 75 at year 15 is shown by the dashed curve (example A). The actual RCI for this roof section is higher than the expected RCI of 63 for a roof section deteriorating at the "normal" rate.

The Expected Life (EL) of a roof section is defined as the time from construction to the time at which the roof is expected to reach an RCI of 33, if no major repair work is performed. Interpolating from the predicted deterioration curve, the EL of the roof section is determined. For example A, EL = 23 years. In this case, the deterioration rate beyond the inspection year is assumed to be the same as the "normal" rate.

The remaining service life (RSL) is the time remaining until the end of service life is reached (RCI = 33) and is determined by the following equation:

$$RSL = EL - Age \qquad \text{[Eq 7]}$$

From Equation 7, the RSL = 8 years (23-15).

The deterioration curve for a roof section with an RCI equal to 31 at year 9 (example B) is also shown in Figure 24. The actual RCI is lower than the expected RCI of 86 for a roof section deteriorating at the "normal" rate. Interpolating from the deterioration curve, the EL of the roof section is determined to be 8.5 years. In this case, where the EL has already been reached (RCI<33), the EL is assumed to be equal to the age of the roof (EL = 9 years). From Equation 7, the RSL for the roof section of example B equals 0 years (9 - 9).

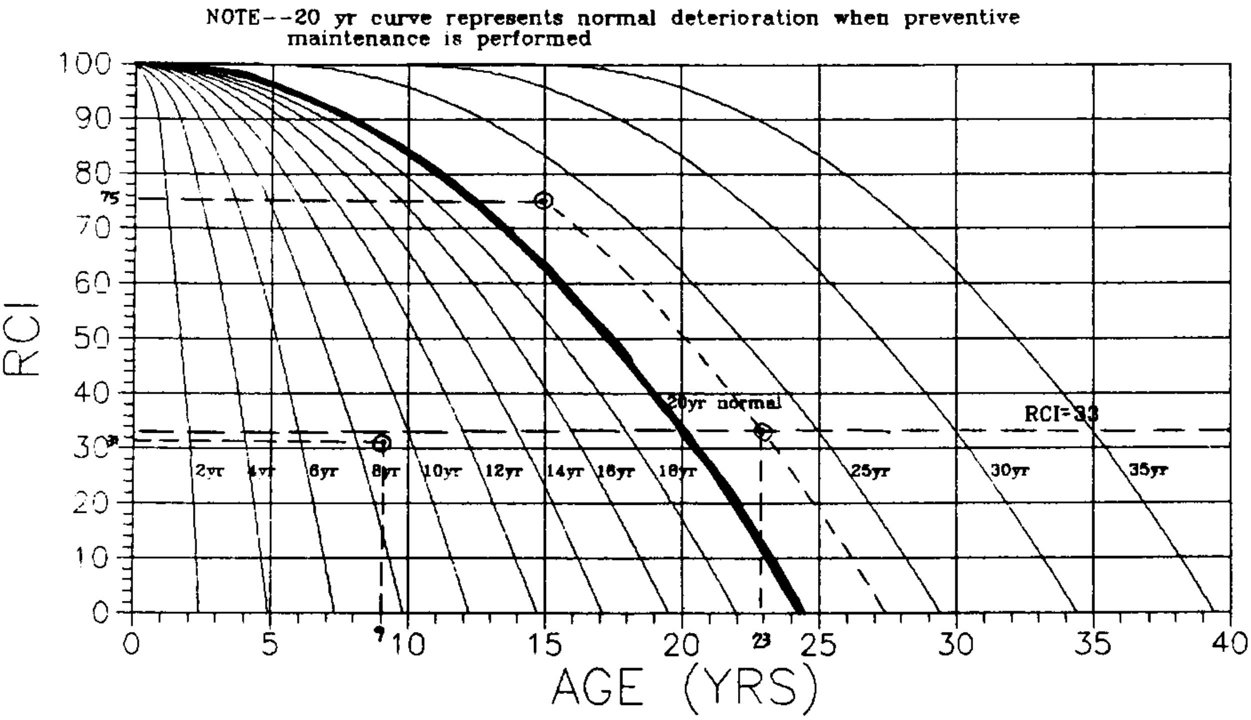


Figure 24. Deterioration curves for built-up roofs.

Maintenance, Repair, and Replacement Alternatives

Building maintenance managers do not have defined or published minimum performance standards for roof assemblies. Corrective and/or preventive maintenance criteria varies from installation to installation. This section presents MRR alternatives based on the evaluation technique presented in this report.

Routine Preventive Maintenance

Every roofing assembly, like every other physical object, deteriorates with time. As the roof ages, it exhibits various levels of deterioration until it reaches the stage described earlier in the report as "Replacement Probable." Further deterioration reduces the index to "Replacement Needed" or "Critical." The "normal" deterioration rate and 20-year service life, as previously defined, cannot be achieved without routine preventive maintenance.

A preventive maintenance program which includes regular inspections and maintenance and repair of localized problems will ensure an acceptable deterioration rate. These repairs can generally be made "on the spot" by the maintenance team. Removing debris, controlling vegetation growth, and cleaning blocked roof drains are relatively easy maintenance tasks. It is also possible to make simple repairs to flashings (such as open seams) and membranes (such as recoating bare areas and repairing punctures). Without this type of routine maintenance and repair, the roof system will deteriorate at a more rapid rate and never achieve its potential life.

Major Repair

Major repair includes the permanent repair of medium and high severity distresses and removal of areas of wet insulation (as identified by the ROOFER inspection procedures). These repairs should be accomplished on the next routine MRR cycle. However, the high severity distresses require immediate attention and should receive temporary repairs before the condition can spread or damage the system beyond repair. These corrective actions will improve the roof condition index ($RCI_{improved}$) and increase the roof's life expectancy. Major repair could include replacement of substantial areas of defective membrane, flashings, and wet insulation as well as procedures to correct poor flashing details at roof projections and equipment supports.

Roof Replacement

At times, it may be more economical to replace the roof than repair it. Usually this means replacing the entire roof system including the insulation. An engineer qualified to analyze roofing is needed at this point to fully evaluate the roof system. Depending on the inspection results, it may be possible to salvage the roof insulation if it is not wet. It may also be possible to do partial replacements of poor roof areas (perhaps damaged by workmen or hail) thereby upgrading the roof section to an acceptable RCI.

Selection of Optimal MRR Alternatives

Selecting between "major repair" and "replacement" requires a cost analysis to determine which alternative is more economical. To do the analysis, the additional service life (ASL) of the roof section as a result of performing major repairs must be determined.

Determination of ASL

Performing "major repairs" on a roof section improves the roof condition and increases the RCI. After repairs are completed, the roof section will be assumed to follow the "normal" deterioration rate. The Remaining Service Life assuming major repairs have been completed (RSL') can be determined from Figure 25 if the improved condition of the roof is known ($RCI_{improved}$). $RCI_{improved}$ can be determined by recalculating the RCI with all medium and high severity distress values eliminated and assuming the ICI to be equal to 100. The ASL is the additional years of service which can be realized by a roof section, if the major repairs are performed and the RCI is improved. The ASL is calculated from the following equation:

$$ASL = RSL' - RSL \qquad \text{[Eq 8]}$$

Using the two examples from page 45 and assuming that major repairs would improve the RCIs to 87, the ASLs are calculated as follows:

Example A.

RCI = 75 Age = 15 EL = 23 RSL = 8 $RCI_{improved} = 87$

RSL' = 11 (fig 25)

ASL = 11 - 8
= 3 yrs

Example B.

RCI = 31   Age = 9   EL = 9   RSL = 0 $RCI_{improved}$ = 87

RSL' = 11 (fig 25)

ASL = 11 - 0
= 11 yrs

Figure 26 shows the relationship between age, EL, RSL, RSL', and ASL for Example A.

While the RCI can be improved by making the necessary repairs, a cost analysis should be made to determine if the repairs are cost effective.

Cost Analysis

To determine the optimal MRR alternative, the cost to repair per year of ASL is compared to the cost per year of service life to replace the roof.

The cost of the major repair alternative includes the cost of correcting all distresses at the medium and high severity levels. Low severity distresses are not corrected. If wet insulation is detected, the cost also includes removing and replacing wet insulation and the overlying membrane and flashing systems. The cost per year of additional service life is then determined by dividing the total cost of the repairs by the ASL.

$$\text{\$ repair/yr} = \frac{\text{total repair cost}}{\text{ASL}} \quad \text{[Eq 9]}$$

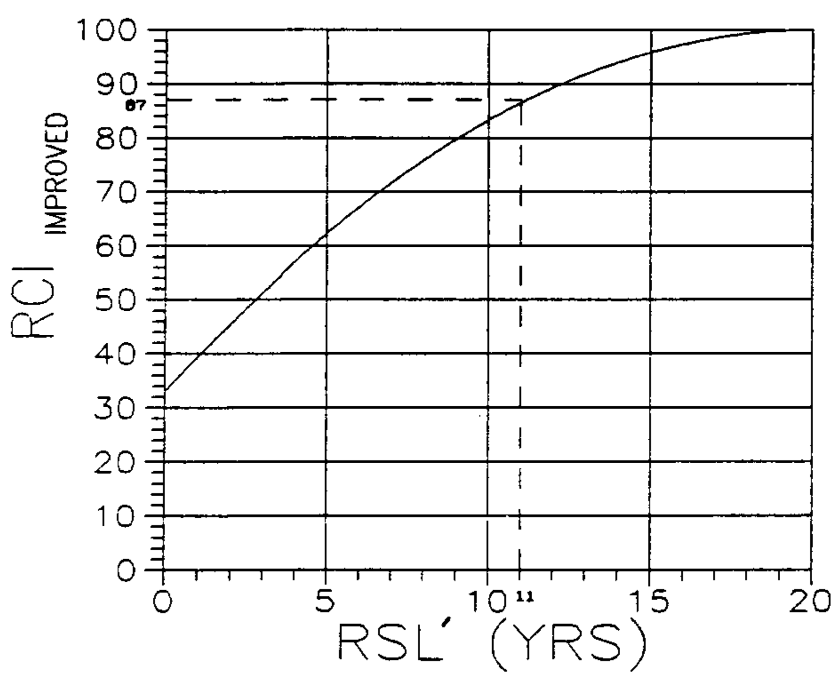


Figure 25. $RCI_{improved}$ vs remaining service life.

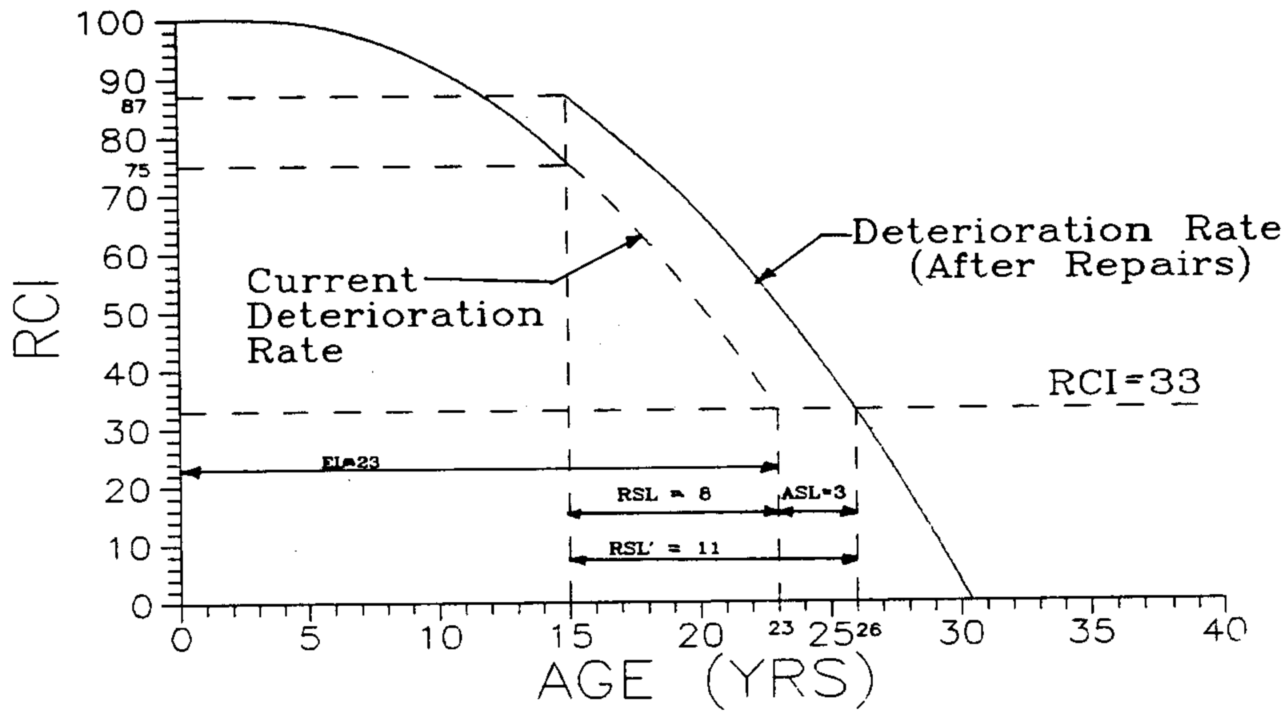


Figure 26. Relationship between age, EL, RSL, RSL', and ASL.

Figure 27 shows a completed worksheet for determining the economic evaluation of a built-up roofing system. NOTE: The unit costs shown in the worksheet are for the Washington D.C. area using 1988 as a base year. These unit costs can be used with regional cost adjustment factors to develop a general cost comparison, or local costs can be inserted to provide a more detailed cost estimate.

Replacement costs generally include the costs of the removal and disposal of the old roof system and wet insulation, the costs of new membrane and flashings, and any additional cost such as new drains, area dividers, expansion joints, and tapered insulation systems or fills to provide drainage. The total cost of replacement is then divided by 20 years (assumed service life of a new roof) to obtain the cost per year for replacement.

$$\text{\$ replace/yr} = \frac{\text{total replacement cost}}{\text{service life (20 yrs)}} \qquad \text{[Eq 10]}$$

The ratio of cost to repair per year to cost to replace per year is determined by:

$$\text{Cost Ratio} = \frac{\text{\$ repair/yr}}{\text{\$ replace/yr}} \qquad \text{[Eq 11]}$$

This cost analysis is a simplified approach and does not take into account the cost of money including inflation and discount rates.

WORKSHEET FOR DETERMINING ECONOMIC EVALUATION OF A BUR ROOFING SYSTEM

Agcy/Ins: FT. JONES   BLDG/SEC: 68 G   AREA: 16800 SF   AGE: 9

FLASHING

DIS-SL-DF	UNIT COST	QTY	TOTAL COST
BF-M-1	5.31		
BF-M-2	5.16	31	$ 160
BF-M-3	6.28		
BF-M-4	20.52		
BF-H-1	26.03		
BF-H-2	11.20		
BF-H-3	33.16		
MC-M-1	17.35		
MC-M-2	19.60		
MC-M-3	8.74		
MC-M-4	4.26		
MC-M-5	7.29		
MC-H-1	10.89		
MC-H-2	10.80	10	$ 108
MC-H-3	6.19		
EM-M-2	7.07		
EM-M-3	7.81		
EM-M-4	7.43		
EM-H-1	7.20		
EM-H-2	9.45		
EM-H-3	16.15		
EM-H-4	8.51		
EM-H-5	25.13		
FP-M-1	5.33		
FP-M-2	6.43		
FP-M-3	38.32		
FP-M-4	21.43		
FP-H-1	18.57		
FP-H-2	56.28	1	$ 56
FP-H-3	93.95		
FP-H-4	24.67	1	$ 25
PP-H-1	21.43		
PP-H-2	46.52		
PP-H-3	23.74		
PP-H-4	61.58	1	$ 62
DR-M-1	23.45		
DR-M-2	44.90		
DR-M-3	21.43		
DR-H-1	29.13		
DR-H-2	62.65		
DR-H-3	50.23	1	$ 50
DR-H-4	111.44		

MEMBRANE

DIS-SL-DF	UNIT COST	QTY	TOTAL COST
BL-M-1	2.31	6	$ 14
BL-H-1	26.99		
RG-M-1	2.33		
RG-H-1	22.35		
RG-H-2	26.99		
SP-H-1	18.50	123	$ 2276
HL-H-1	27.07	1	$ 27
SR-M-1	2.33	520	$ 1212
SR-M-2	2.62		
SR-M-3	1.30		
SR-M-4	3.81		
SR-H-1	6.63		
SR-H-2	4.75		
SR-H-3	4.52		
SR-H-4	29.79		
SL-H-1	20.70		
PA-M-1	14.42	34	$ 490
PA-H-1	14.42		
DV-M-1	6.02		
DV-M-2	25.57		
DV-M-3	6.02	30	$ 181
DV-H-1	39.91		
EQ-M-1	337.74	3	$ 1013
EQ-M-2	181.08		
EQ-H-1	105.90		
EQ-H-2	181.08		
INSULATION:			
IN-H-1	8.00	2876	$ 23008

REPAIR SETUP CHARGE = $ 544

TOTAL REPAIR COSTS = $ 29226

ADDITIONAL SERV. LIFE = 11 YRS

TOTAL REPAIR COSTS/ ADDITIONAL SERV. LIFE = $ 2657 $/YR

REPLACEMENT COST @ 5.25 SF = $ 88200

REPLACEMENT COST/ 20 YEARS = $ 4410 $/YR

COST ANALYSIS   Generated: JUN/12/1987

RATIO = REPAIR COST/YEAR / REPLACE COST/YEAR = 0.60

ADJUSTED RATIO = RATIO + (0.01 x AGE) = 0.69

ADJ. RATIO	RECOMMENDED ACTION
0 - 0.8	REPAIR
0.8 - 1.2	MARGINAL
> 1.2	REPLACE

Figure 27. Economic evaluation of a BUR system.

It is generally accepted that when the cost ratio exceeds 1.0, for roofs at an early age, then replacement is justified. However, as a roof ages, it eventually reaches a state where it will wear out because of physical changes to the materials. To compensate for this, an aging factor is used to adjust the cost ratio.

$$\text{Adjusted Cost Ratio} = \text{Cost Ratio} + (0.01 \times \text{Age}) \qquad \text{[Eq 12]}$$

Using example B (building 68 section G) and the economic evaluation in Figure 27:

$$\text{Cost Ratio} = \frac{\$2657}{\$4410} = 0.60$$

$$\text{Adjusted Cost Ratio} = 0.60 + (0.01 \times 9) = 0.69$$

If the adjusted cost ratio is less than 0.8, it is best to repair. If the ratio is greater than 1.2, replacement is the optimal alternative. When the ratio falls within the "optional" range (0.8 and 1.2), the roof engineer has the option to replace or repair. It is in this range that engineering judgement and budget considerations are needed to make the MRR selection. Funds may not always be available for reroofing all roofs with a ratio indicating replacement. The "optional" range allows the engineer the flexibility needed to make decisions.

In the above example, the RCI was low (31) because of a major split in the membrane and wet insulation covering 17 percent of the roof area. The cost for repairing the split and replacing the insulation when compared to the cost of replacement indicates that it is still a better economic choice to repair the roof and extend its life for possibly 11 years at a cost of $2657 a year than to replace the roof and get an expected life of 20 years at a cost of over $4400 a year.

Corrective Action Requirements

Once an analysis has been performed to determine whether major repair will be performed on a roof section or whether it will be scheduled for replacement, the work must be programmed. A Corrective Action Requirement sheet (CAR) should be generated to initiate the needed work. The sheet should include general information about the building and roof section and details of the work required. The CAR should be submitted with the completed Roof Inspection Worksheet and a work order form for processing.

Figure 28 shows a completed CAR sheet for the repairs to be accomplished on section G, building 68. The decision to repair is based on the cost analysis shown in Figure 27. The CAR sheet lists all the repairs required to bring the roof to an acceptable condition, thereby improving the RCI and adding life to the roof.

Figure 29 shows a completed CAR sheet for replacement of the roof of section G, building 68. If the cost analysis had indicated that it was more cost effective to replace the roofing system than accomplish the necessary repairs, replacement would be programmed. In completing a CAR sheet for replacement, the initiator should review the comments section of the roof inspection worksheet to ensure that all comments referring to the problems that need to be corrected during redesign are considered.

JUN/12/1987

CORRECTIVE ACTION REQUIREMENT SHEET
MAJOR REPAIR

(NOTE: ATTACH A COPY OF THIS FORM, ALONG WITH A COPY OF THE ROOF INSPECTION WORKSHEET TO DA FORM 4283)

AGENCY/INST.: FT. JONES
BLDG NO./SEC: 68 G
BLDG USE: CLASSROOM TRAINING

FACILITY NO: 00068
BLDG NAME: TROOP TRAINING
INSPECTION DATE: MAY/1987

MEMBRANE: BUR: Asphalt
SURFACING: AGG.: Crushed Stone
VAPOR RET: LAMINATED FELTS
INSULATION: PERLITE
POLYURETHANE

AREA (SF): 16800
AGE (YRS): 9
DECK TYPE: CONCRETE STD Cast-In-Pl
EST. REPAIR COST: $ 29226.00

CORRECTIVE ACTION RECOMMENDED: Maintenance, Repair and/or Partial Replacement

JUSTIFICATION: An economic analysis of the roof condition, including age, indicates that it is more cost effective to accomplish the necessary maintenance, repairs and/or partial replacement of the roofing components rather than replace the roofing system. Therefore, accomplish the following actions for the above roof section. (Note: paragraphs refer to TM-617, "Inspection, Maintenance, and Repair of Roofing Systems" Draft) [Note: numbers refer to identification numbers of distresses corresponding with the Roof Inspection Worksheet]

1.	BF-M-2 31 LF	Prime exposed and deteriorated base flashing and coat with heavy bodied asphalt coating. (para 3-4g(3)(a)2) [4]
2.	DR-H-3 1	Remove foreign material clogging roof drains. [10]
3.	FP-H-2 1	Remove damaged flashing sleeves or curbs and replace. (para 3-4g(7)(c)) [8]
4.	FP-H-4 1	Prime surface and three course unsealed flashed penetrations. (para 3-4g(8)) [9]
5.	MC-H-2 10 LF	Replace metal cap flashing with new corrosion resistant material. (para 3-4g(6)(c)) [3]
6.	PP-H-4 1	Fill distressed pitch pans with sealant and crown to assure moisture runoff. (para 3-4g(8)) [7]
7.	BL-M-1 6 SF	Restore surfacing material on blisters which have exposed felts. (para 3-4g(1)(a)4) [17]
8.	DV-M-3 30 SF	Clean surface of all dirt and vegetation. (para 3-4g(4)(a)5) [22]
9.	EQ-M-1 3 SF	Replace improper equipment supports with device allowing for movement of equipment. (para 3-4g(10)) [20]
10.	HL-H-1 1 SF	Repair holes and restore surfacing. (para 3-4g(2)(e)) [19]
11.	PA-M-1 34 SF	Replace patches having inferior repair material with same or better quality than existing membrane. Restore surfacing material. (para 3-4g(2)(b)3) [12,13]
12.	SP-H-1 123 SF	Repair splits and restore surfacing material. (para 3-4g(2)(b)) [14]
13.	SR-M-1 520 SF	Reinstall aggregate on exposed membrane surfaces. (para 3-4g(1)(a)) [16,23]
14.	IN-H-1 2876 SF	Remove wet roof insulation. Inspect the deck, and repair, if necessary. Replace the roofing system, including adjacent flashings. (para 3-5b)

Figure 28. Corrective Actions Requirement Sheet for major repair.

JUN/12/1987

CORRECTIVE ACTION REQUIREMENT SHEET
ROOF REPLACEMENT

(NOTE: ATTACH A COPY OF THIS FORM, ALONG WITH A COPY OF THE ROOF INSPECTION WORKSHEET TO DA FORM 4283)

AGENCY/INST.: FT. JONES
BLDG NO./SEC: 68 G
BLDG USE: CLASSROOM TRAINING
FACILITY NO: 00068
BLDG NAME: TROOP TRAINING
INSPECTION DATE: MAY/1987

MEMBRANE: BUR: Asphalt
SURFACING: AGG.: Crushed Stone
VAPOR RET: LAMINATED FELTS
INSULATION: PERLITE
POLYURETHANE
AREA (SF): 16800
AGE (YRS): 9
DECK TYPE: CONCRETE STD Cast-In-Pl
EST. REPLACE COST: $ 88200.00

CORRECTIVE ACTION RECOMMENDED: Total replacement of roof in 1987

JUSTIFICATION: An economic analysis of the roof condition, including age, indicates that it is more cost effective to totally replace the roofing system, rather than perform the necessary maintenance, repair, and/or partial replacement of the roofing system.

DESIGN CONSIDERATIONS: The following considerations should be addressed during the design and construction phases of the replacement system:

a. Type replacement systems could include
   1) bituminous built-up membrane
   2) single-ply membrane, such as EPDM, PVC etc.. IF a ballasted system is selected, determine if the structural components can sustain the added weight (approx. 10 lbs/SF).

b. Ensure that the roof has positive drainage slope of at least 1/4 inch per foot. Correct all areas that now contain ponded water.

c. Remove all unnecessary roof mounted equipment.

d. Inspect and repair or replace, as necessary, all remaining roof mounted equipment.

e. Ensure that all roof mounted equipment and penetrations are properly installed on the roof.

f. Until the replacement roof is installed, accomplish temporary repairs to ensure that the roof remains leak free.

Figure 29. Corrective Actions Requirement Sheet for replacement.

6 SUMMARY AND RECOMMENDATION

Summary

This report has presented ROOFER, an engineered management system for built-up roofs. The system includes procedures for collecting and managing inventory information, visual inspection and condition evaluation of the membrane and flashing, roof moisture detection and condition evaluation of the insulation, overall roof condition rating, and determination of MRR needs.

The overall roof condition rating procedure is based on the Roof Condition Index. The RCI is composed of three separate condition indexes for the membrane, flashing, and insulation (MCI, FCI, and ICI). These indexes have been field-validated and provide a means of establishing MRR requirements and justification of roof projects. This report has presented ROOFER as a manual system, but as part of this work unit, USACERL has automated the system for a microcomputer application. The automated version improves data storage and retrieval, eliminates calculations, and provides custom designed reports for management use.

Methods of Developing and Collecting Data

The development and collection of data for implementing and maintaining ROOFER at the installation can be accomplished by using one or a combination of the following methods:

- In-house resources, using permanent or a combination of permanent and temporary personnel, supported by USAEHSC.
- Local A/E firm, supported by USAEHSC.
- Indefinite Delivery Type Contract (IDTC), managed by USAEHSC.

Methods of Accomplishing Nondestructive Roof Moisture Surveys

The nondestructive roof moisture surveys outlined in Chapter 4 can be accomplished through one of the following methods:

- Local firms specializing in conducting rooftop surveys using IR scans or nuclear or capacitance moisture meters.
- Aerial IR roof scans accomplished by:

  - direct contract with a firm that specializes in aerial scans

  - IDTC contract managed by USAEHSC

  - USAEHSC directly.

Project Management for Implementation of Roofer

USAEHSC is responsible for providing assistance for implementing and maintaining the ROOFER program at the installation and MACOM level.

Recommendation

It is recommended that Army installations implement ROOFER. The system can be maintained by in-house personnel or contracted to a qualified firm. Contract specifications for implementing ROOFER are available from the Department of the Army, U.S. Army Engineering and Housing Support Center (ATTN: CEHSC-FB-S), Fort Belvoir, VA 22060-5580.

Conversion Factors

1 sq ft	= 0.093 m^2
1 in.	= 2.54 cm
1 ft	= 0.305 m

CITED REFERENCES

Shahin, M. Y., D. M. Bailey, and D. E. Brotherson, *Membrane and Flashing Condition Indexes for Built-Up Roofs, Volume II: Inspection and Distress Manual*, Technical Report M-87/13 (U. S. Army Construction Engineering Research Laboratory [USACERL], September 1987).

Tobiasson, W., and Korhonen, C., *Roof Moisture Surveys: Yesterday, Today and Tomorrow*, CRREL Miscellaneous Paper 2040 (U.S. Army Cold Regions Research and Engineering Laboratory [CRREL], September 1985).

Tobiasson, W., *Aerial Roof Moisture Surveys*, CRREL Miscellaneous Paper 2022 (August 1985);

Tobiasson, W., *A Method for Conducting Airborn Infrared Roof Moisture Surveys*, CRREL Miscellaneous Paper 2436 (CRREL, April 1988).

Technical Manual (TM) 5-617, *Facilities Engineering Maintenance and Repair of Roofs* (Department of the Army, January 1974).

UNCITED REFERENCES

Air Force Manual (AFM) 91-36, *Built-Up Roof Management Program* (U. S. Air Force, 3 September 1980).

Griffin, C. W. *Manual of Built-Up Roof Systems*, 2nd Edition (McGraw Hill Book Company, 1982).

Knehans, A., S. Bunch, and J. Mose, *Roofing Systems Analysis*, Brochure (U.S. Army Facilities Engineering Support Agency, December 1985).

Shahin, M. Y., M. I. Darter, and S. D. Kohn, *Development of Pavement Maintenance and Management System, Volume I: Airfield Pavement Condition Rating*, Technical Report No. AFCEC-TR-76-27 (U.S. Air Force Civil Engineering Center, November 1976), pp 32, 37.

Shahin, M. Y. and S. D. Kohn, *Pavement Maintenance Management for Roads and Parking Lots*, Technical Report M-294 (USACERL, October 1981).

APPENDIX A:

BLANK WORKSHEETS*

BUILDING IDENTIFICATION	AGENCY/INST. NO.: | | | | | |
DATE: __/__/___	AGENCY/INST.:
BUILDING NAME:	
BUILDING NUMBER:	DESIGN CATEGORY CODE | | | | | |
TYPE CONST. | |	FACILITY NUMBER | | | | | |
LOCATION:	
USE:	YEAR BUILT: ________

ROOF SECTIONS:

A	________	SF	F	________	SF	K	________	SF
B	________	SF	G	________	SF	L	________	SF
C	________	SF	H	________	SF	M	________	SF
D	________	SF	I	________	SF	N	________	SF
E	________	SF	J	________	SF	O	________	SF

REMARKS:

BUILDING ROOF PLAN SCALE:

*These forms have been slightly reduced.

ROOF SECTION IDENTIFICATION			AGENCY/INST.:
DATE: ___/____	BLDG NO:	SECTION ID:	AREA: SF
OCCUPANCY:	YEAR ORIG CONST:		YEAR LAST REPLACED:

10 GENERAL

11 PERIMETER:

PARAPET	____ LF	AREA DIVIDER	____ LF		
ROOF EDGE	____ LF	ADJ. WALL	____ LF		
EXP. JOINT	____ LF	OTHER	____ LF		

12 ACCESS:

20 STRUCTURAL FRAME

21 TYPE:

30 ROOF DECK

31 TYPE:

32 DESIGN LOAD:

LIVE ____ PSF
DEAD ____ PSF

33 SLOPE: ____ IN 12

34 DRAINAGE:

40 VAPOR RETARDER

41 TYPE:

50 INSULATION

51 TYPE:

52 PHYSICAL PROPERTIES:

	BOARD STOCK	FILLS
THICKNESS (in.)	____	____
NO. OF LAYERS	____	____
TAPERED	____	____

53 R-VALUE:

54 ATTACHMENT:

60 MEMBRANE

61 PRODUCT:

PROTECTED MEMBRANE ____ (Y/N)

MANUFACTURER ____________
SPECIFCATION NO. ____________

DESCRIPTION ____________
WARRANTY ____________ (Y/N)
EXP. DATE ____________

62 TYPE:	63 ATTACHMENT:	64 REINFORCEMENT:
65 SURFACING:	**66 WALKWAYS:**	

70 FLASHING

71 BASE FLASHING:	72 FLASHING ADHESIVE:	73 COUNTERFLASHING:

74 FLASHING TYPES:

80 REMARKS:

ROOF SECTION IDENTIFICATION WORKSHEET		AGENCY/INST.:	
DATE: ___/_____	BLDG NO:	SECTION ID:	AREA: SF
OCCUPANCY:	YEAR ORIG CONST: _____		YEAR LAST REPLACED: _____

10 GENERAL

11 PERIMETER:

PARAPET _____ LF	EXP. JOINT _____ LF	ADJ. WALL _____ LF
ROOF EDGE _____ LF	AREA DIVIDER _____ LF	OTHER _____ LF

12 ACCESS (check one):

INTERNAL LADDER
__ Permanent
__ Temporary

EXTERNAL LADDER
__ Permanent
__ Temporary

__ PENTHOUSE

__ ACCESSED FROM ADJACENT ROOF SECT (Sec. ID __)

20 STRUCTURAL FRAME

21 TYPE (check one):

STEEL
__ Beams, Girders, Cols.
__ Long Sp Deck, Beams
__ Trusses
__ Bar Joists With Beams and Cols.
__ Bar Joists With Bearing Walls
__ Bar Joists With Combination

CONCRETE
__ Beams
__ Flat Slab

WOOD
__ Laminated Beams
__ Trusses
__ Joists
__ Panels

SPECIAL
__ Dome
__ Space Frame

__ UNKNOWN

30 ROOF DECK

31 TYPE (check one):

NONCOMBUSTIBLE

__ STEEL

CONCRETE, STD.
__ Precast
__ Cast-In-Place

GYPSUM
__ Fiberboard Form
__ Fiberglass Form
__ Gypsum Form
__ Precast

CONCRETE, L.W.
__ Precast
__ Cast-In-Place
__ Vermiculite
__ Cellular
__ Perlite

CEMENT FIBER
__ Bulb-Tees
__ Clipped

COMBUSTIBLE

__ WOOD BOARDS

__ PLYWOOD

__ WOOD FIBER

32 DESIGN LOAD:

LIVE __________ PSF

DEAD __________ PSF

__ UNKNOWN

33 SLOPE: __________ **IN 12**

34 DRAINAGE (check all):

__ INTERIOR DRAINS

__ GUTTERS & DOWNSPOUTS

__ SCUPPERS

__ ADJACENT ROOF SECTION

__ SCUPPERS W/LEADERS AND DOWNSPOUTS

__ OVERFLOW SCUPPERS

__ ROOF EDGE

40 VAPOR RETARDER

41 TYPE (check one):

__ NONE

__ ALUMINUM FOIL

__ POLYETHYLENE

__ COATED ROLL ROOFING

__ LAMINATED ASPH/KRAFT

__ LAMINATED FELTS

__ PVC

__ VINYL

__ UNKNOWN

50 INSULATION

51 TYPE (check all):

__ NONE
__ WOOD FIBERBOARD
__ GLASS FIBER
__ PERLITE
__ POLYURETHANE/BOARD
__ EXPANDED POLYSTY.

__ EXTRUDED POLYSTY.
__ FOAMGLASS
__ PHENOLIC
__ POLYISOCYANURATE
__ CORK
__ FOAMED IN PLACE/PUF

INSULATING FILLS
__ Vermiculite
__ Perlite
__ Cellular
__ Gypsum
__ Lwt. Concrete
__ Fill Type Unknown

__ UNKNOWN

52 PHYSICAL PROPERTIES: __ N/A (No Insul.)

BOARD STOCK

TOTAL THICKNESS ______ INCHES
NO. OF LAYERS ______
TAPERED ______ (Y/N)

FOAMED IN PLACE AND INS. FILLS

TOTAL THICKNESS ______ INCHES
TAPERED ______ (Y/N)

53 R-VALUE (total): ______ __ UNKNOWN __ N/A (No Insul.)

54 ATTACHMENT (board stock only)(check all):

__ MECHANICAL
__ LOOSE LAID

__ ADHESIVE-HOT
__ ADHESIVE-COLD

__ UNKNOWN

60 MEMBRANE

61 PRODUCT: __ UNKNOWN

MANUFACTURER ____________
SPECIFICATION NO. ____________

PROTECTED MEMBRANE __ (Y/N)
DESCRIPTION ____________
WARRANTY ____(Y/N) EXP DATE ___

62 TYPE (check one):

BIT. BUILT-UP
__ Asphalt
__ Coal Tar Pitch
__ Cold Process\ Emulsion
__ Cold Process\ Cutback
__ Bit. Type Unknown

MODIFIED BITUMEN
__ SBS
__ APP
__ Modifier Unknown

ROLL ROOFING
__ Org./Min. Surface
__ Glass/Min. Surface
__ Smooth

SINGLE-PLY
__ EPDM
__ CPE
__ CSPE
__ PIB
__ PVC
__ Butyl
__ Neoprene
__ Nitrile
__ Type Unknown

LIQUID APPLIED
__ Neoprene/Hypalon
__ Acrylic Elastomer
__ Butyl
__ Polysulfide
__ Urethane
__ Silicone
__ Type Unknown

PUF WITH COATING
__ Silicone
__ Urethane
__ Catal. Urethane
__ Acrylic
__ Coating Unknown

63 ATTACHMENT (for Single-Ply only)(check one):

__ FULLY ADHERED
__ LOOSE/BALLASTED

__ PLATE/DISK/PARTIALLY ADHERED

MECH. FASTENERS
__ Penetrating
__ NonPenetrating

64 REINFORCEMENT (check one):

BIT. BUILT-UP
__ Organic Felt
__ Glass Felt
__ Asbestos Felt
__ Felt Type Unknown

MODIFIED BITUMEN & SINGLE-PLY
__ Polyester, Woven
__ Polyester, Nonwoven
__ Glass
__ Asbestos
__ Fleece, Synthetic
__ Felt
__ Laminate Backer
__ Polyethylene
__ Reinforcement Unknown
__ No Reinforcement

65 SURFACING (check one):

AGGREGATE
__ River Gravel
__ Crushed Stone
__ Slag
__ Pea Gravel
__ Volcanic Rock
__ Marble Chip
__ Limestone
__ Aluminum Granule
__ Mineral Granule
__ Agg. Unknown

SMOOTH
__ Cutback
__ Emulsion
__ Hot Asphalt
__ Bit. Type Unknown

__ REFLECTIVE

__ ELASTOMERIC

__ METAL SKIN

__ MINERAL SURF. CAP

__ LATEX COATING

PAVERS
__ Concrete
__ Composite

__ OTHER

__ NONE

66 WALKWAYS (check all):

__ ASPHALT PLANK

__ CONCRETE PAVERS

__ WOOD DUCK BOARDS

__ MINERAL SURFACED FELTS

__ RUBBER MAT

__ OTHER

__ NONE

70 FLASHING

71 BASE FLASHING (check all):

MINERAL SURFACED
__ Organic
__ Glass
__ Fabric Unknown

__ REINFORCED ASBESTOS

__ FIBERGLASS

__ COTTON

__ BURLAP

MODIFIED BITUMEN
__ Granule Surface
__ Foil Surface
__ Smooth Surface

__ VINYL

__ PVC

__ NEOPRENE

__ EPDM

__ PVC COVERED METAL

__ METAL

__ CPE

__ CSPE

__ NONE

__ UNKNOWN

72 FLASHING ADHESIVE (check one):

__ HOT MOPPED

__ COLD MASTIC

__ TORCH APPLIED

__ UNKNOWN

73 COUNTERFLASHING (check all):

__ METAL

__ BITUMINOUS

__ FLEXIBLE

__ NONE

74 FLASHING TYPES (check all):

ROOF EDGE
__ Embedded Edge Met.
__ Metal Cap Flash.

__WALL/PARAPET

__COPING

__AREA DIVIDER

EXPANSION JOINT
__ Metal Cover
__ Flexible Cover

__ ROOF PENETRATION

__ ROOF RELIEF VENT

__ PLUMBING VENT

EQUIPMENT SUPPORT
__ Structural Frame
__ Curbs
__ Conduit
__ Wood Sleepers
__ None (unflashed)

__ PITCH PAN

PIPE SUPPORTS
__ Wood Blocks
__ Rollers

80 REMARKS

ROOF INSPECTION WORKSHEET	AGENCY/INST.:

BUILDING ________ **PER. FLASHING** ________ LF **DATE** ________

SECTION ________ **CURB FLASHING** ________ LF **NAME** ________

				I D #	D I S	S E V	D E F	Q T Y
BF-BASE FLASH MC-METAL CAP EM-EMBEDD MET FP-FLASHED PEN	PP-PITCH PANS DR-DRAIN & SC BL-BLISTERS RG-RIDGES	SP-SPLITS HL-HOLES SR-SURF DET SL-SLIPPAGE	PA-PATCHING DV-DEBRIS & VEG EQ-EQ SUPPORT PD-PONDING					

SCALE: ____________

NORTH

ROOF INSPECTION WORKSHEET - COMMENTS

INSTRUCTIONS: Circle response, i.e., Y = yes, N = no or U = unknown or not observed. If Y (yes), circle the type of problem.

A. EVALUATION OF INTERIOR CONDITIONS

1. Does the roof leak? Describe:______________________ Y N U
____
____

2. Are there water stains on: Y N U
   a. walls c. deck e. structural elements
   b. ceilings d. floor f. other:______________

3. Do structural elements show any of the following: Y N U
   a. cracks d. alteration g. physical damage
   b. splits e. rotting h. insect damage
   c. spalling f. settlement i. other:______________

4. Does the underside of the deck show any of the following: Y N U
   a. rusting c. spalling e. sagging
   b. rotting d. cracks f. other______________

B. EVALUATION OF EXTERIOR CONDITIONS

1. Do the exterior walls shown any of the following: Y N
   a. cracks c. spalling e. water stains
   b. rusting d. movement f. other:______________

2. Does the fascia or soffit show any of the following: Y N
   a. cracks c. spalling e. water stains
   b. rusting d. peeling f. other:______________

3. Do the gutters or downspouts show any of the following: Y N
   a. loose c. missing e. clogged
   b. damaged d. disconnect f. other:______________

C. EVALUATION OF ROOFTOP CONDITIONS

1. Is there any unauthorized, unnecessary, or improperly installed equipment on the roof? Y N
   a. equipment c. antennas e. cables
   b. signs d. platforms f. other:______________

2. Do adjacent parapet walls show any of the following: Y N
   a. cracks c. cap cracked e. sealant
   b. spalling d. cap missing f. other:______________

D. REMARKS: ____
____
____
____
____

ROOF SECTION RATING FORM

BUILDING ______	**SECTION** ______	**DATE** ______	**CALC. BY** ______
PER. FLASHING ______ **FT** **CURB FLASHING** ______ **FT**	**FLASHING TOTAL** ______ **FT**	**AREA** ______ **SQFT**	**CHKD. BY** ______

FLASHING

DISTRESS TYPES

BF - BASE FLASH
MC - METAL CAP
EM - EMBEDDED MET
FP - FLASHED PEN
PP - PITCH PANS
DR - DRAIN & SCUPPER

TYP	SV	QUANTITIES	TOT	DEN	DV
CORRECTED DEDUCT VALUE (CDV)					

FCI = 100 - CDV = ______

FLASHING RATING = ______

MEMBRANE

DISTRESS TYPES

BL - BLISTERS
RG - RIDGES
SP - SPLITS
HL - HOLES
SR - SURF DET
SL - SLIPPAGE
PA - PATCHING
DV - DEBRIS & VEG
EQ - EQU SUPPORTS
PD - PONDING

TYP	SV	QUANTITIES	TOT	DEN	DV
CORRECTED DEDUCT VALUE (CDV)					

MCI = 100 - CDV = ______

MEMBRANE RATING = ______

ICI CALCULATION SHEET	AGENCY/INST.:		
DATE: __/__/____	BLDG. NO.:	SECTION:	AREA: SF
MC CALC. BY: ____________		ISF & ICI CALC. BY: ____________	

1. DETERMINATION OF MOISTURE CONTENT AND INDIVIDUAL ISF OF CORE SAMPLES

CORE	INSULATION TYPE	THICK	A TARE WT	B WET+ TARE	C DRY+ TARE	D WET (B-A)	E DRY (C-A)	F WATER (D-E)	%WATER (F/E) X 100	ISF

2. DETERMINATION OF AVERAGE ISF

CORE	ISF (A)	WET AREA (B)	(A) X (B)
TOTALS		(C)	(D)
AVERAGE ISF (D)/(C)			

3. DETERMINATION OF ICI

PROBLEM DENSITY: ____________

(TOTAL WET AREA / TOTAL AREA) X 100

IDV: ____________

WAF: ____________

ICI: ____________

100 - [(IDV + WAF) X AVERAGE ISF]

RATING: ____________

1. DETERMINE THE ISF FOR EACH COMPONENT OF COMPOSITE INSULATION;
   FOR EACH CORE USE THE LARGEST ISF WHEN DETERMINING THE AVERAGE ISF.
2. DO NOT INCLUDE ANY AREAS THAT HAVE AN ISF OF ZERO
3. ROUND ICI TO NEAREST WHOLE NUMBER.

WET AREA FACTOR (WAF)

WET AREAS	WAF
1	0
2	4
3	6
4	8
5 OR MORE	10

INSULATION CONDITION RATING

ICI	
86 - 100	EXCELLENT
71 - 85	VERY GOOD
56 - 70	GOOD
41 - 55	FAIR
26 - 40	POOR
11 - 25	VERY POOR
0 - 10	FAILED

RCI CALCULATION SHEET	AGENCY/INST.:		
DATE: ___/___/___	BLDG NO:	SECTION ID:	AREA: SF

ROOF SECTION WITH INSULATION:

	VALUE	LOWEST	OTHER
MCI			
FCI			
ICI			
	TOTAL		
		X 0.70	X 0.15
		(A)	(B)
		(A+B) RCI	

RATING: ______________________

ROOF SECTION WITHOUT INSULATION:

	VALUE	LOWEST	OTHER
MCI			
FCI			
	TOTAL		
		X 0.70	X 0.30
		(A)	(B)
		(A+B) RCI	

RATING: ______________________

MRR RECOMMENDATIONS

86 - 100	ROUTINE MAINTENANCE
71 - 85	MINOR REPAIRS NEEDED
56 - 70	MODERATE REPAIRS NEEDED
41 - 55	MAJOR REPAIRS NEEDED
26 - 40	REPLACEMENT PROBABLE
11 - 25	REPLACEMENT NEEDED
0 - 10	REPLACEMENT CRITICAL

APPENDIX B:

TEST TO DETERMINE BITUMEN TYPE

1. Obtain a small specimen of the roofing bitumen from the top pouring. The sample should be as clean as possible with uncontaminated surfaces exposed.

2. Place sample in a glass jar containing mineral spirits, gasoline or other petroleum based solvent.

3. Mix or shake the jar for bout 20 seconds.

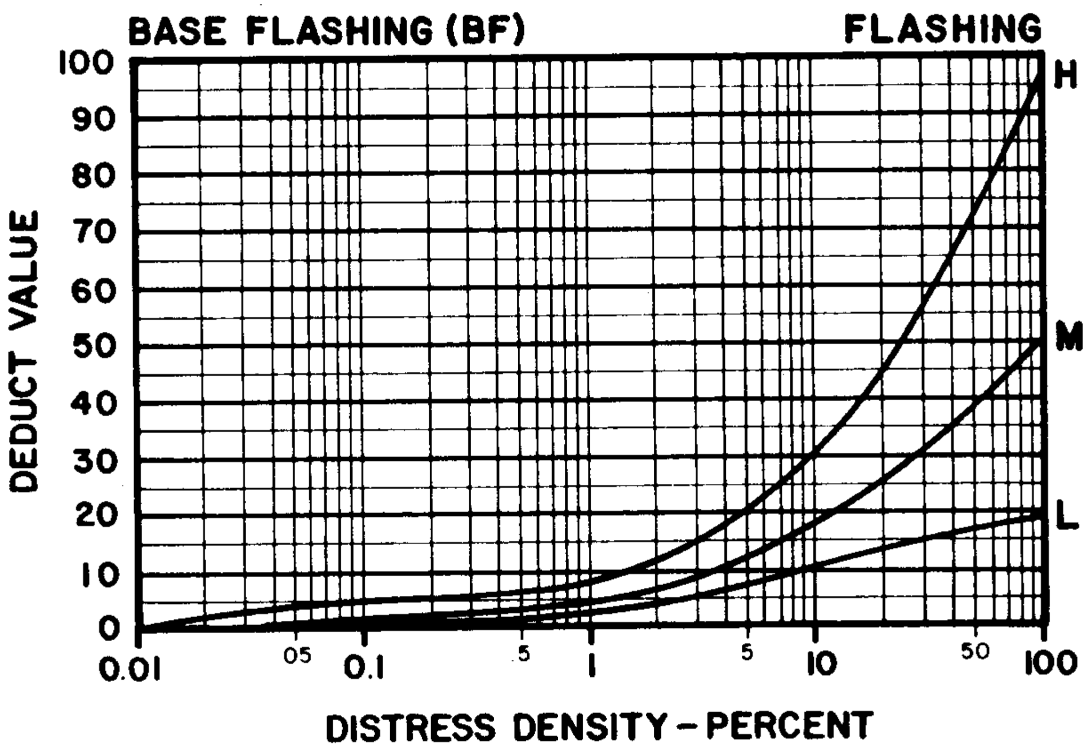
4. If the solvent turns black or is not transparent, the bitumen is asphalt.

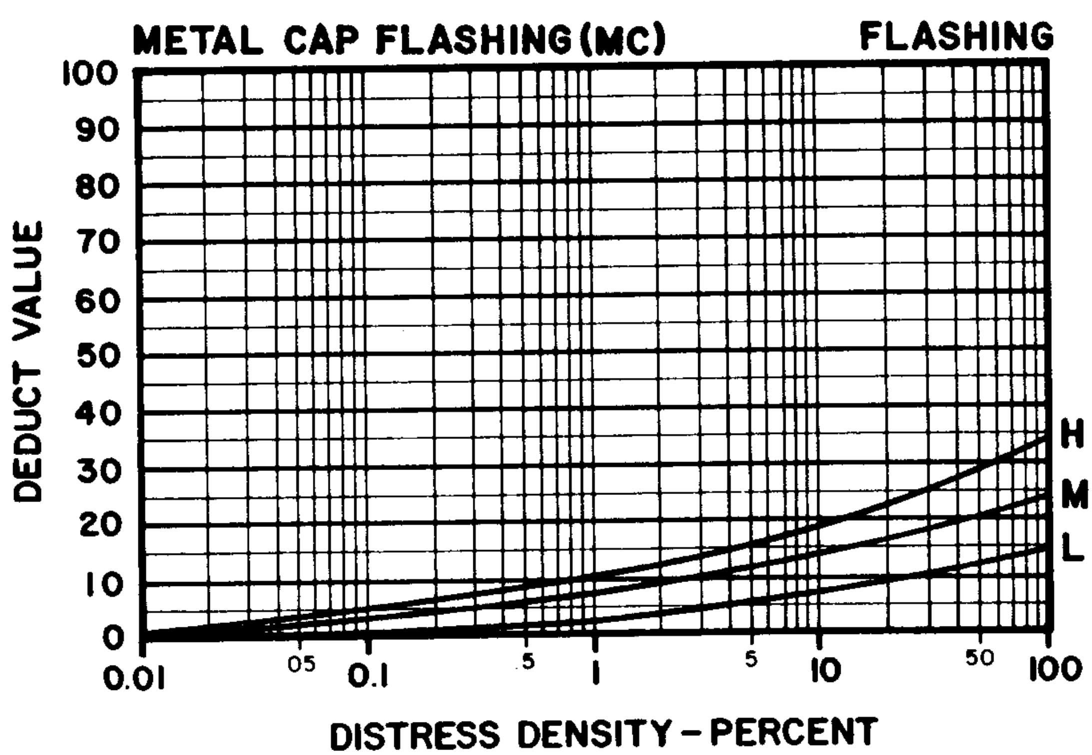
5. If the solvent turns yellow or yellow-green, the bitumen is coal-tar pitch.

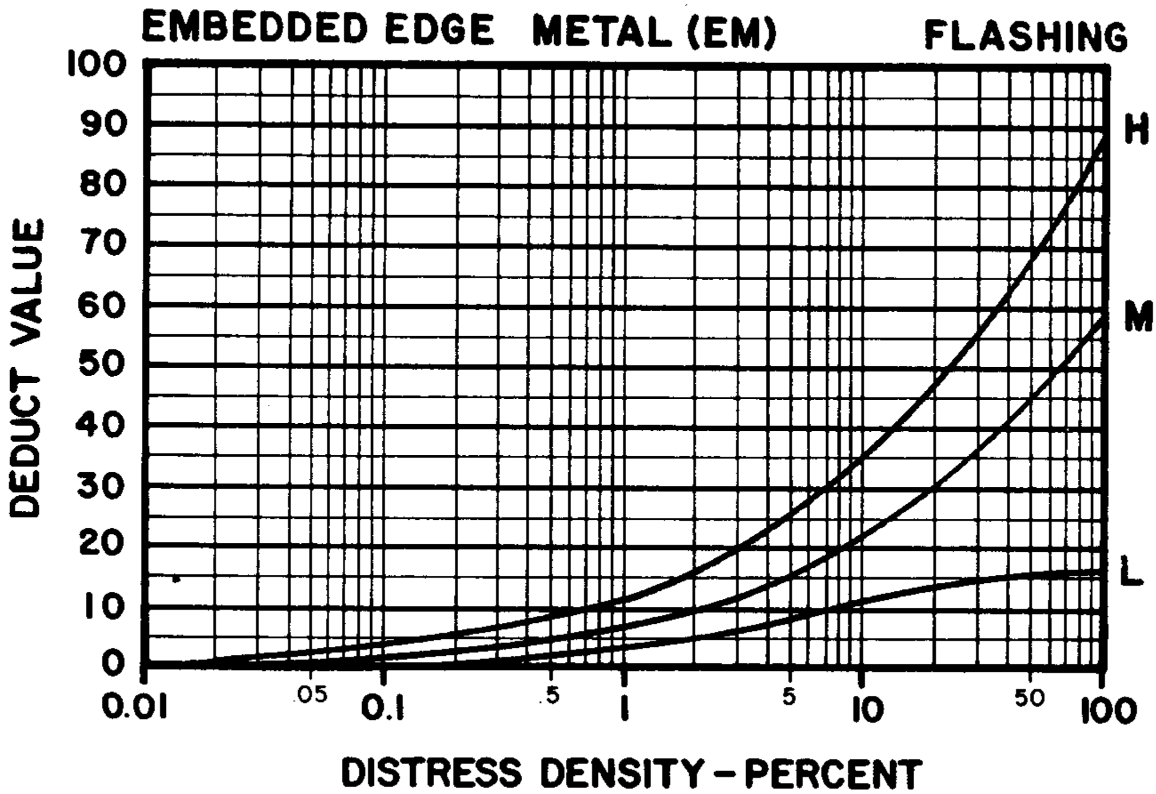
6. Test felt samples in a similar manner using several small torn pieces of felt.

APPENDIX C:

DEDUCT VALUE CURVES






EMBEDDED EDGE METAL (EM)
FLASHING
DEDUCT VALUE
100
90
80
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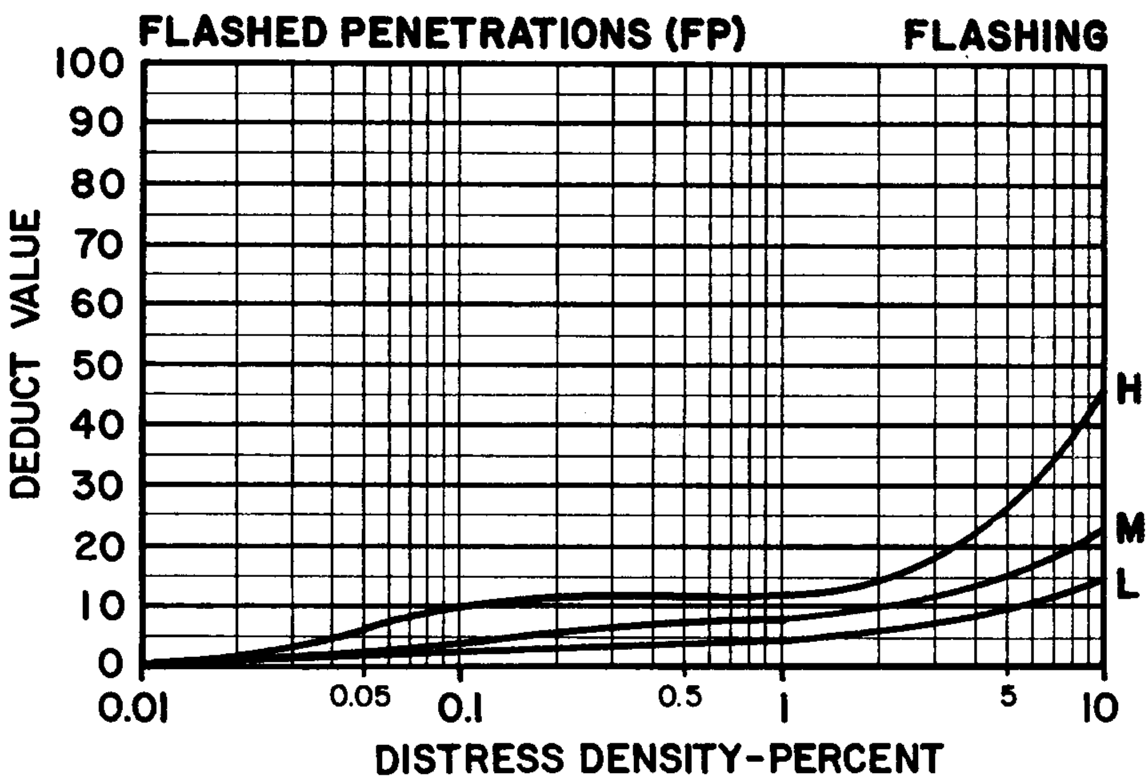
DISTRESS DENSITY - PERCENT


FLASHED PENETRATIONS (FP)
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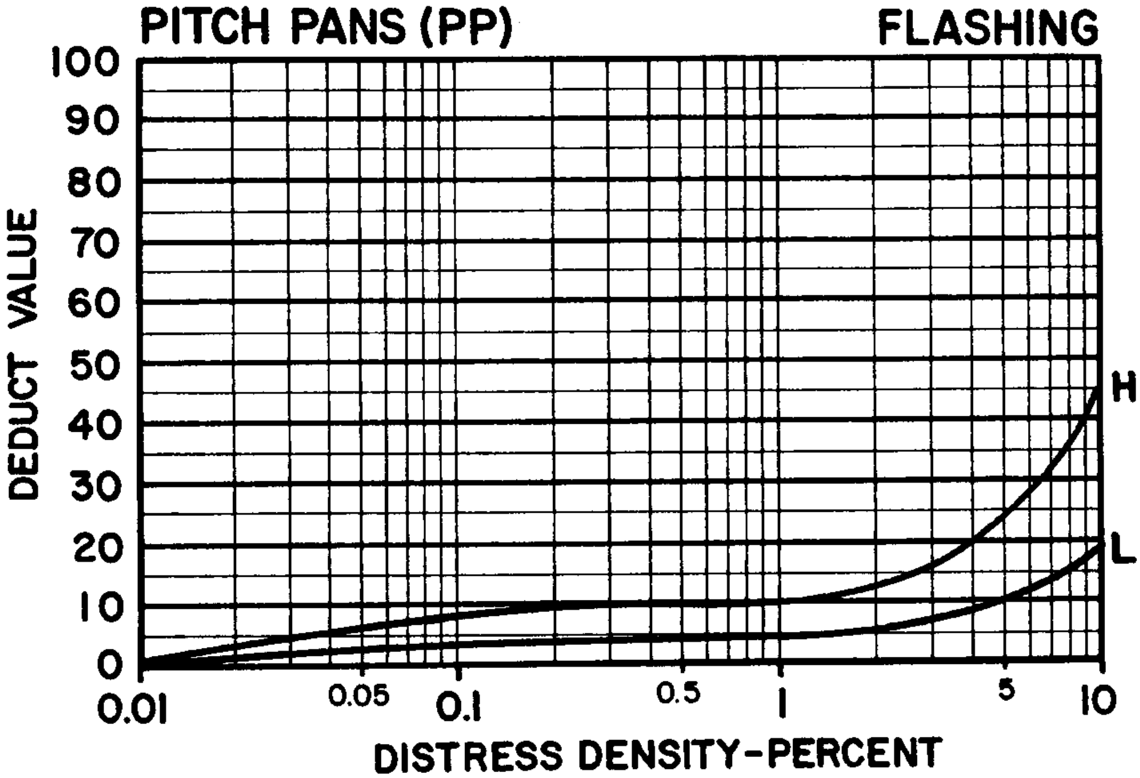
DISTRESS DENSITY-PERCENT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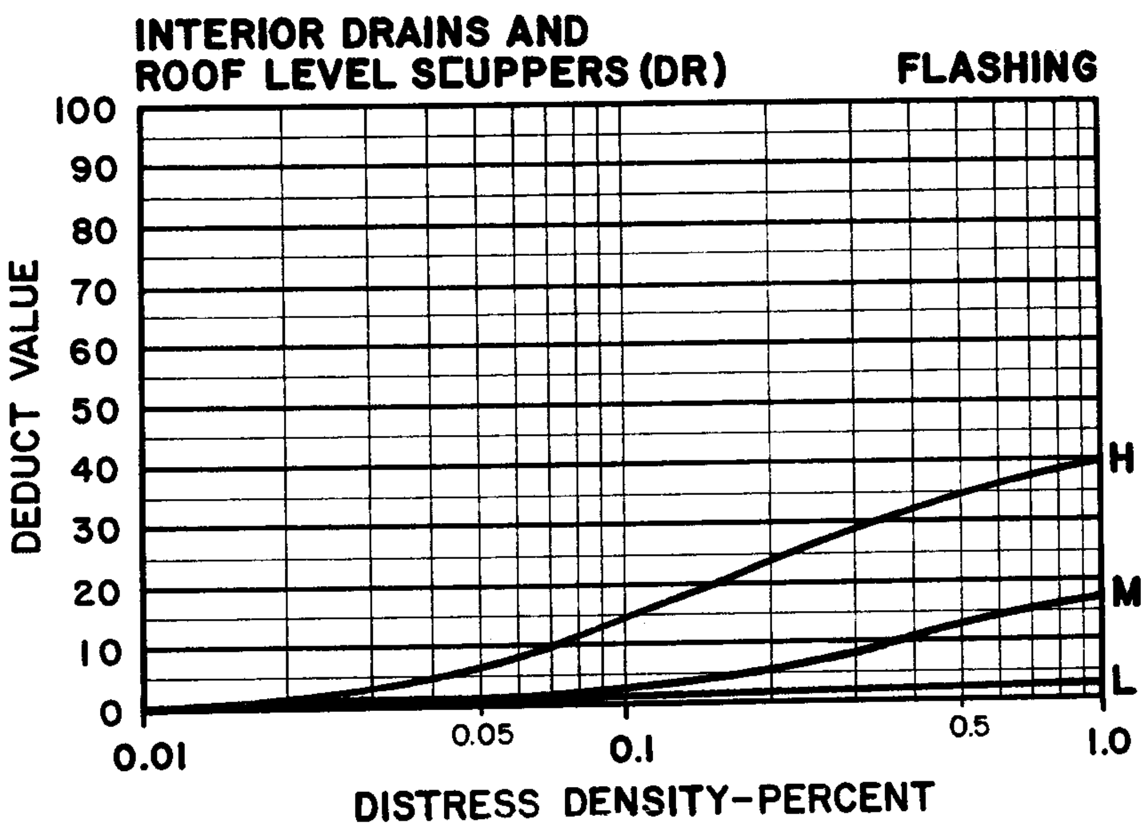
DISTRESS DENSITY-PERCENT


INTERIOR DRAINS AND
ROOF LEVEL SCUPPERS (DR)
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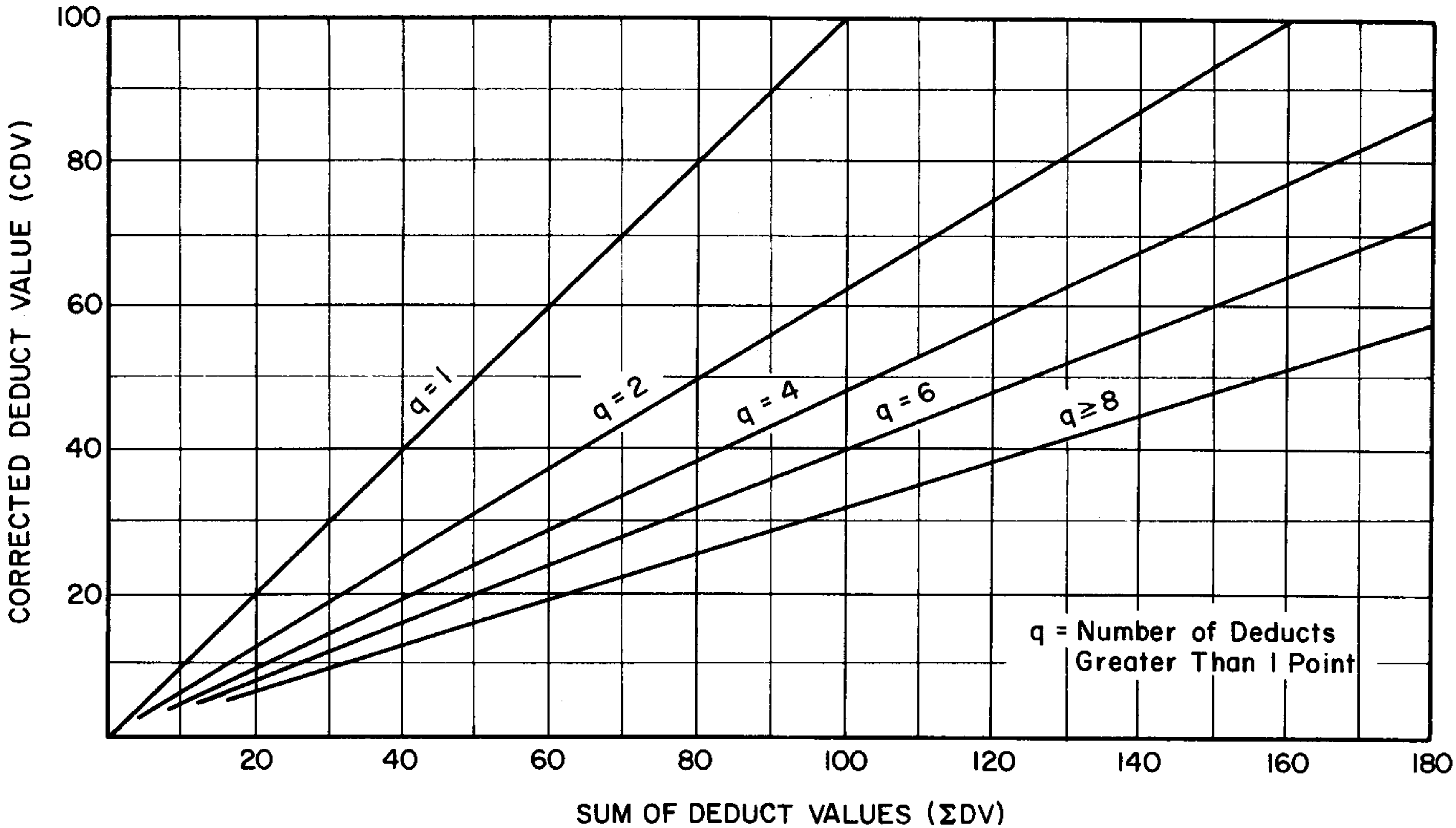
DISTRESS DENSITY-PERCENT



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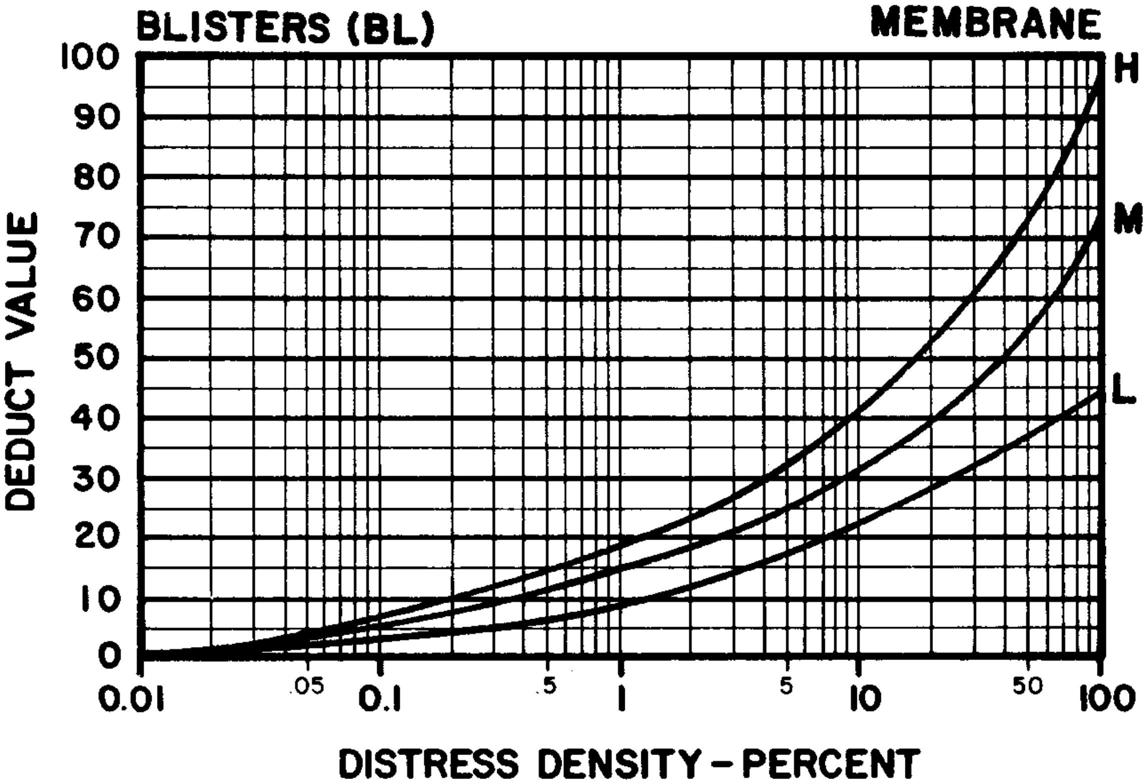

BLISTERS (BL)
MEMBRANE
DEDUCT VALUE
DISTRESS DENSITY - PERCENT
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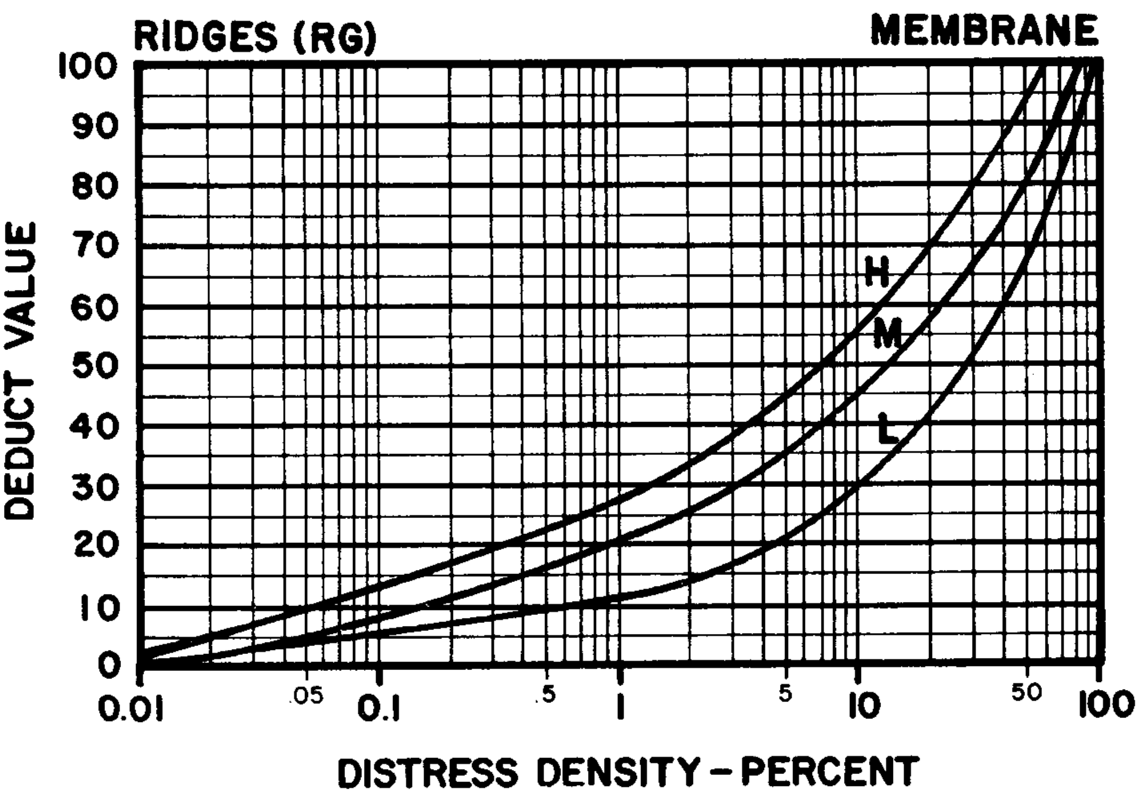

RIDGES (RG)
MEMBRANE
DEDUCT VALUE
DISTRESS DENSITY - PERCENT
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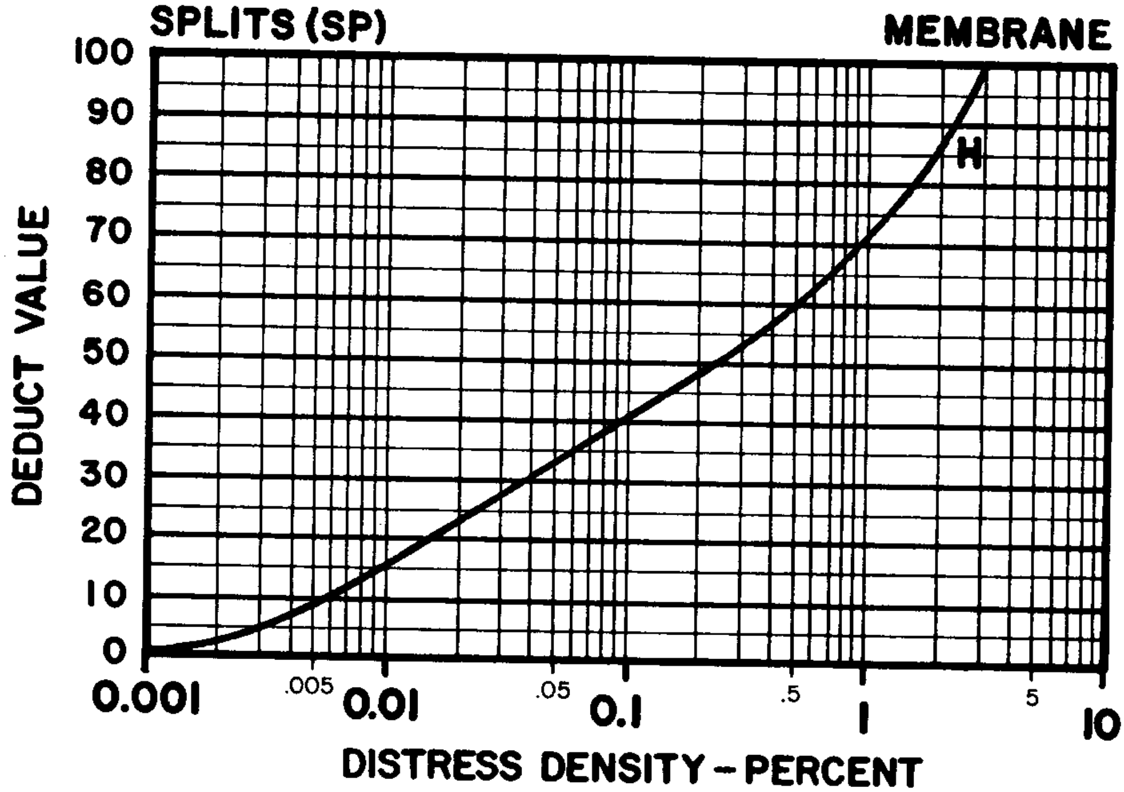
SPLITS (SP)
MEMBRANE
DEDUCT VALUE
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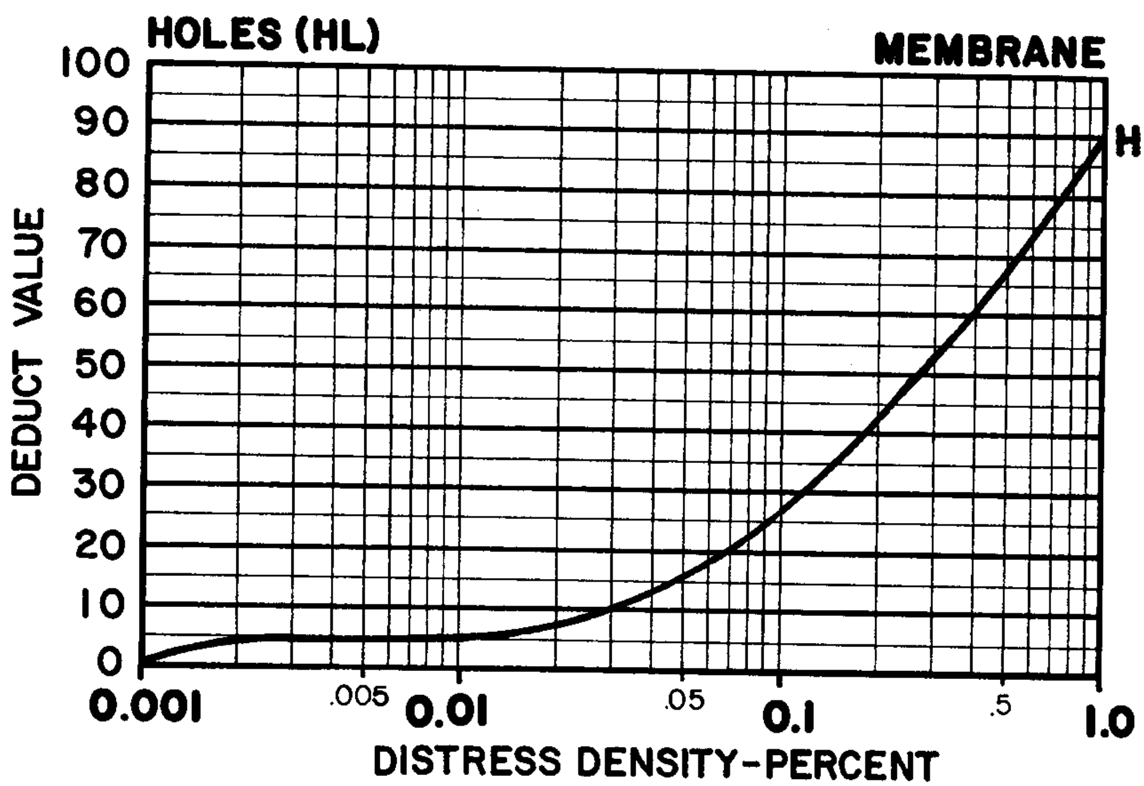
DISTRESS DENSITY - PERCENT


HOLES (HL)
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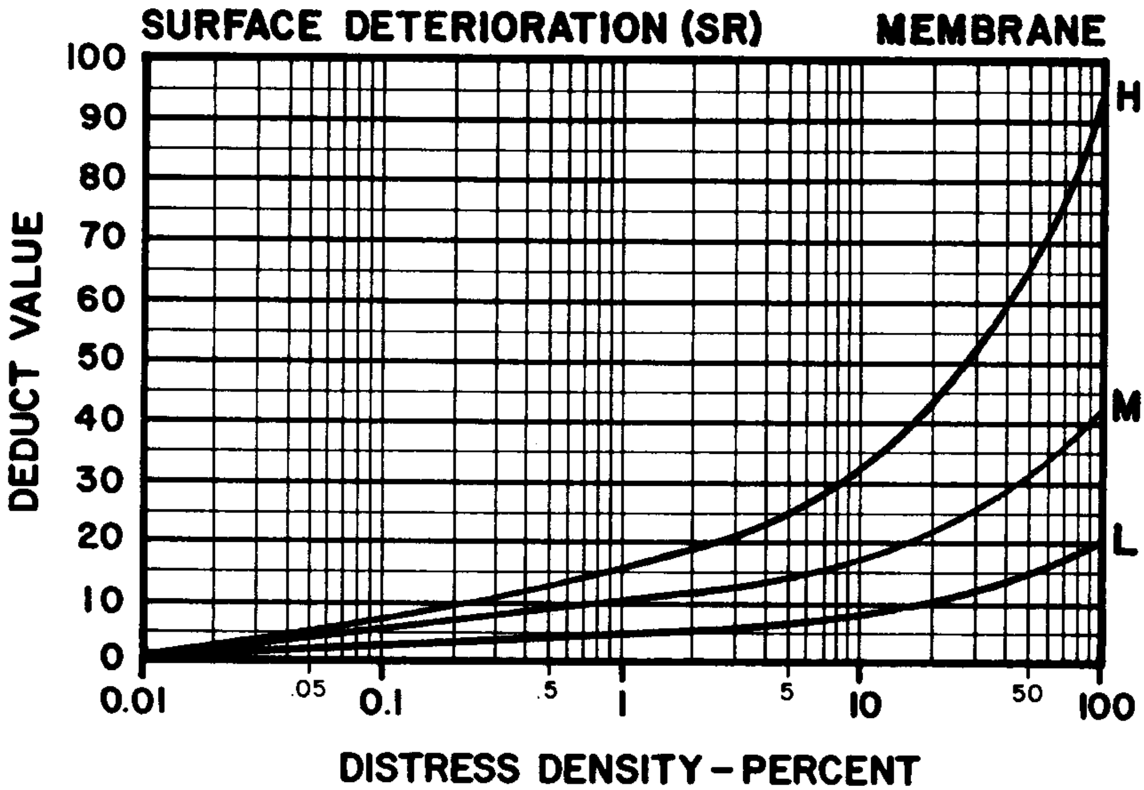
DISTRESS DENSITY-PERCENT


SURFACE DETERIORATION (SR)
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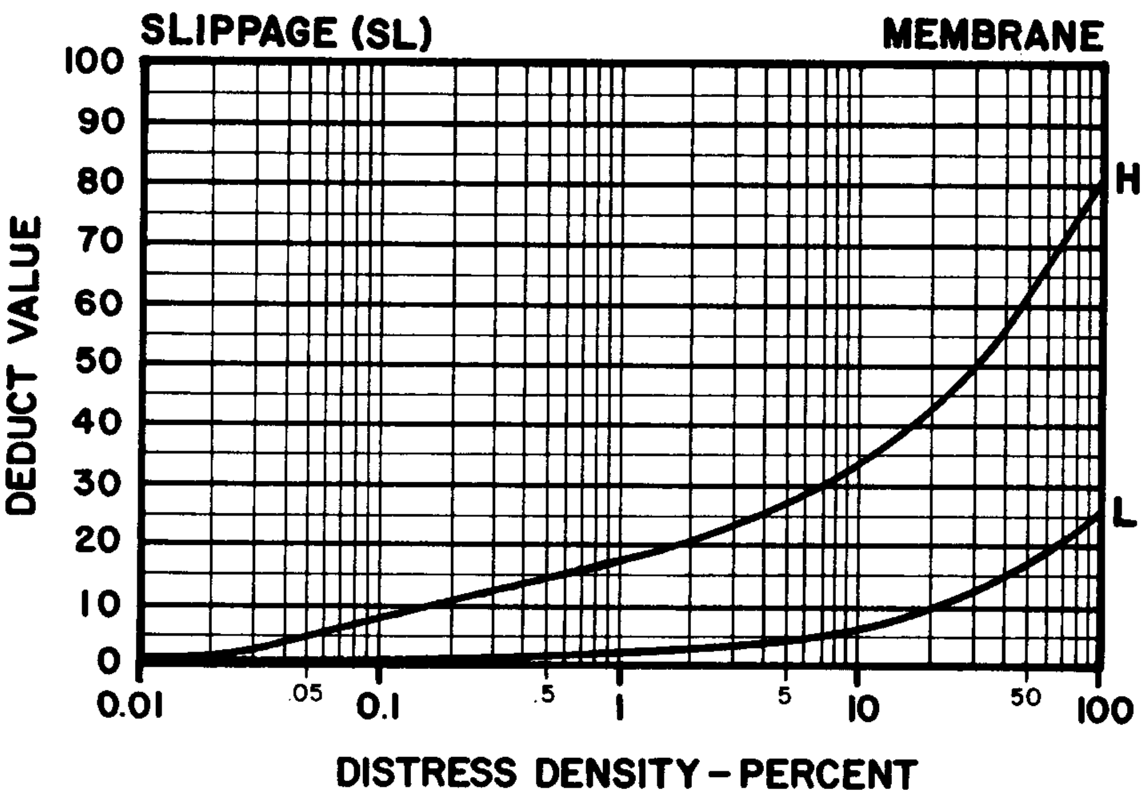
DISTRESS DENSITY - PERCENT


SLIPPAGE (SL)
MEMBRANE
DEDUCT VALUE
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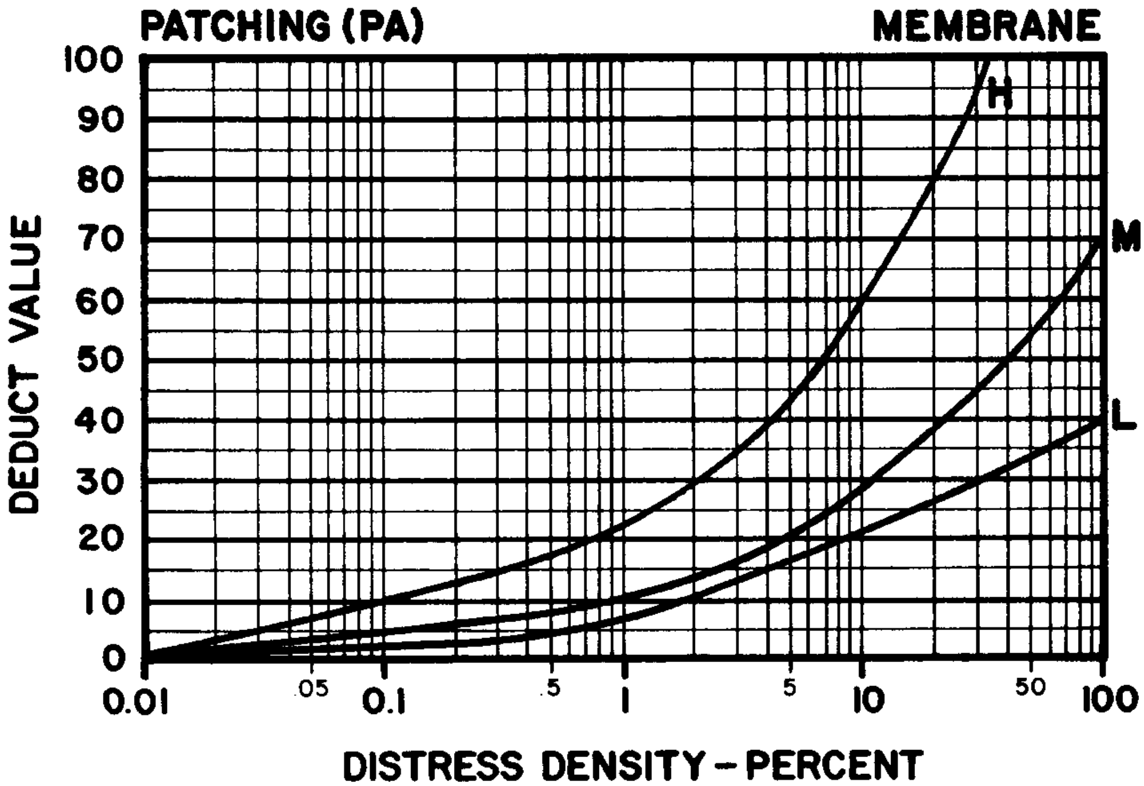
DISTRESS DENSITY - PERCENT


PATCHING (PA)
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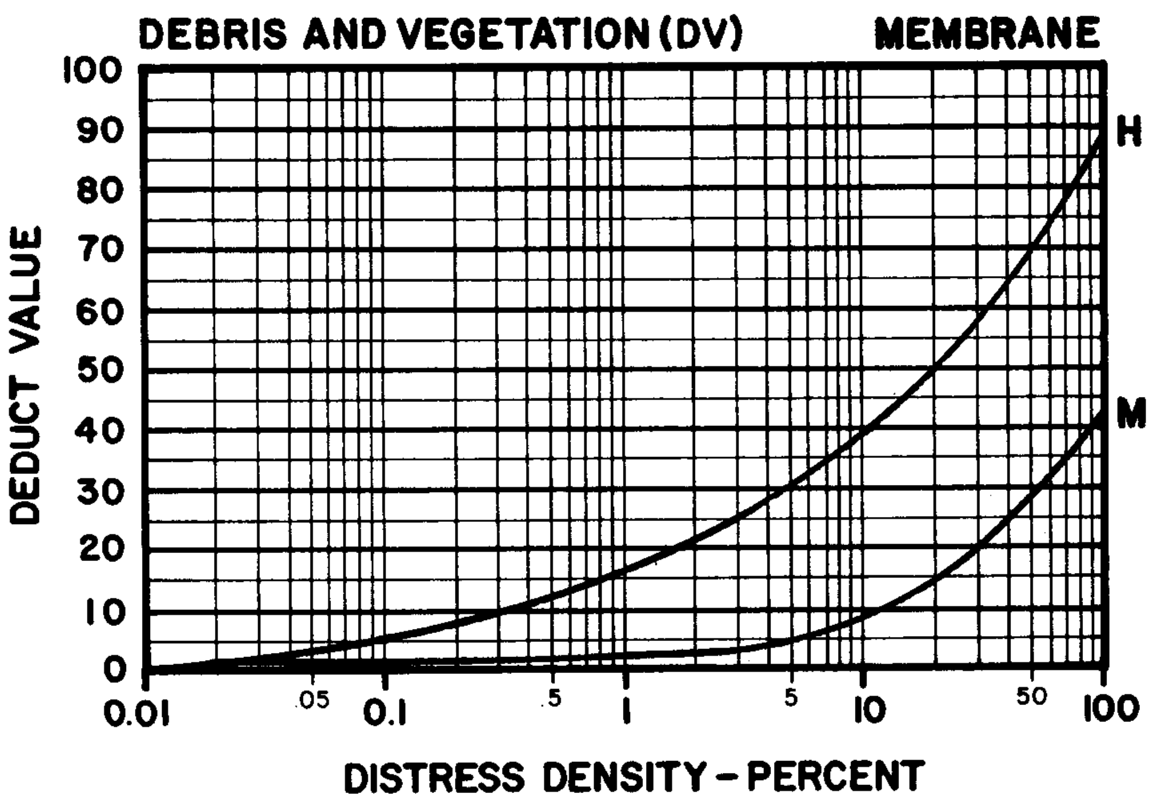
DISTRESS DENSITY - PERCENT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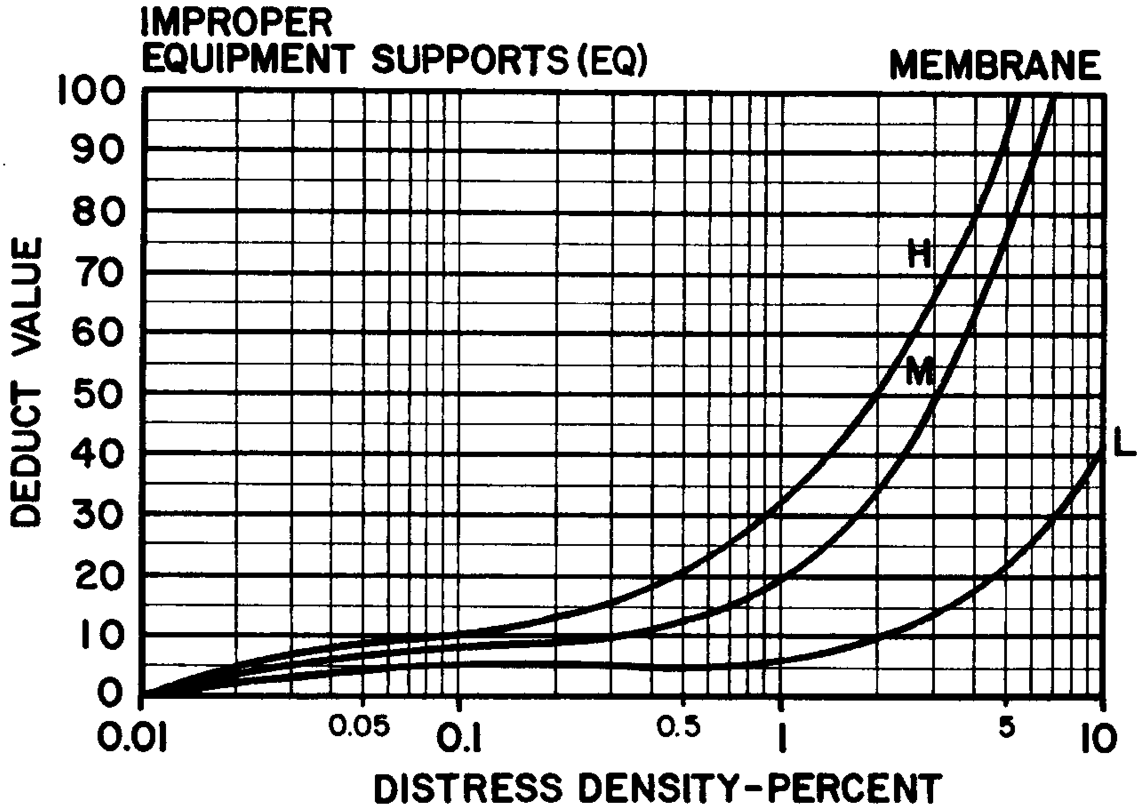
DISTRESS DENSITY - PERCENT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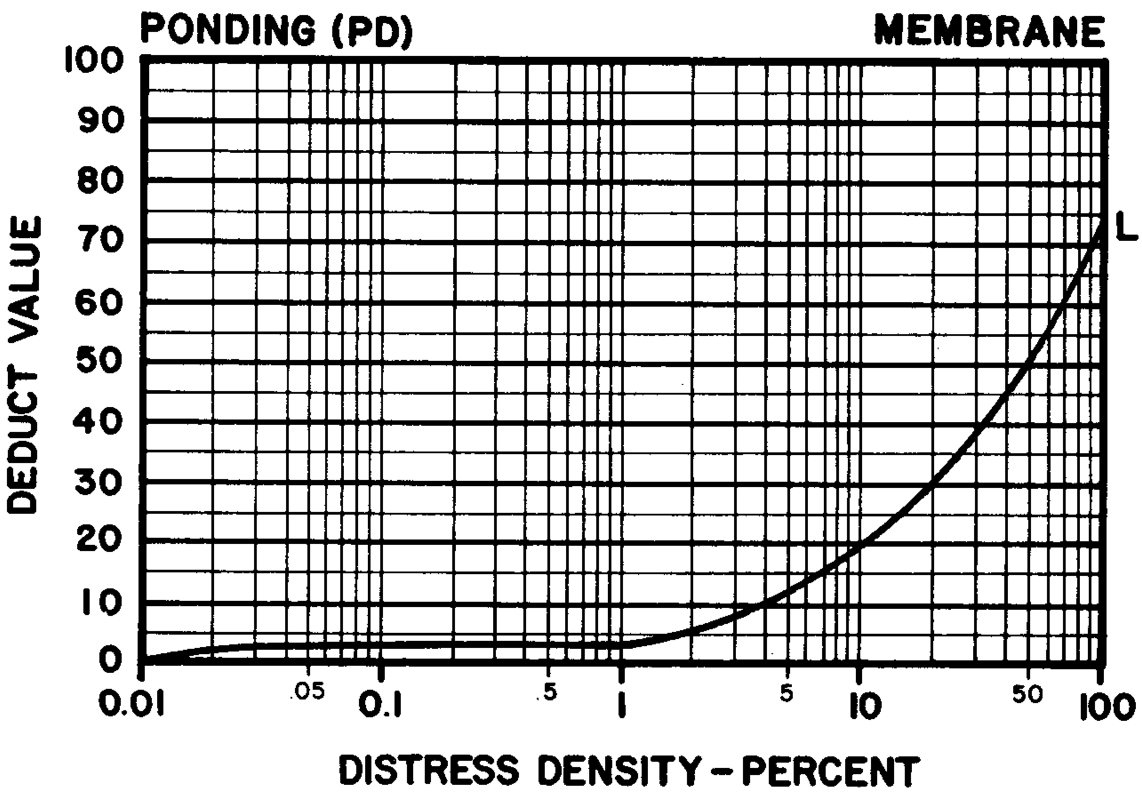
DISTRESS DENSITY-PERCENT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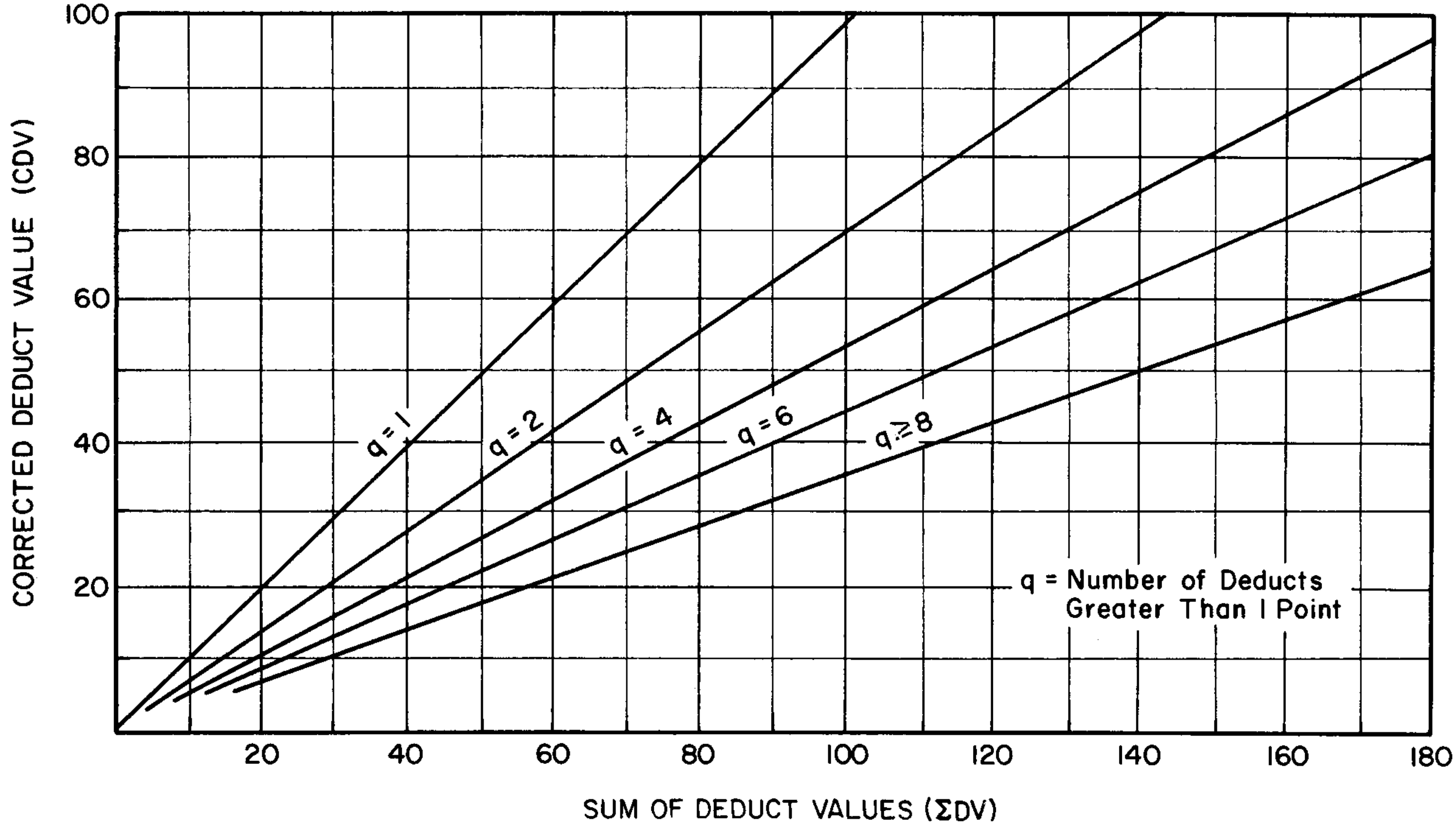
DISTRESS DENSITY - PERCENT



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