MIL-HDBK-772

30 March 1981

MILITARY STANDARDIZATION HANDBOOK

MILITARY PACKAGING ENGINEERING

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NO DELIVERABLE DATA REQUIRED BY THIS DOCUMENT

DEPARTMENT OF DEFENSE
WASHINGTON, DC 20360

MIL-HDBK-772
Military Packaging Engineering
30 March 1981

1. This standardization handbook was developed by the Department of Defense in accordance with established procedures.

2. This publication was approved on 30 March 1981 for printing and inclusion in the military standardization handbook series.

3. This document provides basic and fundamental packaging engineering principles and practices for the packaging of military supplies and equipment. The handbook is not intended to be referenced in purchase specifications, except for information purposes, nor shall it supersede any specification requirements.

4. Every effort has been made to reflect current criteria for packaging of military supplies and equipment. This handbook will be periodically reviewed by its proponent to insure its completeness and currency. Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to Director, US Army Materiel Development and Readiness Command Packaging, Storage, and Containerization Center, ATTN: SDSTO-T, Tobyhanna, PA 18466, by using the self-addressed Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document, or by letter.

FOREWORD

Military packaging has experienced significant changes recently due to a variety of factors, including increasing costs of traditional packaging materials, environmental considerations, expanded use of containers, and the advent of direct delivery to overseas customers. These changes have dictated that new methods and techniques be explored as possible replacements for traditional packaging practices. This handbook provides packaging criteria, materials, and test information for guidance in the design, development, and fabrication of packaging within the framework of the DOD packaging policy.

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1. SCOPE

1.1 Scope. This handbook covers fundamental principles and practices of military packaging engineering. It provides information concerning materials, the basic causes of deterioration, methods of preservation, and types of preservatives. Also included is information on natural and transportation environments, cost and human engineering factors, and other special military packaging considerations.

1.2 Applicability. This handbook is applicable to packaging of all general supplies (excluding ammunition) and equipment used by the Department of Defense (DOD).

2. REFERENCED DOCUMENTS

2.1 Issues of documents. The issues of the following documents, in effect on date of invitation for bids or request for proposal, form a part of this handbook to the extent specified herein. This section also lists documents not referenced, but are included as an aid to users of this handbook.

SPECIFICATIONS

Federal

C-F-202	Felt Sheet (Hair) and Felt Roll (Hair)
L-P-349	Plastic Molding and Extrusion, Molding, Material, Cellulose Acetate Butyrate
L-P-375	Plastic Film, Flexible, Vinyl Chloride
L-P-378	Plastic Sheet and Strip, Thin Gauge, Polyolefin
L-P-386	Plastic Material, Cellular, Urethane (Flexible)
L-P-504	Plastic Sheet and Film, Cellulose Acetate
L-P-505	Plastic Panels, Corrugated, Translucent, Glazing
L-P-517	Plastic Sheet, Scribe-coated
L-T-90	Tape, Pressure-sensitive, Adhesive, (Cellophane and Cellulose Acetate)
L-T-99	Tape, Pressure-sensitive, Adhesive, Identification
O-C-1824	Cleaning Compound, Solvent, Heavy Duty, Liquid
O-T-236	Tetrachloroethylene (Perchloroethylene), Technical Grade
O-T-620	Trichloroethane, 1,1,1, Technical Inhibited (Methyl Chloroform)
O-T-634	Trichloroethylene, Technical
P-C-436	Cleaning Compound Alkali, Boiling Vat (Soak) or Hydrosteam

P-C-437	Cleaning Compound, High Pressure (Steam) Cleaner
P-C-444	Cleaning Compound, Solvent, Grease Emulsifying
P-C-535	Cleaning Compound, Platers Electro-cleaning for Steel
P-D-680	Dry Cleaning Solvent
T-T-871	Twine, Fibrous Cotton, Wrapping
FF-N-105	Nails, Brads, Staples and Spikes, Wire, Cut and Wrought
HH-I-585	Insulation, Thermal (Vermiculite)
MM-L-736	Lumber Hardwood
MM-L-751	Lumber Softwood
NN-P-71	Pallet, Materiel Handling, Wood, Stringer Construction, 2 Way and 4 Way (Partial)
NN-P-530	Plywood, Flat Panel
QQ-A-200	Aluminum Alloy, Bar, Rod, Shapes, Tube and Wire, Extended, and Structural Shapes, General Specification for
QQ-A-225	Aluminum Alloy, Bar, Rod, Wire or Special Shapes, Rolled, Drawn, or Cold Finish, General Specification for
QQ-A-250	Aluminum Alloy Plate and Sheet, General Specification for
QQ-A-1876	Aluminum Foil
QQ-M-31	Magnesium Alloy, Bars, Rods, and Special Shaped Sections, Extended
QQ-M-44	Magnesium Alloy Plate and Sheet (AZ318)
QQ-S-698	Steel, Sheet and Strip, Low Carbon
QQ-S-741	Steel, Carbon, Structural Shapes, Plates and Bars
QQ-S-781	Strapping, Steel, Flat and Seals
RR-W-410	Wire Rope and Strand
TT-P-664	Primer Coating, Synthetic, Rust-inhibiting, Lacquer-resisting
TT-R-271	Resin, Phenol-formaldehyde (Para-phenyl and Para-butyl)
TT-T-291	Thinner, Paint, Volatile Spirits (Regular and Odorless)
TT-W-571	Wood Preservation: Treating Practices
TT-W-572	Wood Preservation: Water-repellent
UU-B-38	Bag, Paper (Hardware)
UU-C-282	Chipboard
UU-P-268	Paper, Kraft, Wrapping
UU-P-553	Paper, Wrapping, Tissue
UU-S-48	Sacks, Shipping, Paper
UU-T-81	Tags, Shipping and Stock
VV-L-800	Lubricating Oil, General Purpose, Preservative (Water-displacing, Low Temperature)

CCC-C-429	Cloth, Osnaburg, Cotton
CCC-C-467	Cloth, Burlap, Jute (or Kenaf)
MMM-A-100	Adhesive, Animal-glue
MMM-A-105	Adhesive, and Sealing Compounds, Cellulose Nitrate Base, Solvent Type
MMM-A-121	Adhesive, Bonding Vulcanized Synthetic Rubber to Steel
MMM-A-122	Adhesive, Butadiene-Acrylonitrile Base, General Purpose
MMM-A-125	Adhesive, Casein-type, Water and Mold Resistant
MMM-A-130	Adhesive, Contact
MMM-A-134	Adhesive Epoxy Resin, Metal to Metal Structural Bonding
MMM-A-138	Adhesive, Metal to Wood, Structural
MMM-A-139	Adhesive, Natural or Synthetic-natural Rubber
MMM-A-150	Adhesive for Acoustical Materials
MMM-A-178	Adhesive, Paper Label, Water-resistant
MMM-A-179	Adhesive, Paper Label, Water-resistant, Water Emulsion Type
MMM-A-180	Adhesive, Polyvinyl Acetate Resin Emulsion (Alkali Dispensible)
MMM-A-181	Adhesive, Phenol, Resorcinol or Melamine Base
MMM-A-182	Adhesive, Rubber
MMM-A-187	Adhesive, Epoxy Resin Base, Low and Intermediate Strength, General Purpose
MMM-A-188	Adhesive, Urea-Resin-Type (Liquid and Powder)
MMM-A-189	Adhesive, Synthetic Rubber, Thermoplastic, General Purpose
MMM-A-193	Adhesive, Vinyl Acetate Resin Emulsion
MMM-A-250	Adhesive, Water-resistant (For Closure of Fiberboard Boxes)
MMM-A-260	Adhesive, Water-resistant (For Sealing Waterproofed Paper)
MMM-A-1058	Adhesive, Rubber Base (In Pressurized Dispensers)
MMM-A-1617	Adhesive, Rubber Base, General Purpose
NNN-P-40	Paper, Lens, Tissue
PPP-B-20	Bag, Cotton, Mailing
PPP-B-26	Bag, Plastic, General Purpose
PPP-B-35	Bag, Textile, Shipping, Burlap, Cotton and Waterproof Laminated
PPP-B-566	Box, Folding Paperboard
PPP-B-576	Box, Wood, Cleated, Veneer, Paper Overlaid
PPP-B-585	Box, Wood, Wirebound

PPP-B-587	Box, Wood, Wirebound, Pallet Type
PPP-B-591	Box, Fiberboard, Wood-cleated
PPP-B-601	Box, Wood, Cleated Plywood
PPP-B-621	Box, Wood, Nailed and Lock Corner
PPP-B-636	Box, Shipping, Fiberboard
PPP-B-640	Box, Fiberboard, Corrugated, Triple-wall
PPP-B-665	Box, Paperboard, Metal Edged and Components
PPP-B-676	Box, Setup
PPP-B-1055	Barrier Material, Waterproofed, Flexible
PPP-B-1163	Box, Corrugated Fiberboard, High Compression Strength, Weather-resistant, Wax-resin Impregnated
PPP-B-1364	Box, Corrugated Fiberboard, High Strength, Weather-resistant, Double-wall
PPP-B-1672	Boxes, Shipping, Reusable with Cushioning
PPP-C-96	Can, Metal, 28 Gage and Lighter
PPP-C-186	Container, Packaging and Packing of Drugs, Chemicals and Pharmaceuticals
PPP-C-569	Container, Plastic, Molded (For Liquids, Plastic and Powders) Overpacked
PPP-C-795	Cushioning Material, Flexible, Cellular, Plastic Film for Packaging Applications
PPP-C-843	Cushioning Material, Cellulosic
PPP-C-850	Cushioning Material, Polystyrene Expanded, Resilient (For Packaging Uses)
PPP-C-1120	Cushioning Material, Uncompressed Bound Fiber for Packaging
PPP-C-1581	Can, Composite, With Metal Ends, for Liquid Items
PPP-C-1683	Cushioning Material, Expanded Polystyrene Loose Fill Bulk (For Packaging Applications)
PPP-C-1752	Cushioning Material, Packaging, Unicellular Polyethylene Foam, Flexible
PPP-C-1797	Cushioning Material, Resilient, Low Density, Unicellular Polyurethylene Foam, Flexible
PPP-C-1842	Cushioning Material, Plastic, Open Cell (For Packaging Application)
PPP-D-705	Drums, Shipping and Storage, Steel, 16- and 30-Gal Capacity
PPP-D-711	Drum, Metal, Shipping, Steel, Lightweight (55 Gal)
PPP-D-723	Drums, Fiber
PPP-D-729	Drums, Shipping and Storage, Steel, 55 Gal
PPP-E-911	Excelsior, Wood, Fabricated Pads and Bulk Form

PPP-E-1533	Envelopes, Packaging, Cushioned
PPP-F-320	Fiberboard, Corrugated and Solid, Sheet Stock (Container Grade) and Cut Shapes
PPP-P-291	Paperboard, Wrapping and Cushioning
PPP-P-704	Pail, Shipping, Steel (1 through 12 Gal)
PPP-P-1660	Pallet, Expendable
PPP-S-30	Sack, Shipping, Paper (Cushioned or Reinforced)
PPP-S-760	Strapping, Nonmetallic (and Connectors)
PPP-T-42	Tape, Packaging/Masking, Paper
PPP-T-45	Tape, Gummed, Paper, Reinforced and Plain, for Sealing and Securing
PPP-T-60	Tape, Packaging, Waterproof
PPP-T-70	Tape, Packaging, Plastic Film
PPP-T-76	Tape, Packaging Paper (For Carton Sealing)
PPP-T-97	Tape, Pressure-sensitive Adhesive, Filament Reinforced

Military

MIL-M-14	Molding Plastics and Molded Plastic Parts, Thermosetting
MIL-C-104	Crate, Wood, Lumber and Plywood Sheathed, Nailed and Bolted
MIL-P-116	Preservation-Packaging, Methods of
MIL-B-117	Bag, Sleeve and Tubing - Interior Packaging
MIL-B-121	Barrier Material, Greaseproofed, Waterproofed, Flexible
MIL-P-130	Paper, Wrapping, Laminated and Creped
MIL-B-131	Barrier Materials, Watervaporproof, Flexible, Heat-sealable
MIL-P-149	Plastic Coating Compound, Strippable (Hot Dripping)
MIL-P-265	Polyvinyl Alcohol, Granular
MIL-S-851	Steel Grit, Shot, and Cut Wire Shot; and Iron Grit and Shot-Blast Cleaning and Peening
MIL-F-2312	Felt, Hair or Wool, Mildew-resistant and Moisture-resistant, Treatment For
MIL-B-3106	Board, Composition, Water-resistant, Solid (For Filler or Cushioning Pads)
MIL-L-3150	Lubricating Oil, Preservative, Medium
MIL-A-3167	Adhesives (For Plastic Inhibitors)
MIL-C-3254	Coating System, Bridging, Strippable, Sprayable
MIL-A-3316	Adhesive, Fire-resistant, Thermal Insulation
MIL-P-3420	Packaging Materials, Volatile Corrosion Inhibitor Treated, Opaque

MIL-D-3464	Desiccants, Activated, Bagged, Packaging Use and Static Dehumidification
MIL-D-3716	Desiccants, Activated, for Dynamic Dehumidification
MIL-R-3745	Resin, Phenol-formaldehyde Laminating
MIL-C-3774	Crate, Wood, Open, 12,000- and 16,000-Pound Capacity
MIL-C-3955	Can, Composite, Spirally Wound
MIL-C-4036	Cleaner, Vapor Pressure, Spray Rinse
MIL-C-4150	Case, Transit and Storage, Waterproof and Watervaporproof
MIL-C-5140	Cleaning Compound, Aluminum Surface, Nonflame-sustaining
MIL-P-5425	Plastic, Sheet, Acrylic, Heat Resistant
MIL-C-5501	Cap and Plug, Protective Dust and Moisture Soil
MIL-C-5537	Cellulose Acetate Butyrate
MIL-A-5540	Adhesive, Polychloroprene
MIL-C-5584	Container, Shipping and Storage, Metal Reusable
MIL-H-5606	Hydraulic Fluid, Petroleum Base, Aircraft Missile and Ordnance
MIL-G-5634	Grain, Abrasive, Soft, for Carbon Removal
MIL-B-5806	Box, Shipping and Storage, Helicopter Blade
MIL-D-6054	Drum, Metal, Shipping and Storage
MIL-D-6055	Drum, Metal Reusable, Shipping and Storage
MIL-E-6060	Envelope, Packaging, Watervaporproof, Flexible
MIL-L-6081	Lubricating Oil, Jet Engine
MIL-H-6083	Hydraulic Fluid, Petroleum Base, for Preservation and Operation
MIL-L-6085	Lubricating Oil, Instrument, Aircraft, Low Volatility
MIL-R-6130	Rubber, Cellular, Chemically Blown
MIL-P-6264	Plastic Sheet and Film, Vinyl Copolymers
MIL-C-6529	Corrosion Preventive, Aircraft Engine
MIL-C-6799	Coating, Sprayable, Strippable, Protective, Water Emulsion
MIL-R-6855	Rubber, Synthetic, Sheets, Strips, Molded or Extruded Shapes
MIL-R-7575	Resin, Polyester, Low-pressure Laminating

MIL-M-7752	Metal Cleaner Silicate-soap
MIL-P-8184	Plastic Sheet, Acrylic, Modified
MIL-C-8188	Corrosion-preventive Oil, Gas Turbine
MIL-A-8421	Air Transportability Requirements, General Specification for
MIL-I-8574	Inhibitors, Corrosion, Volatile, Utilization of
MIL-A-8576	Adhesive, Acrylic Base, for Acrylic Plastic
MIL-V-8712	Valve, Air Relief, Low Pressure
MIL-R-9299	Resin, Phenolic, Laminating
MIL-H-9884	Honeycomb Material, Cushioning Paper
MIL-C-9897	Crate, Slotted Angle, Steel or Aluminum for Lightweight Airframe Components and Bulky Items (Form Maximum Loads of 3000 Pounds)
MIL-P-9902	Panel, Full Cleated, Partially Cleated and Uncleated; Plywood, Veneer Paper-overlaid and Solid Fiberwood for Box, Modular Systems
MIL-C-10382	Corrosion Preventive, Petroleum, Spraying Application, for Food Handling Machinery and Equipment
MIL-W-10434	Window, Observation
MIL-C-10464	Cans, Hermetic Sealing, Metal, Light Gage, Tear-strip Type
MIL-L-10547	Liner Case, and Sheet Overwrap, Watervaporproof or Waterproof, Flexible
MIL-C-10578	Corrosion Removing and Metal Conditioning Compound (Phosphoric Acid Base)
MIL-E-10853	Ethyl Cellulose
MIL-G-10924	Grease, Automotive and Artillery
MIL-C-11090	Cleaning Compound, Degreasing and Depreserving Solvent, Self-emulsifying
MIL-C-11133	Crate, Shipping, Wood, Open, Wirebound
MIL-C-11796	Corrosion Preventive Compound, Petrolatum, Hot Application
MIL-B-11886	Box, Metal, Shipping, Reusable, Trans-porter, Steel, Max. Load, 9,000 Pounds
MIL-D-12491	Degreaser, Solvent, Tank-immersion Type
MIL-G-12803	Gasket Materials, Nonmetallic
MIL-A-13374	Adhesive, Dextrin, for Use in Ammunition Containers
MIL-A-14042	Adhesive, Epoxy
MIL-P-14232	Parts, Equipment and Tools for Army Materials, Packaging and Packing of
MIL-C-14460	Corrosion Removing Compound, Sodium Hydroxide Base, for Electrolytic or Immersion Application

MIL-P-14591	Plastic Film, Nonrigid, Transparent
MIL-P-15011	Pallets, Material Handling, Wood, Post Construction, 4-Way Entry
MIL-C-15074	Corrosion Preventive, Fingerprint Remover
MIL-C-16173	Corrosion Preventive Compound, Solvent Cutback, Cold-application
MIL-C-16555	Coating Compound, Strippable, Sprayable
MIL-D-16791	Detergent, General Purpose (Liquid, Nonionic)
MIL-C-17435	Cushioning Material, Fibrous Glass
MIL-P-17667	Paper, Wrapping, Chemically Neutral (Noncorrosive)
MIL-B-17757	Boxes, Shipping, Fiberboard (Modular Sizes)
MIL-P-18080	Plastic Sheet, Vinyl, Flexible, Transparent, Optical Quality
MIL-N-18352	Nylon Plastic, Flexible, Molded or Extruded
MIL-P-19468	Plastic Rod, Polytetrafluoroethylene, Molded and Extruded
MIL-P-19644	Plastic Molding Material (Polystyrene Foam Expanded Bead)
MIL-P-19904	Plastic Sheet, Acrylo-nitrile Butadiene
MIL-P-20092	Rubber Sheets and Molded Shapes, Cellular Synthetic Open Cell (Foamed Latex)
MIL-P-20293	Paper, Kraft, Asphalt-impregnated
MIL-P-20307	Polyvinylchloride (For Use in Pyrotechnics)
MIL-M-20693	Molding Plastic, Polyamide (Nylon) Rigid
MIL-P-21094	Plastic Sheet, Cellulose Acetate, Optical Quality
MIL-L-21260	Lubricating Oil, Internal Combustion Engine, Preservative and Break-in
MIL-R-21607	Resin, Polyester, Low Pressure Laminating, Fire-retardant
MIL-P-21922	Plastic Rods, and Tubes, Polyethylene
MIL-P-21929	Plastic Material, Cellular Polyurethane, Foam-In-Place, Rigid, 2 and 4 Pounds per Cubic Foot
MIL-R-21931	Resin, Epoxy
MIL-A-22010	Adhesive, Solvent Type, Polyvinylchloride
MIL-B-22019	Barrier Materials, Transparent, Flexible, Sealable, Volatile Corrosion Inhibitor Treated
MIL-B-22020	Bag, Transparent, Flexible, Sealable, Volatile Corrosion Inhibitor Treated
MIL-T-22085	Tape, Pressure-sensitive, Adhesive, Preservation and Sealing
MIL-P-22096	Plastic, Polyamide (Nylon), Flexible Molding and Extrusion Material

MIL-I-22110	Inhibitors, Corrosion, Volatile, Crystalline
MIL-B-22191	Barrier Material, Transparent, Flexible, Heat-sealable
MIL-C-22235	Corrosion Prevention Oil, Nonstaining
MIL-P-22241	Plastic Sheet (and Film), Polytetrafluoroethylene (Tfe - Fluorocarbon Resin)
MIL-A-22397	Adhesive, Phenol and Resorcinol Resin Base (For Marine Service Use)
MIL-C-22806	Crate, Sheathed, Wood, Wirebound
MIL-A-22895	Adhesive, Metal Identification Plate
MIL-I-23310	Inhibitor, Corrosion, Volatile, Oil Type
MIL-G-23827	Grease, Aircraft and Instrument, Gear and Actuator Screw
MIL-A-24179	Adhesive, Flexible Unicellular Plastic Thermal Insulation
MIL-R-25042	Resin, Polyester, High Temperature Resistant, Low Pressure Laminating
MIL-P-25374	Plastic Sheet, Acrylic, Modified, Laminated
MIL-A-25463	Adhesive, Metallic Structural Sandwich Construction
MIL-R-25506	Resin, Silicone, Low-pressure Laminating
MIL-G-25537	Grease, Aircraft, Helicopter
MIL-P-25690	Plastic, Sheets and Parts, Modified, Acrylic Base, Monolithic, Crack Propogation Resistant
MIL-C-26094	Can, Hermetic Sealing, Aluminum, Two-piece
MIL-B-26195	Box, Wood-cleated, Skidded, Load-bearing Base
MIL-C-26514	Polyurethane Foam, Rigid or Flexible, for Packaging
MIL-M-26696	Magnesium Alloy, Bar, Rod, and Special Shaped Sections Extruded (P)ZK60B
MIL-I-26860	Indicator, Humidity, Plug, Color Change
MIL-C-26861	Cushioning Material, Resilient Type, General
MIL-F-26862	Fiberboard, Solid, Noncorrosive Fungi-resistant For Interior Blocking Applications
MIL-V-27166	Valve, Pressure Equalizing, Gaseous Products
MIL-B-38721	Box, Consolidation, Fiberboard
MIL-D-40030	Drum, Plastic, Molded Polyethylene
MIL-T-40625	Tubing, Bias Sewn (Burlap or Osnaburg) Cloth
MIL-T-43036	Tape, Pressure-sensitive Adhesive, Plastic Film, Filament Reinforced (For Sealing Fiber Containers and Cans)

MIL-B-43666	Box, Shipping Consolidation
MIL-P-45021	Plastic Coating Compound, Strippable, Cold Dipping, 120° F. (49° C.)
MIL-A-45059	Adhesive for Bonding Chipboard to Terneplate, Tinplate and Zincplate
MIL-F-45216	Foam-In-Place Packaging, Procedures for
MIL-L-45973	Liner Material, Greaseproof
MIL-P-46002	Preservation Oil, Contact and Volatile Corrosion-inhibited
MIL-P-46036	Plastic Sheets, Rods, Tubes and Discs, Polychlorotrifluoroethylene
MIL-P-46093	Primer Coating, Synthetic (For Brake Drums)
MIL-A-46106	Adhesive Sealants, Silicone, Rtv, General Purpose
MIL-H-46170	Hydraulic Fluid, Rust Inhibited, Fire-resistant, Synthetic Hydrocarbon Base
MIL-B-46176	Brake Fluid, Silicone, Automotive, Operational and Preservative
MIL-D-46845	Design Requirement for Missile Weapon Systems, Packaging and Packing
MIL-A-52194	Adhesive, Epoxy (For Bonding Glass Reinforced Polyester)
MIL-B-52508	Box, Metal, Shipping, Reusable, Transporter, Controlled Humidity, Steel, 270 Cubic Foot Capacity, 9,000-Pound Maximum Load
MIL-C-52950	Crate, Wood, Open and Covered
MIL-P-55010	Plastic Sheet, Polyethylene Terephthalate
MIL-P-58102	Plastic Sheet and Laminates, Flexible, for Environmental Protection Storage and Shipping System
MIL-C-81309	Corrosion Preventive Compound, Water Displacing, Ultra-thin Film
MIL-G-81322	Grease, Aircraft, General Purpose Wide Temperature Range
MIL-T-81533	Trichloroethane (Methyl Chloroform) Inhibited, Vapor Degreasing
MIL-P-81598	Plastic Sheets, Flexible, Weather Resistant, Heat Sealable for Outdoor Storage Use
MIL-B-81705	Barrier Materials, Flexible, Electrostatic-free, Heat Sealable
MIL-B-81916	Barrier Material, Watervaporproof, Flexible, Heat Sealable
MIL-P-81997	Pouches, Cushioned, Flexible Electrostatic-free Reclosable, Transparent
MIL-F-83670	Foam-In-Place Packaging, Procedures for

MIL-F-87075	Foam-In-Place Packaging Systems for Shipboard Use

STANDARDS

Federal

FED-STD-101	Preservation, Packaging and Packing Materials, Test Procedures

Military

MIL-STD-105	Sampling Procedures and Tables for Inspection by Attributes
MIL-STD-129	Marking for Shipment and Storage
MIL-STD-147	Palletized and Containerized Unit Loads, 40-inch x 48-inch Pallets, Skids, Runner or Pallet Type Base
MIL-STD-163	Steel Mill Products, Preparation for Shipment and Storage
MIL-STD-171	Finishing of Metal and Wood Surfaces
MIL-STD-210	Climatic Extremes for Military Equipment
MIL-STD-281	Automobiles, Trucks, Truck-tractors, Trailers and Trailer Dollies, Preservation and Packaging of
MIL-STD-290	Packaging of Petroleum and Related Products
MIL-STD-647	Packaging Standards, Preparation and Use of
MIL-STD-649	Aluminum and Magnesium Products, Preparation for Shipment and Storage
MIL-STD-678	Design Criteria for Specialized Shipping Containers
MIL-STD-726	Packaging Requirements Codes
MIL-STD-731	Quality of Wood Members for Containers and Pallets
MIL-STD-794	Parts and Equipment, Procedures for Packaging and Packing of
MIL-STD-810	Environmental Test Methods
MIL-STD-1186	Cushioning, Anchoring, Bracing, Blocking and Waterproofing; with Appropriate Test Methods
MIL-STD-1187	Standard Size Unit, Intermediate, and Exterior Containers for Modular Packaging and Unitization on the 40-inch x 48-inch Pallet
MIL-STD-1188	Commercial Packaging of Supplies and Equipment

MIL-STD-1235	Single- and Multi-Level Continuous Sampling Procedures and Tables for Inspection By Attributes
MIL-STD-1246	Product Cleanliness Levels and Contamination Control Program
MIL-STD-1366	Packaging, Handling, Storage, Transportation System Dimensional Constraints, Definition of
MIL-STD-1367	Packaging, Handling, Storage, and Transportability Program Requirements (for Systems and Equipment)
MIL-STD-1472	Human Engineering Design Criteria for Military Systems, Equipment and Facilities
MIL-STD-1510	Container Design Retrieval System, Procedures for Use of
MIL-STD-2073	DOD Materiel, Procedures for Development and Application of Packaging Requirements
MIL-STD-2073-1	DOD Packaging Data Forms, Instructions for Preparation and Use
MIL-STD-2073-2	Packaging Requirements Codes
MS-18011	Containers, Reusable, Aluminum, Hand Portable-assembly for Shipping
MS-20003	Indicator, Humidity Card, Three Spot, Impregnated Areas (Cobaltous Chloride)
MS-27757	Pack, Instrument, With Star Design Polyurethane Cushioning Insert (For Delicate Item)

HANDBOOKS

Military

MIL-HDBK-7	Lumber and Allied Products
MIL-HDBK-138	Container Inspection Handbook for Commercial and Military Intermodal Containers (Dry Cargo Type)
MIL-HDBK-236	Index of Standards for Palletizing, Truck Loading, Rail Car Loading, and Container Loading of Hazardous Materials
MIL-HDBK-304	Package Cushioning Design
MIL-HDBK-693	Magnesium and Magnesium Alloy
MIL-HDBK-694	Aluminum and Aluminum Alloys
MIL-HDBK-700	Plastics
MIL-HDBK-701	Blocking, Bracing and Skidding of Industrial Production Equipment
MIL-HDBK-770	Shrink Film in Military Packaging
MIL-HDBK-157	Transportability Criteria

BULLETIN

Department of the Army

SB 38-100	Preservation, Packing, and Marking Materials, Supplies, and Equipment Used by the Army
TB 55-100	Transportability Criteria, Shock and Vibration

MANUALS

Defense Logistics Agency

DLA 4145.5	Packaging Cost Estimating

Joint Service

AFM 71-4	Preparation of Hazardous Material for Military Air Shipments (NAVSUP PUB 505(REV); MCO P4030.AI; DLAM 4145.3; TM 38-250

INSTRUCTIONS

Department of Defense

DOD 3224.1	DOD Engineering for Transportability Program
DOD 4145.19	Storage and Warehouse Facilities

REGULATIONS

Joint Service

AR 70-44	DOD Engineering for Transportability (OPNAVINST 4600.22; AFR 80-18; MCO 4610.14C; DLAR 4500.25)

Department of the Army

AR 70-38	Research, Development, Test, and Evaluation of Materiel for Extreme Climatic Conditions

TECHNICAL ORDER

Department of the Air Force

TO 00-85-37 Foam-In-Place Packaging

(Copies of specifications, standards, drawings, and publications required by contractors in connection with specific procurement functions should be obtained from the procuring activity or as directed by the contracting officer.)

2.2 Other publications. The following documents form a part of this handbook to the extent specified herein. This section also lists documents not referenced, but included as an aid to users of this handbook.

AMERICAN NATIONAL STANDARDS INSTITUTE, INC. (ANSI)

S 1.1	Acoustical Terminology, Including Mechanical Shock and Vibration
MH 5.1	Basic Requirement for Cargo Containers
MH 10.1	Unit Load Sized for Dimension of Transport Packaging
MH 10.2	Transport Packaging Sizes for MH 10.1 Unit Load Sizes
Z 210.1	Metric Practices

(Application for copies should be addressed to the American National Standards Institute, Inc., 1430 Broadway, New York, NY 10018.)

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

A 700	Packaging, Marking, and Loading Methods for Steel Products for Domestic Shipments
D 570	Water Absorption of Plastics
D 638	Tensile Properties of Plastic
D 642	Compression Test for Shipping Containers
D 685	Conditioning Paper and Paper Products for Testing
D 695	Compression Properties of Rigid Plastic
D 703	Polystyrene Molding and Extrusion Materials
D 775	Drop Test for Shipping Containers
D 781	Puncture and Stiffness of Paperboard, and Corrugated and Solid Fiberboard

D 782	Shipping Containers in Revolving Hexagonal Drum
D 786	Cellulose Acetate Plastic Sheets
D 792	Specific Gravity and Density of Plastics by Displacement
D 880	Incline Impact Test for Shipping Containers
D 882	Tensile Properties of Thin Plastic Sheeting
D 951	Water Resistance of Shipping Containers by Spray Method
D 959	Drop Test for Bags
D 996	Packaging and Distribution Environments, Definitions of Terms Relating to
D 997	Drop Test for Cylindrical Shipping Containers
D 998	Penetration of Liquids into Submerged Loaded Shipping Containers
D 999	Vibration Testing of Shipping Containers
D 1008	Water Vapor Transmission of Shipping Containers
D 1083	Large Cases and Crates
D 1084	Viscosity of Adhesives
D 1149	Rubber Deterioration - Surface Ozone Cracking
D 1185	Pallets, Testing
D 1203	Loss of Plasticizer from Plastics (Activated)
D 1276	Water Vapor Tranmission of Shipping Container by Cycle Method
D 1372	Packaging Cushioning Materials
D 1596	Shock Absorbing Characteristics of Packaging Cushioning Materials
D 1621	Compression Properties of Rigid Cellular Plastic
D 1638	Urethane Foam Isocyanate Raw Materials
D 2221	Creep Properties of Packaging Cushioning Materials
D 2341	Rigid Urethane Foam
D 2738	Bursting Strength of Corrugated and Solid Fiberboard
D 2860	Adhesion of Pressure-sensitive Tape to Fiberboard at 90° Angle and Constant Stress
D 2956	Controlled Shock Input Tests for Shipping Containers
D 3331	Assessment of Mechanical-shock Fragility Using Package Cushioning Materials
D 3332	Mechanical-shock Fragility of Products Using Shock Machines

D 3499	Toughness of Plywood
D 3500	Plywood in Tension
D 3501	Plywood in Compression
D 3502	Moisture Absorption of Compressed Wood Products
D 3503	Swelling and Recovery of Compressed Wood Products Due to Moisture Absorption
D 3580	Vibration (Sinusoidal Motion) Test of Products
D 3611	Accelerated Aging of Pressure-sensitive Tapes
D 3652	Thickness of Pressure-sensitive and Gummed Tapes
D 3653	Holding Power of Lineal and Multidirectional Filament-reinforced Pressure-sensitive Tapes
D 3654	Holding Power of Pressure-sensitive Tapes
D 3662	Bursting Strength of Pressure-sensitive Tapes
D 3813	Curling and Twisting on Unwinding of Pressure-sensitive Tapes
D 3816	Water Penetration Rate of Pressure-sensitive Tapes
D 3833	Water Vapor Transmission of Pressure
D 3892	Packaging/Packing of Plastic
E 380	Metric Practices
F 37	Sealability of Gasket Materials
F 88	Seal Strength of Flexible Barrier Materials
F 104	Nonmetallic Gasket Materials
F 146	Fluid Resistance of Gasket Materials

(Application for copies should be addressed to the American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.)

AMERICAN TRUCKING ASSOCIATION

Tariff No. 111C	ATA Hazardous Materials Tariff Summary of Size and Weight Limitations

(Copies may be obtained from the American Trucking Association, Inc., 1616 P Street, NW, Washington, DC 20036.)

AIR TRANSPORT ASSOCIATION OF AMERICA

ATA 300	Specification for Packing of Airline Supplies

(Copies may be obtained from the Air Transport Association of America, 1709 New York Avenue, NW, Washington, DC 20006.)

ASSOCIATION OF AMERICAN RAILROADS (AAR)

Freight Loading and Container Publication

(Application for copies should be addressed to the Secretary, Freight Loading and Container Bureau AAR, 59 East Van Buren Street, Chicago, IL 60605.)

BUREAU OF EXPLOSIVES

Tariff No. 6000	Hazardous Material Regulations of the Department of Transportation
Pamphlet No. 6	Illustrates approved methods for loading and bracing carload and less-than-carload shipments of explosives and other hazardous materials.
Pamphlet No. 6A	Illustrates approved methods for loading and bracing carload shipments of military ammunition and explosives.
Pamphlet No. 6C	Illustrates approved methods for loading and bracing trailers and less-than-trailer-load shipments of explosives and other dangerous articles via trailer-on-flat-car (TOFC) or container-on-flat-car (COFC).

(Application for copies should be addressed to the Bureau of Explosives AAR, Suite 620, 1920 L Street, NW, Washington, DC 20036.)

CODE OF FEDERAL REGULATIONS (CFR)

Title 14 CFR	Aeronautics and Space
Title 39 CFR	Postal Service
Title 46 CFR 146	Shipping
Title 49 CFR 178	Shipping Containers

Title 49 CFR 100-199	Transportation
Title 49 CFR 310-398	Federal Highway Administration

COAST GUARD

CG 108	Rules and Regulations for Military Explosives and Hazardous Munitions, Department of Transportation

US POSTAL SERVICE

Domestic Mail Manual

Domestic Mail Service Information, Mail Class, and Special Service

(Copies may be obtained from the Superintendent of Documents, Government Printing Office, Washington, DC 20402.)

INTER-GOVERNMENTAL MARITME CONSULTATIVE ORGANIZATION (IMCO)

International Maritime Dangerous Goods (IMDG) Codes

(Application for copies should be addressed to New York Nautical Instrument and Service Corp., 140 W. Broadway, New York, NY 10015.)

INTERNATIONAL AIR TRANSPORT ASSOCIATION (IATA)

IATA Restricted Articles Regulation

(Application for copies should be addressed to Labelmaster, 6001 North Clark Street, Chicago, IL 60660.)

NATIONAL MOTOR FREIGHT TRAFFIC ASSOCIATION, INC., AGENT

National Motor Freight Classification

(Application for copies should be addressed to the American Trucking Association, Inc., 1616 P Street, NW, Washington, DC 20036.)

OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION (OSHA)

Occupational Safety and Health, Volume I, General Industry Standards and Interpretation

(Application for copies should be addressed to the Superintendent of Documents, US Government Printing Office, Washington, DC 20402.)

TECHNICAL ASSOCIATION OF THE PULP AND PAPER INDUSTRY (TAPPI)

T-411	Thickness (Caliper) of Paper and Paperboard
T-477	Blocking Resistance of Paper and Flexible Materials
T-483	Odor of Packaging Material
T-807	Bursting Strength of Paperboard and Liner Board

(Application for copies should be addressed to the Technical Association of the Pulp and Paper Industry, One Dunwoody Park, Atlanta, GA 30341.)

UNIFORM CLASSIFICATION COMMITTEE, AGENT

Uniform Freight Classification Rules

(Application for copies should be addressed to the Uniform Classification Committee, Room 1106, 222 South Riverside Plaza, Chicago, IL 60606.)

(Technical society and technical association specifications and standards are generally available for reference from libraries. They are also distributed among technical groups and using Federal agencies.)

3. DEFINITIONS

3.1 Abrasion. The damage caused by the scuffing or friction of a part against the package, or of a package against an external object.

3.2 Absorption. The penetration of one substance into the mass of another.

3.3 Absorption packing. The inclusion of absorbent within a package to take up liquids resulting from leakage or liquefaction of the contents.

3.4 Adhesive. A fluid or semifluid material used to bond two surfaces together, by forming upon setting, a solid or semisolid interface between the contacting surface.

3.5 Adhesive, pressure-sensitive. An adhesive that requires only briefly applied pressure at room temperature for adherence to a surface.

3.6 Adsorption. A concentration of a substance at a surface or interface resulting from the attraction of molecules of the two substances, e.g., the condensation or adhesion of gases, liquids, or dissolved substances on the surface of solids.

3.7 Anchoring. The securing of an item to a base by means of bolts, tie-rods, tie-down timbers, steel strapping, etc., to prevent movement.

3.8 ASTM. American Society for Testing and Materials.

3.9 Baffle. A piece of plywood, wood, or metal placed over ventilation holes to deflect air or water entering the crate.

3.10 Barrier. A discrete layer or ply of material designed to separate contiguous materials and to limit the mitigation or infiltration of undesirable elements into a package and to prevent the loss of desirable elements from the package.

3.11 Barrier material. A material designed to withstand, to a specified degree, the penetration of water, oils, water vapor, or certain gases. May serve to exclude or retain such elements without or within a package.

3.12 Box, cleated fiberboard. A rigid container having five or six cleated panel faces made of solid or corrugated fiberboard and wooden strips.

3.13 Box, cleated plywood. A rigid container having five or six cleated panel faces made of plywood and wooden strips.

3.14 Box, corrugated and solid fiber. A three-dimensional shipping container, made either of solid fiberboard or of corrugated fiberboard.

The major basic styles are:

a. Regular slotted box (RSC).

b. Center special slotted box (CSSC).

c. Overlap slotted box (OSC).

d. Full overlap slotted box (FOL).

e. Five panel folder (FPF).

f. One piece folder (OPF).

g. Full telescope (FTC).

3.15 Box, set-up. A stiff paperboard box of three-dimensional construction, delivered "set up" ready to use.

3.16 Box, wirebound. A shipping container whose sides, top, and bottom are of rotary cut lumber, sliced lumber, resawn lumber, fiberboard or a combination, fastened to cleats and to each other by means of binding wire and staples.

3.17 Carton. Folding boxes generally made from boxboard, for merchandising consumer quantities of products (for example, shelf packages or prime packages).

3.18 Cellulose. A carbohydrate constituent of the walls and skeletons of vegetable cells.

3.19 Centipoise. One-hundredth of a poise. A measure of viscosity conveniently and approximately defined as the viscosity of water at room temperature (20.2° C.).

3.20 Check. Split or crack in wooden boards, staves, or heading.

3.21 Cleats. Pieces of material, such as wood or metal, attached to a structural body to secure, strengthen, or furnish a grip.

3.22 Clinch. After nailing, to bend or turn over the protruding points so that nails will hold fast.

3.23 Container Design Retrieval System (CDRS). A program to provide a DOD centralized, automated data base system for storing, retrieving, and analyzing container designs and test information concerning specialized containers. The purpose of the CDRS is to avoid duplication in container designs and promote reuse of existing DOD speicalized containers for new items development and procurement. CDRS is governed by MIL-STD-1510.

3.24 Container, fast pack. A family of standard size reusable, polyurethane foam cushioned containers consisting of four types: type I, vertical star; type II, folding convoluted; type III, telescoping encapsulated; type IV, horizontal star.

3.25 Container, reusable. A shipping and storage container which is designed for reuse without impairment of its protective function and which can be repaired and/or refitted to prolong its life or to adapt it for shipment of items other than that for which it was originally employed.

3.26 Containerization. The use of an article of transport equipment designed to facilitate and optimize the carriage of goods by one or more modes of transportation without intermediate handling of the contents.

3.27 Corrosion. Deterioration of a material by chemical action, usually as a result of galvanic, acid, or alkali action, oxidation of metals, etc.

3.28 Crate, wood. A rigid shipping container of framed construction joined together with nails, bolts or any equivalent method of fastening. The framework may not be inclosed with sheathing. It may be demountable (reusable) or nondemountable.

3.29 Crate, slotted angle. A lightweight reusable shipping container of frame metal construction joined together with bolts, screws, or any equivalent method of fastening. The framework may be fully inclosed or sheathed with solid material.

3.30 Critical items. Items meeting one or more of the following critera are considered critical.

3.30.1 Critical chemically. Items which are of such a nature that any degree of deterioration (in the form of corrosion, stain, scale, mold, fungi, bacteria, etc.) caused by oxygen, moisture, sunlight, living organisms, temperature, time and other contaminants, will result in premature failure or malfunction of the item or equipment in which installed or to which the item is related.

3.30.2 Critical physically. Items of such a nature that a slight degree of physical action on the items or any integral surfaces thereof renders them unfit for use. This includes items having a surface finish of 50 microinches roughness height ratio (RHR) or less and which require a high degree of cleanliness and freedom from contamination as well as those requiring special protection against shock, vibration, abrasion, and distortion damage.

3.31 Cube. The volume of space occupied by the unit under consideration computed by multiplying overall exterior length, width, and height. For shipping purposes, cube is expressed to nearest 0.1 cubic foot.

3.32 Cushioning. The protection from physical and mechanical damage afforded an item by means of compressible and resilient materials designed to absorb the energy of shocks and vibration caused by external forces.

3.33 Degrees of protection.

3.33.1 Maximum protection--designated as Level A--the degree of preservation or packing required for protection of materiel against the most severe conditions known or anticipated to be encountered during shipment, handling, and storage.

3.33.2 Intermediate protection--designated as Level B--the degree of preservation or packing required for protection of materiel under known favorable conditions during shipments, handling, and storage.

3.33.3 Minimum protection--designated either as industrial packaging or as Level C--the degree of protection applied to items intended for immediate use or short-term favorable storage and favorable transportation from the source of supply to the first user. The terms industrial packaging and Level C are not to be construed as being synonymous.

3.34 Density. Weight per unit volume. Its numerical value varies with the unit selected to measure it.

3.35 Desiccant. A dehydrating agent. A material that will absorb moisture by physical or chemical means.

3.36 Dew point. The temperature at which air or other gases become saturated with vapor, causing the vapor to deposit as a liquid. The temperature at which 100 percent relative humidity (RH) is reached.

3.37 DOT. Department of Transportation.

3.38 Drum. A cylindrical shipping container designed for storage and shipment as an unsupported outer package without boxing or crating. May be made of metal or plywood or fiber with wooden, metal, or fiber ends. Drums are also made of rubber and polyethylene.

3.39 Dunnage. Temporary blocking, flooring or lining, racks, standards, strip, strapping, stakes, or similar bracing or supports, not constituting part of the carrying vehicle used to protect or make freight secure in or on a carrying vehicle.

3.40 Expendable container. A shipping and storage container which is intended primarily for use for a one-way trip.

3.41 Exterior pack. A container, bundle, or assembly which is sufficient by reason of material, design, and construction to protect materiel during shipment and storage. This can be the unit pack or a container with any combination of unit or intermediate packs.

3.42 Foam-in-place. The basic term identifying the process of forming a polyurethane foam around a mold, form or product so that the resulting foam becomes either the final product or a part thereof.

3.43 Fragile. A fragile item is one whose physical characteristics permit fracturing or shattering of the item when it is subjected to moderately light impact forces. Fragile items include those made of glass, plastic, and low tensile strength brittle metals which are rendered vulnerable to light impact forces by the fact that the materials of which they are made are both brittle and present in relatively thin cross sections.

3.44 Fragility factor. Maximum force acceleration or deceleration expressed in units of gravity (G's) that can be applied to an item in its nonoperating state without causing physical damage or changes in its operational characteristics. The fragility factor shall be expressed in terms of the maximum amplitude of a trapezoidal-shaped (square wave generated) shock pulse with a duration of between 20 and 60 milliseconds and a rise time and fall time equal to or less than one-tenth of the pulse duration.

3.45 Hazardous material. A substance or material which has been determined by the Secretary of Transportation to be capable of posing an unreasonable risk to health, safety, and property when transported in commerce and which has been so designated. (This includes all items listed in 49 CFR and in AFR 71-4 as hazardous.)

3.46 Humidifier. A device that causes water vapor to be diffused into the atmosphere of an inclosure, as in a freight car or storage compartment.

3.47 Humidity. Water vapor in air. Absolute humidity is the actual weight of water vapor contained in a unit weight of air. Relative humidity is the ratio of actual humidity to the maximum humidity which air can retain without precipitation at a given temperature and pressure.

3.48 Humidity indicator. An instrument or device used to determine approximate humidity conditions within packages.

3.49 Impact strength. Resistance of a material or item to damage or deformation due to shocks such as from dropping and hard blows.

3.50 Inhibitor. A substance or agent that slows or prevents chemical reactions such as those of corrosion, oxidation, and adhesive deterioration, even though present only in small quantities.

3.51 Intermediate pack. A wrap, box, or bundle which contains two or more unit packs of identical items.

3.52 Ionization. A condition occurring when an acid, base, or salt is dissolved in water. A part of all of the molecules of the dissolved substance is separated into electrically charged parts called ions.

3.53 Load types. Types of loads are determined by the degree of structural strength supplied the shipping container by the contents. Loads are classified as type 1, easy loads; type 2, average loads; and type 3, difficult loads; as described herein. A type 3, difficult load shall not be packed in a single fiberboard box unless converted to a type 1 or 2 load by an appropriate packaging technique.

3.53.1 Type 1, easy load. A type 1, easy load is developed for an item which completely fills the outer shipping container or from items of moderate density prepackaged in an interior container which completely fills the outer shipping container. Easy load items are not easily damaged by puncture or shock and do not shift or otherwise move within the package.

3.53.2 Type 2, average load. A type 2, average load is developed for items of moderately concentrated weight which are packed directly into the shipping container and provide support to all panels thereof. A type 2, average load also consists of items prepackaged by wrapping or by positioning in partitions, cells or paperboard boxes, or by other means which provide support to all panels of the shipping container.

3.53.3 Type 3, difficult load. A type 3, difficult load is developed for items which require a high degree of protection to prevent puncture, shock, or distortion of the shipping container.

It may also consist of items which do not provide complete support to the panels of the shipping container. A type 3, difficult load shall not be shipped in a single fiberboard box unless it is converted to a type 1 or 2 load by an appropriate packaging technique.

3.54 Long life container (or category 1 container--100 trips minimum). A shipping container having features so that it can be used repeatedly, and its service life can be expected to equal the service life of the item it is designed to protect. These containers may be refurbished by appropriate maintenance practices and restored to full usage or stockpile.

3.55 Marking. Application of numbers, letters, labels, tags, symbols or colors for handling or identification during shipment and storage.

3.56 Modular containers. Modular containers are families of containers designed to be assembled into standard unit loads.

3.57 Multi-application containers. A container designed to protect a variety of reparable components with a given fragility and size range. Containers of this type may or may not incorporate energy absorbing systems and/or special features to facilitate safe handling and shipment. Engineering drawings are used to define form, fit, function, materials, tolerances, and manufacturing procedures.

3.58 Nail, anchor. A cement-coated nail designed for use with anchor strapping and doorway-protection retaining strips.

3.59 Nail, anchor plate. A ringed nail for use with anchor plates, mechanical brakeman plates, and holdfast cleats.

3.60 Nail, cement-coated. Nail to which a coating has been applied to increase its holding power.

3.61 Nail, cooler. Same as sinker except that the head is flat underneath and of slightly greater diameter than a sinker of the same penny-size.

3.62 Nail, corker. Nail with flat countersunk head (see nail, sinker).

3.63 Nail, etched. Nail with surface roughened by etching in acid bath. Has more holding power than cement-coated nails.

3.64 Nail, sinker. Nail of slightly less gauge than the common nail, with the underside of the head tapered.

3.65 Packaging. The processes and procedures used to protect materiel from deterioration and/or damage. It includes cleaning, drying, preserving, packing, marking, and unitizing.

3.66 Packaging design validation. The establishment of the actual capability of the prototype pack to provide the level of shock and vibration protection it was designed to provide.

3.67 Packing. Assembling of items into a unit, intermediate, or exterior pack with necessary blocking, bracing, cushioning, weatherproofing, reinforcement, and marking.

3.68 Pallet. A low, portable platform of wood, metal, fiberboard, plastic, or combinations thereof, to facilitate handling, storage, and transportation of materiel as a unit.

3.69 Paperboard. One of two broad subdivisions of paper (general term, the other being paper as a specific term). Paperboard is, in general, heavier and thicker than "paper" and is constructed primarily for strength properties such as stiffness, tearing resistance, and the like.

3.70 Permeability. Property of a film which permits gases and liquids to diffuse through an essentially continuous film.

3.71 Plastic. Any one of a large group of materials, of high molecular weight, consisting wholly or in part of a combination of carbon with oxygen, hydrogen, and other elements which, while solid in the finished state, at some stage in their manufacture can be made to flow, and thus are capable of being formed into various shapes, most usually through the application, either singly or together, and under control of heat, pressure, or time.

Plastics are of two types:

a. Thermoplastics - those which repeatedly become soft when exposed to heat and harden again when cold.

b. Thermosets - those which set into permanent shape in processing under heat and pressure and do not soften upon reapplication of heat and pressure.

3.72 Poise. The c.g.s. unit of absolute viscosity, derived from Poiseuille, discoverer of the laws of flow. A centipoise is one-hundredth of a poise. Water at 20.2° C. (68.4° F.) has the viscosity of one centipoise.

3.73 Preservation. Application of unit protective measure, including cleaning, drying, preservative materials, barrier materials, cushioning, and containers when necessary.

3.74 Prototype (pilot) pack. A pre-production pack designed and constructed to meet specified requirements and which is the model for production packaging.

3.75 Quantity per unit pack (QUP). The quantity of items to be contained in a unit pack shall be given in the terminology of the definitive unit of issue. If a nondefinitive unit of issue is assigned to the stock item, the unit of issue shall be further quantified by a unit of measure and measurement quantity as required in DOD 4100.39-M, Defense Integrated Data Systems (DIDS) Procedures Manual.

3.76 Relative humidity. The ratio of the actual water vapor content of air to the maximum amount of water vapor the air can retain without precipitation at a given temperature and pressure.

3.77 Short life container (category 2 container--10 trips minimum). A shipping container that can be used for a limited number of times. The container is usually made of wood, plywood, fiberboard or similar material and includes cushioning, die-cuts, inserts, fasteners, etc., which may be described by a drawing and a bill of materials. The container can be identified by military or Federal specification numbers.

3.78 Shrink film. A film which has been stretched and oriented to varying degrees during manufacture, the film having a "memory" which causes it to return to its original form (shrink) when exposed to a specified source of heat, as in a shrink tunnel or chamber.

3.79 Shroud. A protective cover of flexible material used to shed water from the top and sides of the item or load.

3.80 Skid. One of a pair or series of parallel wooden runners affixed to the underside of boxes or crates to allow entry of truck forks.

3.81 Skin packaging. A process whereby a product is covered by a closely fitting transparent film. The article is usually placed on a porous, rigid backing sheet, heated film draped over it, and vacuum applied, to draw the film tightly over the article.

3.82 Specialized container. A specialized container is uniquely configured to support and protect its prescribed contents while being handled, stored, shipped to, and unpacked by the user or to protect personnel and equipment from hazardous contents. Containers of this type frequently incorporate energy absorbing systems, temperature control systems or special features to make handling or shipment possible, easier or safer. Engineering drawings, or equivalent, are used to define form, fit, function, materials, tolerances, and manufacturing techniques. Specialized shipping containers result from original design effort as well as from modification of existing container designs to meet some specific application or need.

3.83 Storage life. The period of time during which a packed item can be stored under specific temperature conditions and remain suitable for use. Sometimes called shelf life.

3.84 Stretch wrapping. The use of thermoplastic films having elastic properties that enable them to be stretched and sealed around small groups of products as well as pallet loads.

3.85 Tape, pressure-sensitive adhesive. A type of tape that is coated with an adhesive which adheres under pressure and does not require moistening, heat, or solvent for activation.

3.86 Tare weight. The weight of the container or packaging materials. When container is filled, or partially filled, the weight of the contents is termed the net weight, the weight of the container is the tare weight. The net weight added to the tare weight is the gross weight.

3.87 Transportability criteria. The physical characteristics of the individual modes of transportation, together with legal and administrative requirements, which should be considered in the design of items of systems/equipment/munitions (S.E.M.) to assure that they can be moved efficiently by existing and proposed transportation systems.

3.88 Truck, fork. A truck with vertical, elevating back plates and horizontal forks, for raising loads. Used for short distance hauls in warehouses, vanloading, and for stacking palletized items.

3.89 Unit pack. The first tie, wrap, or container applied to a single item or a quantity thereof, or to a group of items of a single stock number, preserved or unpreserved, which constitutes a complete and identifiable pack.

3.90 Unitization. Assembly of packs of one or more line items of supply into a single load in such a manner that the load can be handled as a unit throughout the distribution system. Unitization (unitized loads/unit loads) encompasses consolidation in a container, placement on a pallet or load base, or securely binding together.

3.91 Vacuum packaging. Packaging in containers, whether rigid or flexible, from which substantially all air has been removed prior to final sealing of the container.

3.92 Volatile corrosion inhibitor (VCI). A chemical which slowly releases vapor that inhibits corrosion by neutralizing the effects of moisture laden air within the package.

3.93 Waterproof. Extreme resistance to damage, deterioration or permeation by water in liquid form.

3.94 Water-resistant. Having a degree of resistance to permeability of and damage caused by water in liquid form.

3.95 Watervaporproof. (1) Not subject to damage by water vapor. (2) Exerts a barrier effect to passage of water in either liquid or vapor form.

3.96 Weather-resistant. Ability of a material to retain a high percentage of its original physical properties and original appearance under even prolonged exposure to outdoor weather conditions.

3.97 Wrap. A flexible material used to protect individual items within a container.

4. GENERAL REQUIREMENTS

4.1 Military packaging policy. The nature of the military material design, procurement, and supply distribution makes it imperative that a consistent packaging policy be implemented. Determining factors include a multiplicity of manufacturers and manufacturing conditions, a variety of transportation and storage conditions, global distribution, and insufficient information about the ultimate destination of an item.

4.1.1 Purpose. The basic purpose of military packaging is to assure that items will be fit to perform their intended functions when the time comes for them to be used. Packaging must protect an item from the time of production, through transport and storage, until delivery to its ultimate user. Protection during transport, which includes both handling and carriage, must be achieved while complying strictly with DOT and military transportation regulations. Military items may be stored for indefinite periods of time in both protected and unprotected storage. Packaging must protect the item against physical damage and environmentally induced deterioration during this storage period. In addition, packaging must, in many instances, incorporate provisions for inspecting and performing maintenance on the packaged item.

4.1.2 Objectives. It is the aim of the military packaging policy to achieve a high degree of packaging protection in a uniform, efficient, and economical manner. In general, this requires that similar items be preserved, packed, and marked in a similar way, and that the number and type of packaging requirements and packaging materials used be kept to the minimum consistent with the desired protection. The resulting uniformity leads to efficient procurement, receipt, storage, inventory, shipment, and issue of supplies and equipment. The elimination of excessive packaging (where excessive packaging is the use of extra or more expensive types of preservation, or the use of more packing materials than necessary to adequately protect an item) is an inherent objective of military packaging policy. Excessive packaging can be avoided by strict adherence to good packaging principles, and by giving full consideration to storage, shipping, and end-use factors. The task of meeting these objectives through packaging design can be briefly restated as follows: Select the best possible approach to achieve the necessary degree of packaging protection with economy, uniformity and efficiency. This section discusses the fundamentals that govern the design of packaging to meet these objectives.

4.1.3 Methods of expressing packaging data. Preservation and packing requirements may be prescribed by a variety of documents. The most commonly used include packaging data sheets, Federal and military specifications and standards, purchase descriptions, and drawings.

4.1.3.1 Data sheets. Data sheets are generally used to document the packaging requirements of replenishment type items. They may also be used for major items when the packaging details can be conveniently and accurately described on the form.

4.1.3.2 Specifications. Specifications explicitly state the preservation and packing and marking requirements that must be met when packaging items or equipment. They define methods to be used or state the properties and characteristics that must be met by materials. Specifications have as their aim the use of efficient and economical materials and methods, and the achievement of economy through standardization. The specification serves as a guide for procurement, as well as a guide for packaging personnel and inspectors. When referenced in contracts, specifications become part of the contract and serve as legal documents. There are three types of coordinated specifications used in military packaging--Federal, military, and those prepared by nonprofit, non-Government specifications-standards developers. Federal specifications cover those materials, products, or methods of interest to, and in common use by, two or more Federal Departments, at least one of which is civilian. Military specifications cover materials, products, or methods used exclusively or predominantly by military activities. In addition, there are limited coordination specifications that are prepared by a single service or command for their particular use, but which can also be used by other branches of service. The non-Governmentally prepared specifications and standards can cover the same areas as those by the Government, but are prepared by industry associations such as American Society for Testing and Materials (ASTM) and American National Standard Institute (ANSI).

4.1.3.3 Standard. A standard is a document that establishes engineering and technical limitations and applications for items, materials, methods, designs, and engineering practices.

4.1.3.4 Purchase description. Purchase descriptions, which consist of data normally prepared for publication in a military specification or standard, may be issued when the need for the data is extremely urgent or when information is for onetime use. The content and format should conform to applicable requirements of specifications and standards.

4.1.3.5 Drawing. For certain items, a drawing shall be required to show the packaging requirements. When needed, the drawing is the preferred document for prescribing packaging.

4.2 Packaging methods.

4.2.1 Criteria to be considered. From the military standpoint, good packaging methods are those that protect material from deterioration and damage at a minimum cost. In determining the best method, the first four criteria listed are usually the primary considerations. The remaining seven criteria may become important considerations under certain conditions.

a. Does the method afford the required protection?

b. Does the method result in the lowest cost consistent with required protection?

c. Does the method permit minimum depreservation effort at time of use?

d. Does the method result in the least cube and weight consistent with required protection?

e. Can the method be easily adapted for mechanization when conditions, such as quantity to be procured, warrant?

f. Does the method provide for reuse of containers for recoverable and repairable items?

g. Is the method consistent with quantity end-use?

h. Does the method provide continued protection for more than one like item in a multiple quantity unit pack until the contents are depleted?

i. Does the method promote uniformity in the application of packaging methods?

j. Does the method meet statutory requirements?

k. Does the method consider and incorporate material handling aids when necessary?

4.2.2 Degrees of protection. The concept of degrees of protection was adopted to permit the military services to state their requirements objectively. Usually, the protection to be used is not determined by the packaging activity. Supply management guidelines designate the normal degree of protection to be used in the preservation and packing of materiel for various shipment and storage conditions, and provide basic packaging requirements for each degree. The degree of preservation and packing protection required to maintain the item from time of procurement to use should be provided--to the maximum practicable extent--at the time of initial procurement. Military degrees of protection are described in terms of the performance expected of the package or pack and must be translated into specific technical or design requirements for individual items or categories of items (see 3.33).

4.3 Role of the packaging engineer. The packaging engineer is responsible for the development and engineering execution of all technical data pertaining to the preservation, packing, processing, and marking of all supply items. The engineer's functions and responsibilities are closely related to activities of supply management, field service maintenance, procurement, and production. Major areas of responsibility include:

a. Development and preparation of all preservation, packing, and processing technical requirements for inclusion in data sheets, military specifications and standards, purchase descriptions and drawings, and for use as data source in field-type documents such as technical bulletins and technical manuals.

b. Determination and recording of shipping weights, sizes, and cubes of packed or processed items of supply for use by other interested activities.

c. Furnishing of packaging engineering support to field service activities and other applicable authority as required or requested.

d. Consideration of the delaying effect packaging engineering requirements have on production by the specification of unobtainable or unusual packaging methods or materials.

e. Assurance that packaging documentation contains proper provisions for applicable marking requirements. Marking includes item identification, contract, shipping, and required special marking. Procedures, methods, and materials specified by packaging engineering must be capable of accomplishment and readily available to packaging and processing organizations in both the industrial and military areas of operation. This requirement is necessary because an item may--as a result of split shipments, pack damage, or extensive time in storage--be preserved, packed, or processed by military activities as it progresses through the supply system from point of manufacture to the user. The packaging engineer must be acquainted with a wide variety of scientific and technical fundamentals in varying fields such as supply system, distribution, and storage. This range of knowledge and skills is important not only for the selection of packaging materials and methods, but also to make possible a close and beneficial relationship between packaging engineering and design and development engineering. Because the availability of packaging data at the time of bid is essential to proper cost estimating for bidding, the packaging engineer should be furnished available prototype and pilot models of end items to facilitate preparation of preliminary or final packaging engineering data. Figure 1 illustrates the role of the packaging engineer.

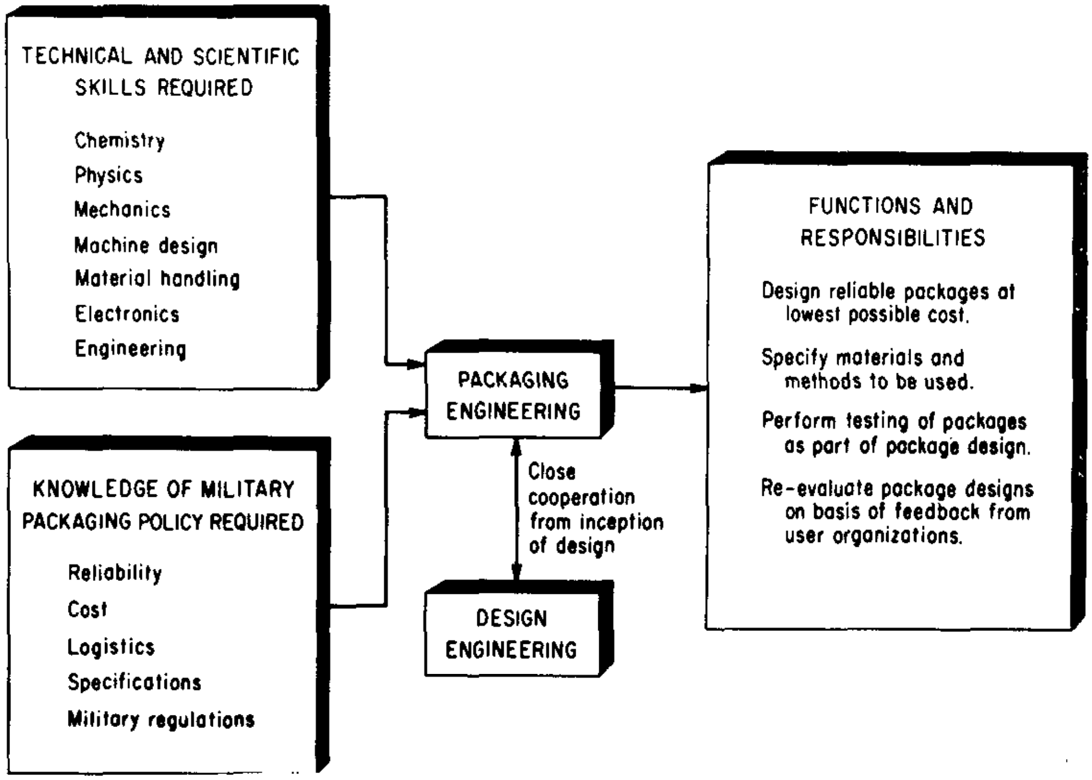


FIGURE 1. Role of packaging engineer.

4.4 Packaging engineering procedures. The procedures below should be followed to insure the highest practicable standards of packaging protection. Although these procedures will be useful in serving as guidelines to packaging design, the packaging engineer must select the most suitable and appropriate methods and materials for each particular application. Therefore, the sequence of step-by-step procedures is only a suggested approach and will vary according to the particular requirements of the project.

a. Obtain item drawings, specifications, procurement documents, and the actual hardware item whenever possible.

b. Determine item characteristics (size, weight, configuration, chemical characteristics, etc.).

c. Determine the degree of protection required.

d. Determine unit pack quantities and intermediate pack quantities.

e. Establish method of preservation.

f. Establish method of cleaning, drying, and preserving.

g. Select unit and intermediate pack materials.

h. Determine barrier and cushioning requirements.

i. Select an exterior container, or design special containers or pallets when required.

j. Establish marking requirements.

k. Prepare packaging documents which describe these listed requirements along with sketches or drawings, when necessary, to describe special bracing, cushioning, or container designs.

4.5 Sources of data. Ideally, the critical packaging features of an item are identified during the design of the item. If the packaging engineer is consulted during this phase, he/she can often suggest changes that will in no way compromise the effectiveness of the item, but will minimize packaging problems. Whenever there is no opportunity for consultation during the design phase of the item, the packaging engineer should have, for his/her guidance, both the item and the drawings from which the item was developed. Drawings will point out, for example, fragility problems not readily apparent during visual inspection. Drawings are often the only source of information available to the packaging design engineer, and his/her ability to read them in terms of packaging requirements is essential. Close coordination between the manufacturer and the packaging engineer is always beneficial in establishing packaging criteria.

4.6 Item characteristics. It is desirable to minimize the number of packaging methods and the types and sizes of packages. One method of simplifying and standardizing packaging is by grouping items which are dissimilar in their function but which are, for packaging purposes, similar in their chemical and physical properties, e.g., nails-screws, radio tubes-light bulbs, air filters-oil filters. This method, however, cannot be extended to all items because of peculiar weight, configuration, fragility, and other characteristics, e.g., engine-transmissions which have configuration differences, radio set-telephones which have different fragilities. This area is covered in more detail in a later paragraph. The following paragraphs briefly discuss three types of item characteristics that are frequently critical in determining packaging methods and materials:

a. Susceptibility to chemical deterioration.

b. Susceptibility to physical damage.

c. Maximum disassembly and breakdown allowable.

Of equal importance in determining the packaging methods and materials to be used are logistical considerations (see 4.8) and item characteristics (see 5.1) which are discussed in later paragraphs (see 5.3, 5.6, 5.7 and 5.8).

4.6.1 Susceptibility to chemical deterioration and physical damage. There are two considerations concerning the item to be packed that are of major importance in packaging. One consideration is that some items can be rendered useless by chemical action such as rust, stain, and decomposition. The other is that some items can be rendered useless by physical damage such as abrasion, shock, and vibration. Chemical damage is usually prevented by using preservative compounds, atmosphere control, and other means that will combat conditions that contribute to deterioration. Physical damage is usually prevented through the use of cushioning, blocking, and bracing. These two types of vulnerability are not always separate. In combating physical damage, it is also necessary to consider deterioration. For example, cushioning materials selected must not add to further chemical deterioration of items vulnerable to chemical change.

4.6.2 Feasibility of disassembly. The degree of disassembly an item can undergo will affect the overall package dimensions and the degree of protection required. Cube reduction is a particular advantage that may be gained through disassembly. (Figure 2 is an example of a disassembled rack that saves both space and costs.) Excess weight or cube--because of oversize containers, lost space, and unnecessary cushioning and blocking--not only constitutes excessive packaging but also increases storage and shipping costs. In addition to cube reduction, disassembly may offer, in all or in part, a reduction or simplification of the protection needed against physical and chemical damage. Before disassembly, the complete unit may have required a cushioning level suitable for its most delicate parts; after disassembly, each part will require cushioning only to its own level of fragility. In the same manner, disassembled items may offer less of a preservation problem than when they are in the assembled state. However, the cost and difficulty involved in disassembly and reassembly, as well as the space and time involved in storing removed equipment, must be considered.

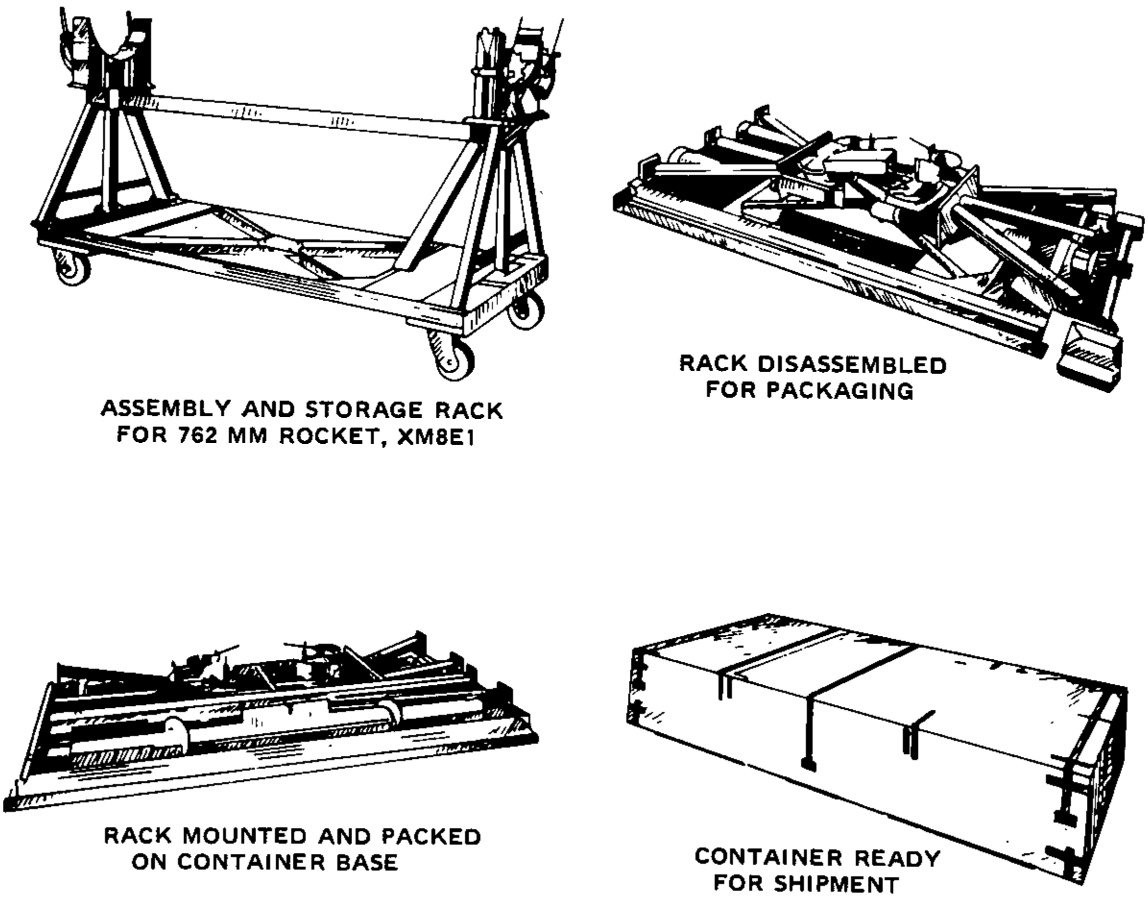


FIGURE 2. Disassembly - a means of saving cube.

4.6.3 Other item characteristics. Although function, end use, and ultimate destination of an item do not usually play a major role in the selection of packaging procedures or materials, these and other characteristics may become critical design factors for particular items. The following listing is intended only as a sample of the types of factors, other than the primary chemical and physical properties of the item, that may become critical:

a. Requirement for field force protection. Sensitive electronic devices can be quickly ruined or degraded upon exposure to various environmental field forces--electrostatic, electromagnetic, magnetic or radioactive. Proper shielding and precautionary marking are necessary to protect these sensitive, miniature electronic parts--both alone and as part of assemblies.

b. Requirement for a high degree of cleanliness. The cleanliness requirement applies also to the packaging materials in contact with the item.

c. Requirement for surveillance of item throughout the manufacturer-to-user sequence. Methods of monitoring pressure and electrical continuity without opening the container may be necessary.

d. Requirement for item orientation within a container to facilitate complete checkout without removal of the unit from its suspension frame.

e. Requirement for the securing of heavy items within their containers in the same manner that they will be secured when in use.

f. Requirement that items destined for site with little depreservation facilities be preserved with compounds that need not be removed.

g. Requirement for reuse of the container.

4.7 Additional factors affecting packaging design. Many questions of package design can be resolved only by a study of the military characteristics and the manufacturer-to-user sequence of an item. Factors such as overall simplicity, cost, ease of maintenance, and optimum use of available space in storage all bear on which package design is best for a particular situation. Human factor considerations may also have an important bearing because, where possible, packages should not exceed weights and sizes that can be handled with ease and safety. For the best possible design, the packaging engineer needs full information on the requirement that the package is expected to fulfill; i.e., he/she must know as much as possible about the logistical plans, distribution, and end use of the item. Generally, the more that is known about the planned logistic, distribution, and end use of an item, the more the package can be tailored to the needs of the item. When little is known about these requirements, the package must provide protection for worldwide use with all possible types of transportation and storage.

4.8 Logistical considerations. From the logistics plans, the packaging engineer can often learn the anticipated type of storage and duration, the quantity and rate of issue, and, in some cases, the mode of transportation to be used. The importance of ready access to, and removal of, contents is another requirement which may be predetermined.

4.8.1 DOD Engineering for Transportability Program. This program provides for the inclusion of transportability requirements in the design of end items which are obtained through the materiel acquisition program for adoption into the military services supply systems. DOD Directive 3224.1, Engineering for Transportability, is a directed DOD-wide function. This directive assigned transportability functions to the three military departmental secretaries and the Director, Defense Logistics Agency. The designated transportability agents are: The Department of the Army--Commander, Military Traffic Management Command, Washington, DC 20315; The Department of the Navy--Commander, Naval Supply Systems Command, Deputy Commander for Transportation, Washington, DC 20376; The Department of the Air Force--AFSC/LGTT, Washington, DC 20334; The US Marine Corps--Commandant, US Marine Corps, (LFT-3), Washington, DC 20380, and for the Defense Logistics Agency--Director, Defense Logistics Agency, DLA-HT, Cameron Station, Alexandria, VA 22314. It was implemented by the Joint Regulation DOD Engineering for Transportability AR 70-44, OPNAVINST 4600.22, AFR 80-18, MCO 4610.14C and DLAR 4500.25. This regulation designates the transportability agencies, promulgates policy, assigns responsibilities, and outlines procedures for conducting the Engineering for Transportability Program within the DOD to insure that transportability is considered.

4.8.2 Handling. Because the packaging engineer rarely knows the handling system to the point of use, he/she must design a package that will protect the item against the most severe hazards that the item is likely to encounter. Methods of handling and loading--especially for large, heavy items--should also be anticipated at the time of design. Although wheeled items present few problems because they can be rolled aboard the carrier and lashed in place, other large items may require casters, dollies, and special skids. Containers must be designed to be strong enough to withstand handling forces without being distorted. Packed items may be moved by forklift trucks, dollies, or rollers. All of these methods provide support for only a portion of the pack with a large overhang often resulting. For items moved by slings and grab hooks, tremendous pressures are often exerted against the top corners and edges of the upper sides of the pack.

4.8.3 Storage. Storage of general supplies, ammunition, and selected commodities is contained in the DOD 4145.19 series documents. They list provisions for the safe storage of packed items. Coverage includes storage, conservation, stability, and safety.

4.8.4 Human factor considerations. Although human factor considerations are primarily item design considerations, they may be involved in package design. If economically feasible, packages should be designed so they do not exceed the minimum and maximum dimensions that personnel can carry or disassemble with ease. For information on this handling consideration, refer to Human Engineering Guide to Equipment Design,[1] which gives human body dimensions, range of movement of body members, muscle strength, etc. Specific measurements for human factors can be found in MIL-STD-1472, Human Engineering Design Criteria for Military Systems, Equipment and Facilities, and HEL Standard S-6-66, Human Factors Engineering Design Standard for Wheeled Vehicles.

4.8.5 Weight and cube. Tare weight and cube are measures of shipping and storage costs. To achieve the best use of space in all types of transportation and storage at the least cost, container design should take account of weight and cube (fig 3) concurrently with end use, protection, and cost.

4.8.6 Distribution.

4.8.6.1 Pattern. A lack of knowledge of the distribution pattern for a particular item at the time of package design is a contributing factor in military packaging costs. Packaging for limited distribution patterns can, therefore, result in cost savings. These savings, however, are worthless if the assumption of limited distribution is erroneous and the protection of the packaged item is impaired as a result.

[1]C.T. Morgan, et al, McGraw-Hill Book Company, Inc., New York, 1963.

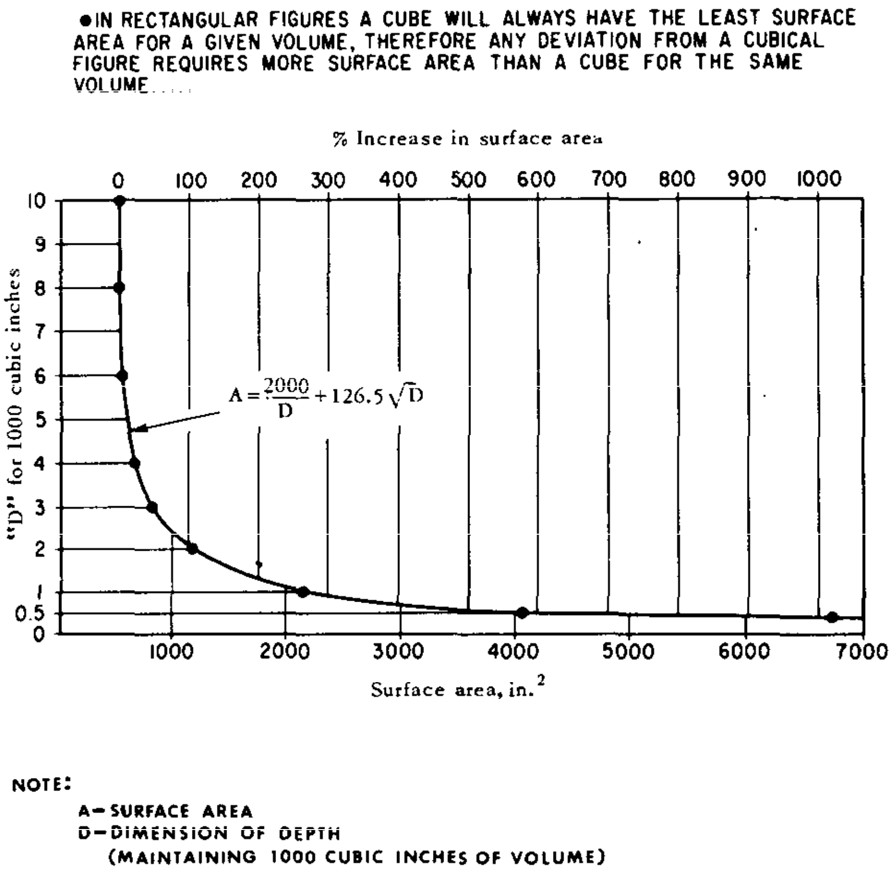


FIGURE 3. Relationship of surface area to volume.

4.8.6.2 Unit quantity. The unit quantity to be used in a unit pack is another important distribution consideration. Ideally, it should be the smallest quantity normally distributed to the ultimate user. Unit quantities smaller than this usually result in additional packaging, storage, and shipping costs because of the extra operations and materials involved and the resultant increase in weight and cube of the exterior container. Unit quantities larger than those desired by the ultimate user can result in intermediate redistribution and packaging costs, as well as deterioration of those items remaining in the opened unit pack after some items have been removed for use.

4.8.7 Destination. Shipping containers, in particular, will vary depending on whether the destination is domestic or overseas. The various protection degrees, as described previously (see 4.2.2), will determine the type of container selected.

4.8.8 Statutory limitations. Freight and other regulations are extremely important because they govern the construction of shipping containers and set forth the procedures for loading and shipping the materials within common carriers. All shipping containers must comply with such regulations and other limitations discussed in later paragraphs.

4.9 Preservation, packing, and shipping costs. Although protection is the prime consideration in military packaging, packaging engineers are expected to choose the least costly of acceptable methods promising the required protection. When only one method meets all the requirements, cost can still be minimized through design. Cost is understood to include all factors from manufacture to end item use. All costs affected or created by package design are pertinent to engineering considerations. Personnel concerned with estimating packaging costs are referred to DLAM 4145.4, Packaging Cost Estimating (0). Although this document does not give rules for achieving packaging economy, it may be used as a yardstick to measure contract prices. Allowance must be made to include costs of items such as indirect labor, administrative costs, insurance, burden on equipment, and a reasonable profit, which the standard does not include.

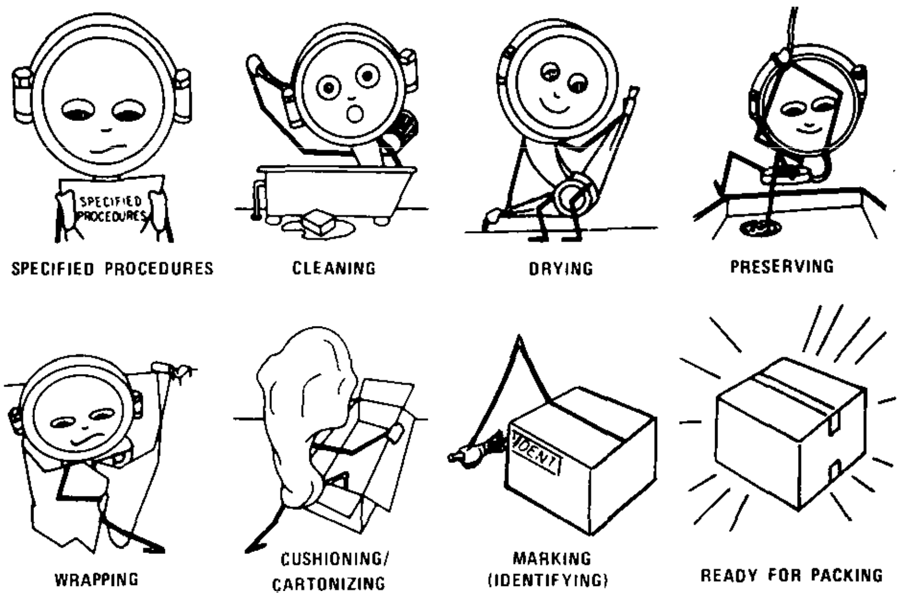
4.10 Testing and inspection. Testing during the item design phase is directed toward proving the adequacy of the proposed package or container, but often provides valuable feedback to the item design engineers as to the fragility of certain components within the item. Development and testing of packages and containers should begin as soon as possible after initiation of item development. Some of the tests most commonly used in proving design adequacy include vibration, impact, mechanical handling, rough handling, and environmental. One or more of these tests is usually applicable to the design of military packs. In many cases, the technical activity responsible for design has internal tests and procedures that are applicable to a specific design problem. The documents most generally used for test guidance are MIL-STD-1186, MIL-P-116, Federal Test Method Standard Number 101, and ANSI, ASTM, and TAPPI Test Method Standards. Later paragraphs describe testing in greater detail. After unit pack and containers are selected and in use, information on their performance can be obtained by a continuing inspection of items in storage by depot storage personnel and by the packaging engineer's analysis of damage reports or notices of improper shipments. Improper handling practices and misinterpretation of specifications, as well as inadequate packaging methods and materials, may be revealed in this way.

4.11 Authorized and approved methods and materials. By choosing authorized methods and materials already covered by specifications, which can be obtained by using the Qualified Products List (QPL), the packaging engineer can often reduce the engineering effort required to produce packaging data. This restricting of packaging methods and materials also reduces requirements for testing and documentation. By depending on factors such as item characteristics, item distribution, and the supply system, the engineering effort required for packaging items covered by specification is largely limited to modifying or adding to these authorized methods rather than establishing new procedures for each new item to be packaged. The application of authorized methods limits the number of methods and materials used for a great variety of items. The known performance of these methods, when applied under specified controls, eliminates costly and time-consuming tests. Besides reducing engineering effort and testing, the use of a limited number of methods and materials reduces documentation because basic packaging instructions can apply to a group of items rather than just to a single item.

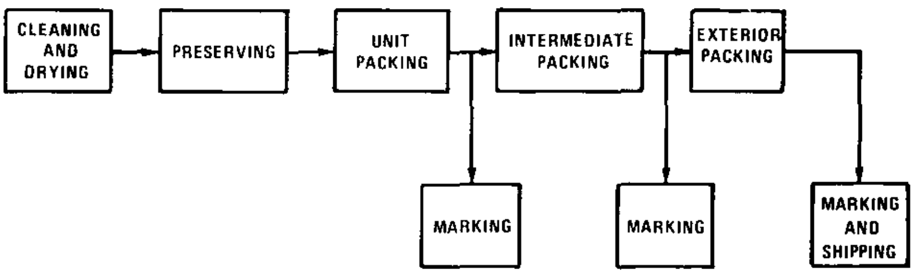
4.11.1 Special requirements. Occasionally, the packaging engineer will not follow specified methods or use specified materials. For example, large or complex items such as vehicles, artillery, and missiles often cannot be processed by a single method or submethod. This may also be the case when packaging a kit combining a number of parts of various complexities requiring different degrees of protection. Also, in certain cases, a particular material or combination of materials, or an automatic packaging process may provide adequate protection and is more suitable or preferred.

4.11.2 New methods and materials. The existence of specifications and standards does not mean that the packaging engineer is strictly limited in his/her choice of methods and materials. Approved methods and materials are preferred because they reduce the design effort. However, there may be other overriding factors and the packaging engineer should be on the alert to review packaging requirements in the light of any new application of practices and materials. Certain designs may lend themselves to plant economics in packaging operations; others may make field service surveillance and maintenance simpler; or a particular design may offer especially rapid access to the item by the user.

4.12 Summary of packaging and pack design. Figure 4 shows the basic packaging steps and the sequences in which they are normally carried out. Often, because of the nature of an item and its distribution requirements, not all of these steps are required. For example, a preservative may not be needed, or the unit pack might also serve as the exterior container. The various materials and methods that can be used in carrying out each of the basic steps are documented in specifications and standards. It is the task of the military packaging engineer to select the best materials and methods for each particular application.



(A) BASIC STEPS IN MILITARY PACKAGING



(B) NORMAL SEQUENCE OF PACKAGING STEPS

FIGURE 4. Basic steps in military packaging and their normal sequence.

5. DETAILED REQUIREMENTS

5.1 Item characteristics. Packaging decisions, methods, and materials always hinge on the most critical feature of the item being packaged. This section discusses the chemical and physical properties of military items that most often determine packaging requirements. Although individual item characteristics are described separately, they are interrelated. Usually, no one particular item characteristic is directly related to a specific packaging method or material. When item characteristics are analyzed and grouped, a pattern may be distinguished that can be related to specific packaging methods and materials.

5.1.1 Like items. The packaging of like items in the same way can usually be accomplished by applying sound technical and engineering principles to each design effort. The disparity of design among military items precludes their classification into groups by function or nomenclature, and requires individual treatment for each item. The primary cause of difficulty in determining true likeness is that likeness is not always a function of composition and configuration only, but often depends also on factors such as end use and item distribution. The packaging engineer may, for general guidance, use such compilations as SB 38-100 which lists materials and equipment for which stock numbers have been assigned and which are commonly used. He/she may also use DSAM 4141.2/TM 38-230-1/NAVSUP PUB 502/AFP 71-15/MCO P4030.31B and DSAM 4145.2 Vol II/TM 38-230-2/NAVSUP PUB 503, Vol II/AFP 71-16/MCO P4030.21C which present methods that have been successfully used to protect materiel from physical damage and deterioration. When such guidance is used, it must be determined that the item is, in fact, similar. Adaptation of similar packaging for like items should not be made until it is determined that the item is similar in all important respects.

5.1.2 Common, selective, and special grouped items.

5.1.2.1 Common group items. Items falling into this classification will be of a type for which complete packaging detail can be expressed without the use of drawings, sketches, figures, or narrative instructions which are peculiar to a single or limited number of such items. Group items are those items which have basically the same physical and chemical characteristics.

5.1.2.2 Selective group items. These are items that cannot use predetermined packaging developed by common group technique, yet do not require drawings, sketches, illustrations or narrative type packaging details.

5.1.2.3 Special group items. Special group items are items that have characteristics which prevent the use of packaging standards in prescribing the packaging requirements (see 4.6). Such items--because of peculiar weight, configuration, complexity, fragility, or other considerations--require packaging data which are applicable only to an individual type of item, or a limited group of items. Generally, an item will be considered as special if drawings, sketches, or illustrations are required.

5.1.3 Packaging requirements. Basic characteristics of the item to be considered at the time of package design are as stated in the paragraphs which follow. These characteristics can be used in preliminary design analysis to determine the following major packaging requirements:

a. Required protection against deterioration.

b. Required protection against shock and vibration.

c. Required degree of disassembly.

d. Required points for supporting, clamping, and holding the item in the container.

5.1.4 Categorizing item characteristics.

54.1.4.1 Objectives. There are four main objectives in grouping item characteristics:

a. To package in a similar manner items that have the same or similar chemical and physical characteristics.

b. To reduce the number of packaging materials used.

c. To reduce the cost of producing engineering data.

d. To reduce administrative time and costs.

An example of how item characteristics have been categorized to meet these objectives and form the basis of an efficient, economical packaging system is the system defined in MIL-STD-647 and described in 5.1.4.2.

5.1.4.2 Pre-engineering packaging data. Two types of items may be distinguished for packaging purposes: (1) those that can be packaged by pre-engineered packaging data, and (2) those that must have specifically engineered packaging data. Item characteristics are primarily intended to provide a means of grouping large numbers of items by their chemical and physical similarities so that packaging may be accomplished with the minimum of engineering effort. By providing criteria for defining and identifying critical item characteristics, a means is provided for comparing items to these criteria and placing all items having the same characteristics in a single group. MIL-STD-647, MIL-STD-794, and MIL-STD-2073 establish certain criteria and requirements for using a limited number of the same materials and methods for a great number and variety of items. Criteria and instructions for converting the general data, applicable to a group of items, to data for specific items are given in this handbook. The five chemical and physical characteristics selected for this system are:

a. Surface chemistry.

b. Surface, mechanical.

c. Configuration, miniaturization-complexity.

d. Flexibility-fragility.

e. Size and weight.

These five primary categories of item characteristics and their divisions are intended to identify specific characteristics that, when added together, will permit a single method of packaging to be used on all items having the same category symbols. Most of the categories and divisions have only a general relationship to any specific packaging method.

5.1.4.3 Minimum criteria. The study of item characteristics includes the chemical and physical properties, the corrosion prevention requirements, and any special use requirements that might affect the packaging operations. The following item characteristics, which are discussed in paragraphs below, are minimum essentials that must be considered before the packaging requirements of any item can be determined:

a. Vulnerability to chemical deterioration.

b. Vulnerability to physical damage.

c. Vulnerability to field force damage.

d. Strength and fragility.

e. Type of load.

f. Configuration.

g. Size and weight.

h. Nature of the item.

i. Relation of item design to package.

j. Compatibility of materials.

k. Cost of item.

These item characteristics are discussed separately, in the order listed, although they would be grouped for practical use in devising a packaging system.

5.1.4.4 Vulnerability to chemical deterioration. Depending on the chemical nature of the surfaces exposed to the atmospheric environment, items will differ in their vulnerability to, and rate of, deterioration. An all-ferrous item (steel or iron) requires different preservation treatment than a nonferrous (copper, aluminum) or composite item. Similarly, when a ferrous item has been completely painted or plated, the surface chemistry of the item has been changed to that of the material used for treating the surface. For example, preservation treatment for the clad metals and clad electrical contact materials would depend on the characteristics of the outer surface of the items. Table I lists four main categories of materials or surfaces that may require different preservation methods and materials.

5.1.4.5 Vulnerability to physical damage.

5.1.4.5.1 Shock. The resistance of an item to shock constitutes its ability to withstand impact without damage. The maximum amount of rough handling the item can withstand, and still function properly, determines the fragility level of the item (see table II). The basis for the measurement of fragility is the

TABLE I. Categories of items differing in vulnerability to deterioration.

A. Inorganic Materials

(1) Metals and alloys
  (a) Ferrous
  (b) Nonferrous
(2) Platings
  (a) Tinplate
  (b) Terneplate
(3) Coatings
  (a) Oxide
  (b) Phosphate
  (c) Sulfide
  (d) Vitreous
  (e) Plastic
(4) Nonmetals

B. Organic Materials

(1) Rubber
(2) Plastics
(3) Oils and greases
(4) Wood
(5) Fabric

C. Surfaces Requiring Preservation

(1) Ferrous metals and alloys
(2) Critical surfaces

D. Surfaces Not Requiring Preservation

(1) Noncritical and nonferrous surfaces
(2) Plated, coated, primed, and painted surfaces

TABLE II. Approximate fragility of typical packaged articles.

Extremely Fragile	
Missile guidance systems, precision instruments	15-25 Gm
Very Delicate	
Mechanically shock mounted instruments and electronic equipment	25-40 Gm
Delicate	
Aircraft accessories and other electrically operated equipment	40-60 Gm
Moderately Delicate	
Television receivers and components	60-85 Gm
Moderately Rugged	
Appliances, etc.	85-115 Gm
Rugged	
Machinery, weldments, etc.	115 Gm and up

Gm factor, a dimensionless ratio of the maximum acceleration that an object can safely withstand to the acceleration of gravity:

$a = ft/sec^2$ (maximum allowable acceleration an object can safely withstand)

$Gm = a/g$

$g = 32\ ft/sec^2$ (acceleration due to gravity)

Whenever the anticipated shock environment during shipping and handling is greater than an item's fragility level, some form of shock mitigation system must be incorporated into the package design. Before a shock or vibration mitigation system can be designed, certain data must be available to the packaging engineer. These data constitute the basic design criteria and include:

a. Item description with dimensions, outline sketch, and center of gravity location.

b. Item weight and moment of inertia about the three principal axes.

c. Item shipping position, attachment points, clamping position and permissible pressure on surface.

d. Item fragility level (the number of Gm's the item can withstand and direction of application).

e. Maximum allowable vibration input to item--frequency and amplitude.

f. Anticipated shock and vibration environment (ref TB 55-100, MIL-HDBK-304, ASTM D3331, and ASTM D3332).

g. Anticipated environmental requirements other than shock and vibration.

h. Any special requirements, such as nuclear radiation, special testing, or inspection.

Certain items can be protected from shock by the use of shock mounts. Other items require cushioning and suspension systems (see fig 5 and 6). All containers that provide shock mitigation should be designed so that the system occupies as little space as possible. Bulk cushioning should be no thicker than necessary to provide adequate protection to the item. Similarly, when shock mounts, spring suspensions, or other flexible shock mitigation systems are used, the mechanism should be kept as small as possible, and the free space allowed for movement of the item in the container should be limited to that required for adequate protection. Sometimes the method used for attaching shock mounts and other systems to the container structure has an important effect on the cube of the container and should be considered in determining the feasibility of a design.

5.1.4.5.2 Vibration. For some items, resistance to damage caused by vibration is an important packaging consideration. In these cases, some form of vibration isolation system must be incorporated into the container design. When such systems are used, their size and the space they occupy should be kept to a minimum, the same as for shock mitigation systems. Many studies have been conducted to determine the most common forcing frequencies that will be encountered by different carriers and, although exceptions are found, the following summary is generally applicable.

1. Railroad - 2 to 7 cps
2. Truck - 20 to 200 cps
3. Aircraft - 20 cps and 60 cps
4. Ships - 11 to 100 cps

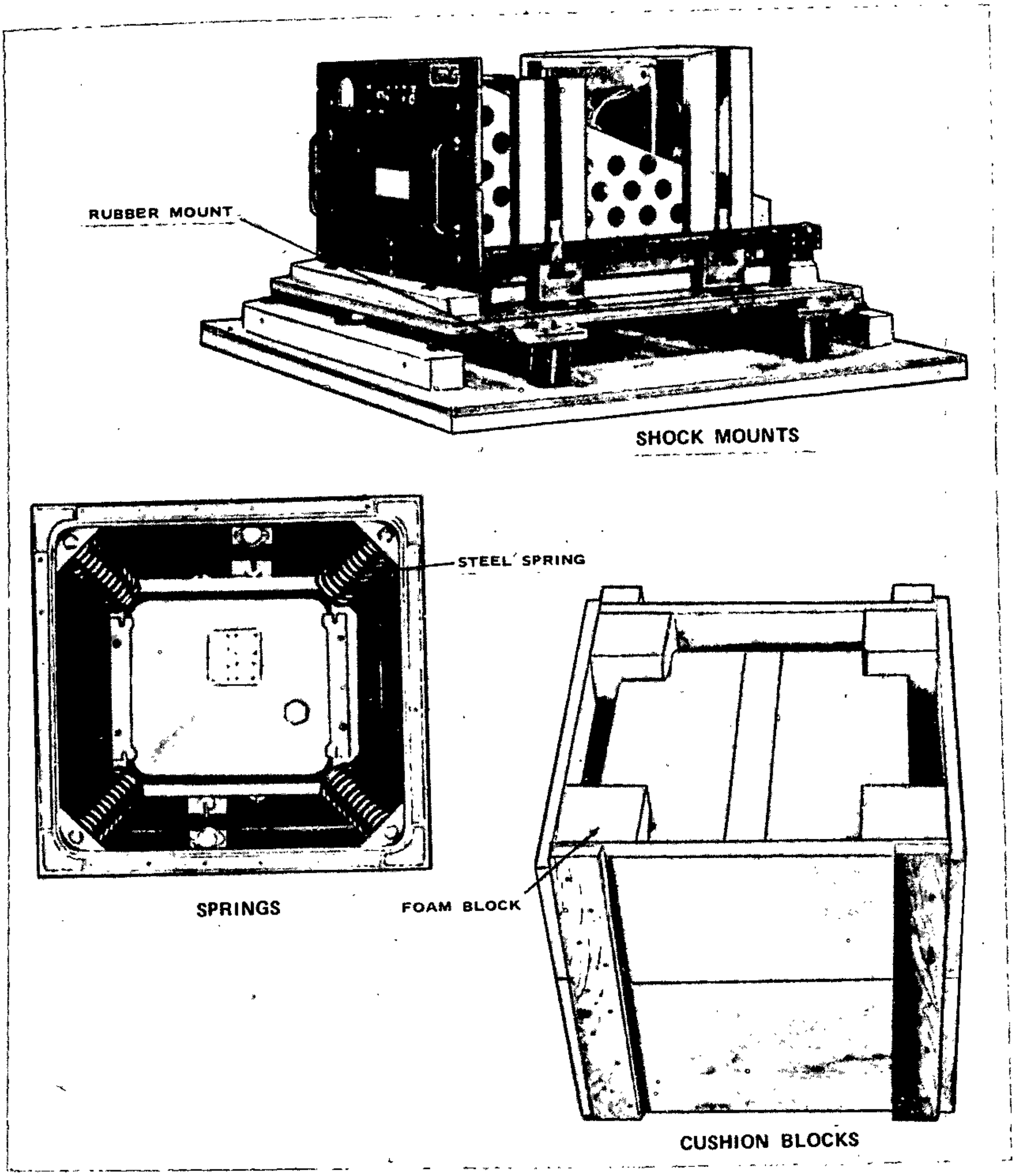


FIGURE 5. Methods of shock mitigation.

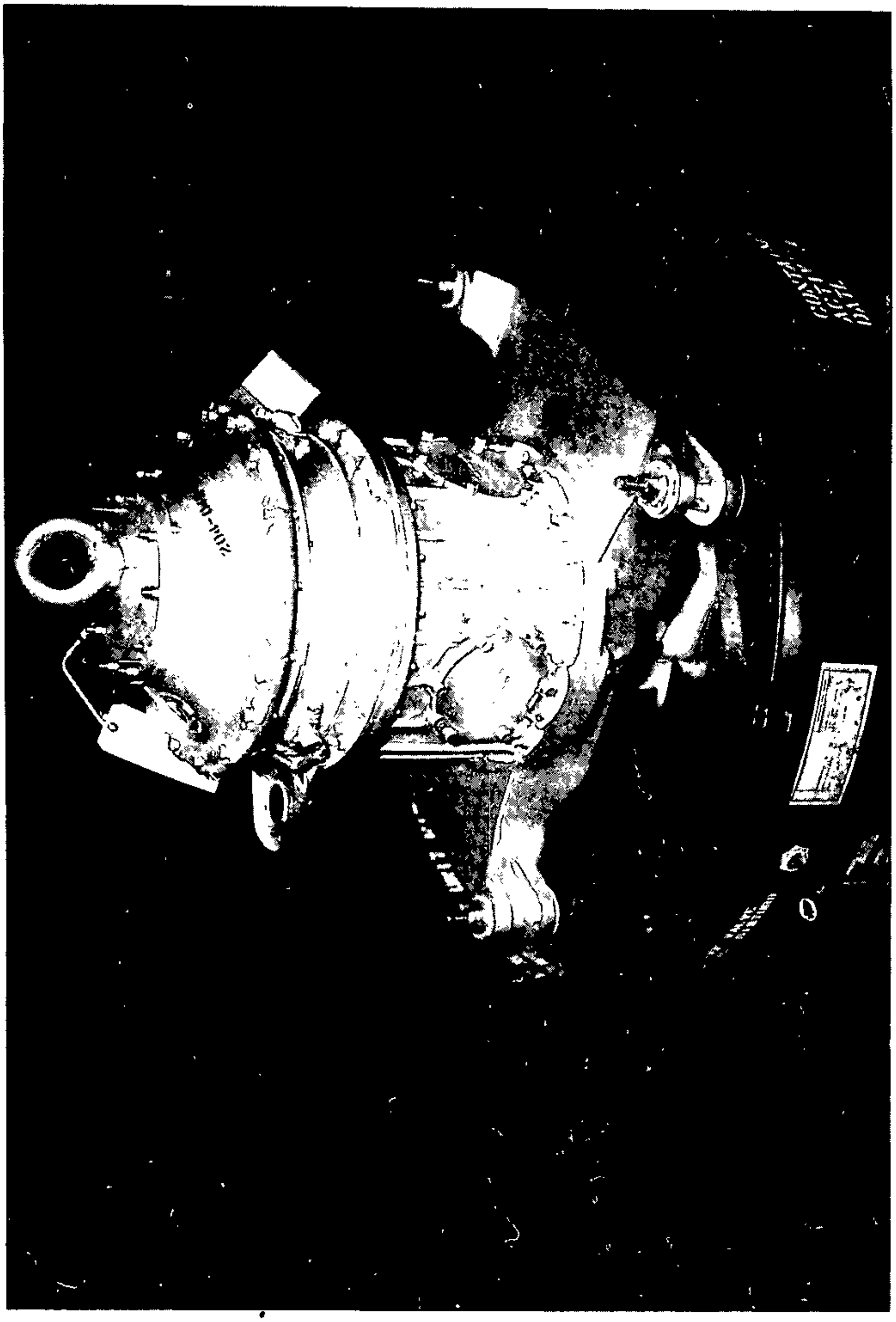


FIGURE 6. Shock mitigation using rubber shear mounts.

The mode of transportation and the applicable frequencies tabulated provide the required data relating to imposed vibrations. Because shock and vibration are related phenomena, it is often necessary to protect an item from both. Care should be taken in such instances so that features incorporated to protect an item from one do not aggravate the effects of the other.

5.1.4.5.3 Surface finish. This refers to both the type of worked finish that has been accomplished on the item and to whether the surface moves on or against another item or whether another surface moves upon it. If intimate contact with the surface of another component or an assembly is involved and close fit is required, the degree of protection required will be greater than for a surface that is not critical in the functioning of the item. Other item surfaces may not move in relation to the contact part but will have accurately controlled surfaces for intimate contact with a mating part, or for close sealing. Certain surfaces such as those on reflective or optical devices will be polished or ground and, therefore, are very susceptible to abrasion. Figures 7 and 8 illustrates two items with different surface characteristics.

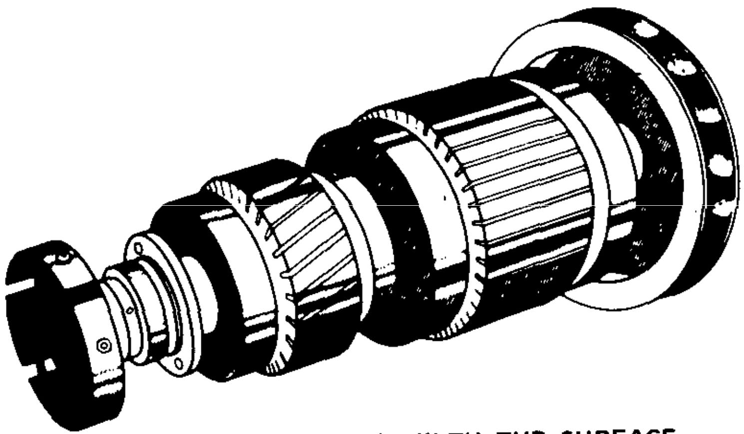


FIGURE 7. Surface finish characteristics.

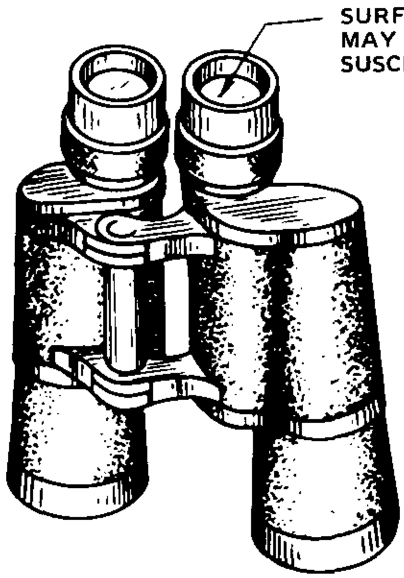


FIGURE 8. Surface finish characteristics.

5.1.4.5.4 Degree of hazard. Some problems of protection center on the harm that the item itself can do. Included in this group are items that use the following materials:

a. Corrosive materials.

b. Flammable materials.

c. Explosive materials.

d. Toxic materials.

e. Radioactive materials.

5.1.4.5.5 Regulatory requirements. The following referenced documents apply to the packing and marking of containe s with dangerous and hazardous materials.

a. Code of Federal Regulation, Title 49, Parts 100-199 (49 CFR 100-199), prescribes the requirements of DOT governing the transportation of hazardous materials in commerce within the United States by highway, rail, water, and air. This includes the required packaging, inspection, weight restrictions, marking and labeling, and billing and shipping certification.

b. Coast Guard 108 promotes safety in the handling, storage, and transportation of military explosives aboard vessels on any navigable waters within the limits of the jurisdiction of the United States, including its territories and possessions, except the Panama Canal Zone. Included are requirements for loading, unloading, packing, marking, and preparation of holds and compartments for such items.

c. Joint Regulation TM 38-250/AFM 71-4/NAVSUP Pub 505 (REV)/MCO P4030.19D/DLAM 4145.3 gives instructions for the preparation, packing, marking, labeling, handling, and stowing of explosives and other dangerous materials for shipment by military aircraft.

d. Bureau of Explosives Pamphlets No. 6 and 6A illustrate methods for loading and bracing carload and less-than-carload shipments of explosives and other dangerous articles to conform with DOT regulations.

e. Bureau of Explosives Pamphlet No. 6C illustrates methods for loading and bracing trailers and less-than-trailer shipments of explosives and other dangerous articles via Trailer on Flat Car (TOFC) or Container on Flat Car (COFC) to conform with DOT regulations. More detailed data on transportation limitations for hazardous materials are covered in a later paragraph.

f. International Maritime Dangerous Goods (IMDG) codes prescribe individual requirements to assist in compliance with legal requirements of the International Convention for the Safety of Life at Sea (chapter VII), currently in force, regarding the carriage of dangerous goods by sea. Chapter VII deals with the application, classification, packing, marking and labeling documents, temporary exception and storage requirements in the carriage of dangerous goods, and the transport of explosives in passenger ships.

g. International Air Transport Association Restricted Articles regulations prescribe the classification, labeling, marking, packing, net quantity per package for passenger and cargo aircraft, and the procedures for the control, handling and processing of restricted articles and their loading and unloading onto aircraft.

5.1.4.6 <u>Vulnerability to field force damage</u>.

a. Sensitive electronic devices (i.e., resistor networks, resistor chips, thin film resistors, microwave diodes, metal oxide semiconductors, metal insulated semiconductors, insulated gate field effect transistors and microcircuits together with modules, printed circuit boards, and other assemblies containing one or more of the aforementioned sensitive components) are sensitive to damage, in various degrees, from field forces (electrostatic, electromagnetic, magnetic or radioactive) encountered in nonoperating environments. These sensitive items are also susceptible to damage from more mundane forces such as water vapor corrosion and physical shock and vibration.

b. One of the special problems with items damaged in this manner is that the damage is not readily apparent. The packaging materials are undamaged and even the items themselves appear not to have been affected. These subtle forms of damage are not evident unless the affected devices are tested or are put into use. More extensive tests can be conducted after the housings or cases inclosing the devices are removed. A scanning electron microscope is usually required to ascertain the full extent and particular type of damage. In some instances, the microminiature circuitry of affected devices is found to have been degraded. This type of damage is even more subtle. Although fully operable, the working life of such devices is considerably shortened.

c. The MIL-B-81705, type I barrier provides in one material protection from electrostatic and electromagnetic fields as well as protection from water vapor corrosion. Since damage from these sources is by far the most commonly reported and likely to occur, this barrier material is frequently cited for the preservation of these sensitive electronic devices. Other materials, of course, can be used to provide specific protection from known or anticipated hazards (e.g., type II of MIL-B-81705 for electrostatic fields, aluminum conforming to QQ-A-1876 for electromagnetic fields, ferrous metals or ferritic compositions for magnetic fields, and lead or lead field compositions for radioactive fields).

d. It is important to realize, however, that none of the barrier materials described above commonly offers full protection from strong or intense fields. It is for this reason that the sensitive electronic device symbol and associated label specified in MIL-STD-129 must be used to complement whatever protection is provided. This marking will identify the sensitive nature of the container contents as well as caution those who handle shielded packs of the sensitive electronic devices not to do so near strong or intense electrostatic, elecromagnetic, magnetic or radioactive fields.

e. The use of the sensitive electronic device caution label may preclude the need for shielding against every possible hazard. In many instances where damage from magnetic or radioactive field forces is not considered likely, specific shielding from these fields may be omitted provided the sensitive electronic device caution label is used as required in MIL-STD-129.

5.1.4.7 Strength and fragility. The degree of fragility and the rigidity of an item determine to a great extent the amount and type of physical protection that must be designed into a package.

5.1.4.7.1 Fragile, delicate, and rugged items.

5.1.4.7.1.1 Fragile items. Fragility refers to the physical characteristics that permit fracturing or shattering of the item when it is subjected to moderately light impact forces (see table II). Examples of fragile items are those of glass, some plastics, and low-tensile brittle metals that are vulnerable to light impact forces because they are both brittle and relatively thin (see fig 9).

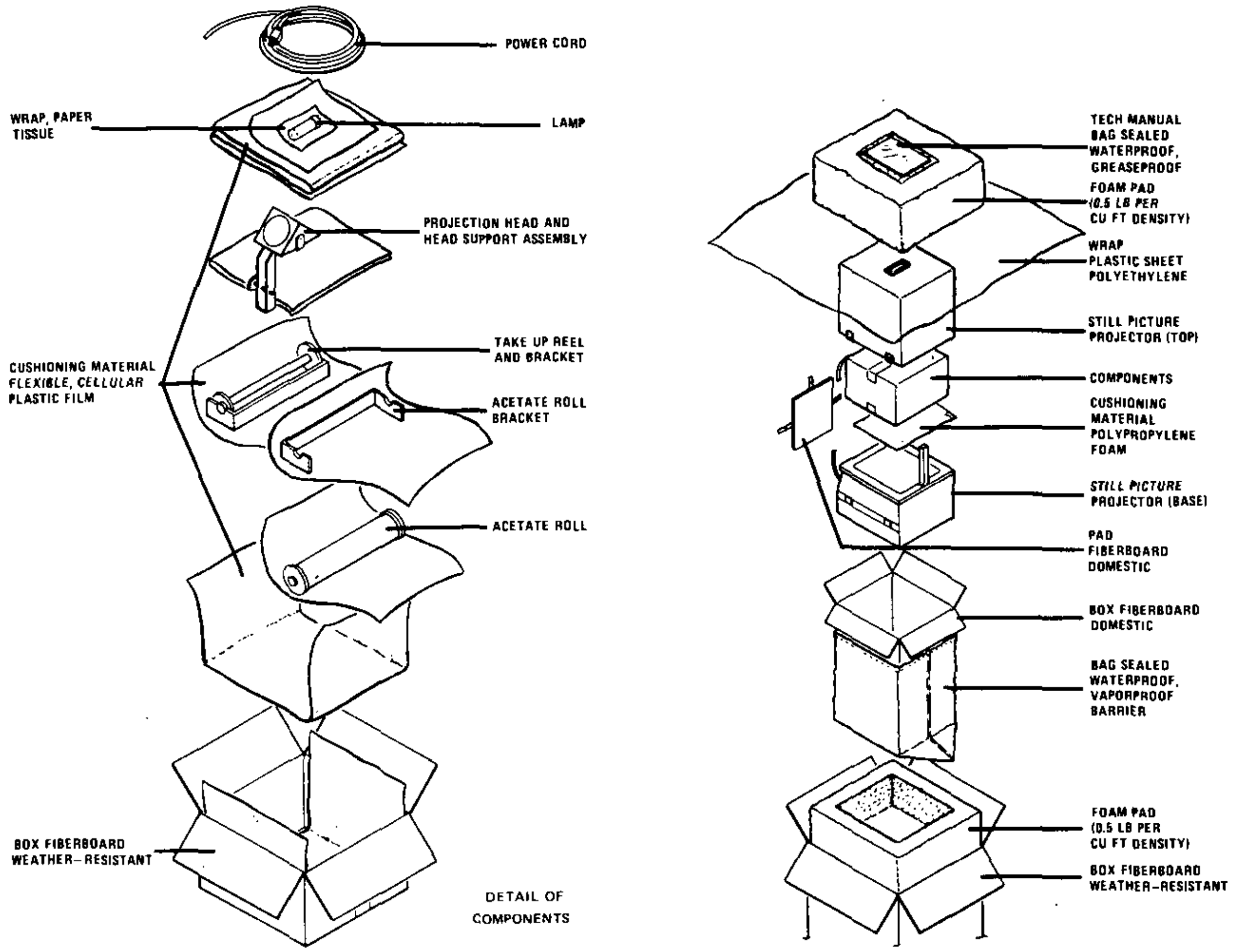


FIGURE 9. Cushioning of a still picture projector--a fragile item.

5.1.4.7.1.2 Delicate items. Delicate items are those so constructed that light moderate forces will either distort, displace, or deform elements in parts of the item to such an extent that malfunction or misfit of the item occurs. Delicate items generally require some provisions within the package for impact and vibration isolation. Examples of delicate items are gyroscope equipment, galvanometers, and devices with filaments (see fig 10).

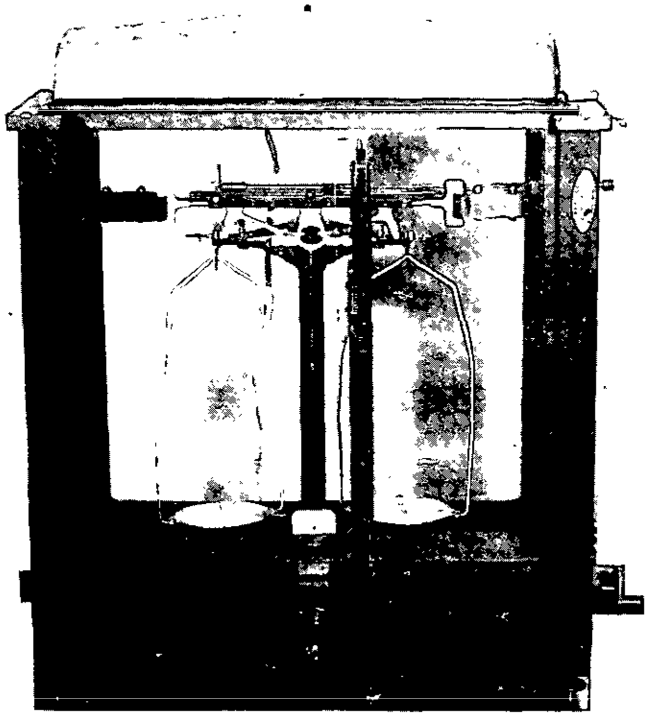
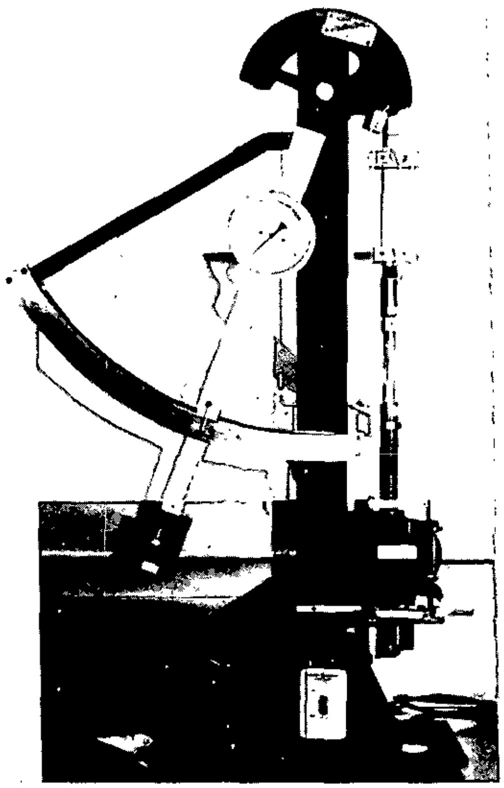


FIGURE 10. Analytical balance scale--a delicate item.

5.1.4.7.1.3 Rugged items. Items are generally considered to be rugged or highly resistant to shock and vibration when bracing and blocking within the container are all that is required for protection. Some items are strong and rugged except for one or more fragile component parts (see fig 11). When the fragile part cannot be removed for separate packaging, the entire item must be treated as being as fragile as the most fragile component. Some items that do not require physical protection must still be packaged for ease in handling and storage.



NOTE: THIS STURDY ITEM WOULD BE CONSIDERED FRAGILE FOR PACKAGING PURPOSES IF FRAGILE COMPONENTS CANNOT BE REMOVED.

FIGURE 11. Tensile tester--a fragile item.

5.1.4.7.1.4 Flexible and rigid items. Flexibility refers to both the coilability of the item and the need for stiffeners within the package. Flexible items can be formed into coils, folded, or rolled to provide more convenient package forms. Because of their assembly characteristics, material content, or disproportionate dimensional relationships, flexible items will change shape under very moderate pressure, including pressure exerted by the item itself when not fully supported over its load-bearing surface. Examples of flexible items are chains, cables, baskets, and rubber items (see fig 12). Rigid items are built so that force must be exerted to change their shape, but once they encounter such forces, they are permanently marked, deformed, or damaged.

5.1.4.8 Type of load. Items may be classified by the type of load they produce when packed, i.e., their influence on the strength of, and their tendency to apply damaging forces to, the package. An easy load would be one composed of items of moderate density packed in an inside container. For this type of load, the outer container facilitates handling and preserves and protects the surfaces of the packaged item from abrasion and

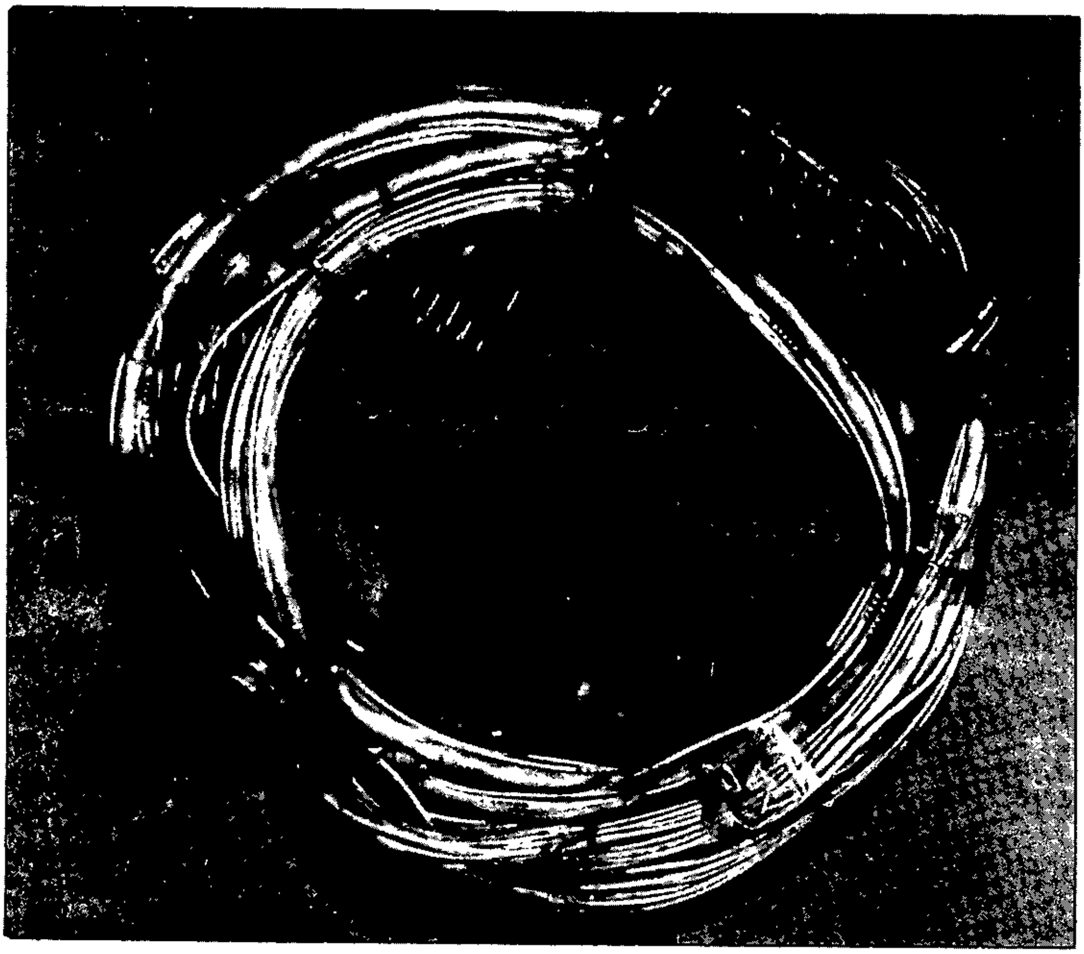


FIGURE 12. Cable--a flexible item.

weathering. Solid material, a chest, or a kit of tools are examples of easy loads. An average load would consist of items, such as metal cans or bottles individually cushioned in cartons, that require a medium amount of protection. A difficult load would be composed of items such as rivets, nails, or bolts that are free to shift or flow, or delicate instruments that do not completely fill the container. Such items furnish no support to the faces of the container and, in many cases, tend to concentrate forces on the container surfaces. The center of gravity (CG) of a container may not be at the geometric center and may cause handling problems. The CG is obtained by the equal distribution of weight on both sides of the point of balance of a container. This point (CG) must be marked on the container, as specified in applicable directives, to aid in safe handling.

5.1.4.9 Configuration. Configuration, which is the exterior shape of an item, is a factor in determining the type and amount of cushioning and support required to retain the item within the package and to protect the packaged material against the forces imposed by the item on these materials. To an important degree, the amount and type of cushioning to be used is affected by the shape and severity of surface characteristics. For example, a light smooth item with no projections requires less cushioning than a heavy item, such as shown in figure 13, having sharp edges or points that could damage the package. Cushioning required to protect the item against vibration and impact shock is determined by additional consideration of the fragility of the item and its size and weight.

5.1.4.10 Size and weight. These characteristics are important in selecting submethods as defined in MIL-P-116 and the type and amount of cushioning required. They seldom influence the type or degree of preservation required for an item, but do directly influence the kind of container that will be used and the type, grade, and class of container applicable.

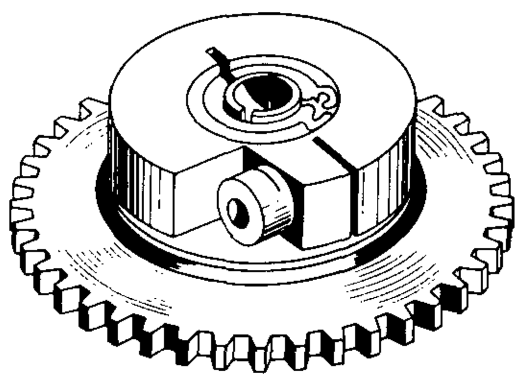
5.1.4.10.1 Size. A large item does not necessarily require more extensive or stronger blocking or larger amounts of cushioning than a smaller item because of its size alone. But the container needed by the larger item may require more extensive and stronger blocking to bridge the wider spans between the container faces or frame members. Also, a large item may require that the cushioning be distributed over larger areas than on a smaller one.

5.1.4.10.2 Weight. The weight of an item determines the design of blocking, bracing, and cushioning because the impact force

FIGURE 13. Transmission system--a heavy item having projections.

developed by the sudden stop of a moving item is directly proportional to its weight (mass). The heavier and more concentrated the weight of an item, the stronger must be the blocking and bracing to safeguard the life of the pack. When weights are concentrated in small areas, it may be necessary to distribute the weight over a larger area, or to transmit part of the weight from one container face to the edges or to the corners of the container.

5.1.4.11 Nature of the item. Not all items are simple enough to be preserved and packed by the single one-step procedures of clean, preserve, wrap, and containerize. Items may be of composite chemical nature (fig 14), contain assembly features, or be peculiarly susceptible to corrosion. They may have a chemical nature that requires preservatives on one or more areas, but will not tolerate a preservative on another area. They may also tolerate preservatives on all areas but not the same type of preservative on each. Or, items may be assembled in such a way that certain areas cannot or should not be in contact with a preservative. Sometimes contact type preservatives may be ruled out and another means of protection must be designated.



NOTE: ON THIS ITEM, THE GEAR IS LUBRICATED SINTERED BRONZE, THE BODY AND SPRING ARE CORROSION-RESISTANT STEEL, AND THE CLAMP IS ANODIZED ALUMINUM.

FIGURE 14. Gear unit--a multimetallic item.

5.1.4.12 Relation of item design to package. The advantages of disassembling items to reduce the size of the package or to simplify preservation have been briefly mentioned earlier (see 4.6.2). However, before designing a unit pack for a disassembled item, the packaging engineer must consider the skills, equipment, and tools needed at the point of use, and determine if these will be generally available. Also, any functional checks that must be made during storage for compatibility and recalibration must be considered when designing the pack. It must be considered that the time and effort necessary to disassemble and reassemble an item may outweigh any advantages that would be gained.

5.1.4.13 Compatibility of materials. Table III lists a number of areas where compatibility becomes a packaging consideration. If moisture is expected as part of the environment of the item, compatibility tables similar to MIL-STD-171 should be used in the selection of packaging materials to avoid electrolytic corrosion. If incompatible metals must be used, some design features which will insulate the metals from each other should be included.

TABLE III. Compatibility of packaging materials.

A. Compatibility of Cleaning Methods and Materials:
- (1) With items.
- (2) With packaging materials.

B. Compatibility of Preservatives:
- (1) With items.
- (2) With unclean surfaces.
- (3) With packaging materials.

C. Compatibility of Inhibitors:
- (1) With nonferrous metals.
- (2) With nonmetals.
- (3) With preservatives.
- (4) With packaging materials.

D. Compatibility of Metal Platings.

E. Compatibility of Dissimilar Materials.

F. Other Compatibility Data:
- (1) Naphthalene on asphalt laminates.
- (2) Rocket fuels on packaging materials.

5.1.4.14 Cost of item. Maximum efficiency and lowest cost cannot always be determined with certainty, and sometimes may appear to conflict. If the costs associated with providing a particular packaging feature are exceeded by practicable costs associated with failure to provide it, then the feature is economically justified. Costs associated with failure to provide a particular feature may not be readily apparent, but they may include higher shipping, handling, or storage costs. Safety considrations, however, cannot be evaluated from the standpoint of cost alone. They must be given primary consideration.

5.2 Deterioration. Item characteristics that make some military items vulnerable to deterioration were briefly discussed in the preceding section (see 5.1). This section describes in detail the types of deterioration caused by the contributing factors of climate, physical forces, chemical agents, and biological agents. Succeeding sections discuss methods and materials prescribed by the packaging engineer to help combat this deterioration.

5.2.1 Deterioration of metal. Except for the physical changes brought about by low temperatures, deterioration of metals is in the form of corrosion. Corrosion of metals (fig 15) is closely related to the environment, particularly the temperature, humidity, and the presence of chemicals. The destructive effects of moisture, chemical action, electrochemical action, and low temperature and their prevention are described below.

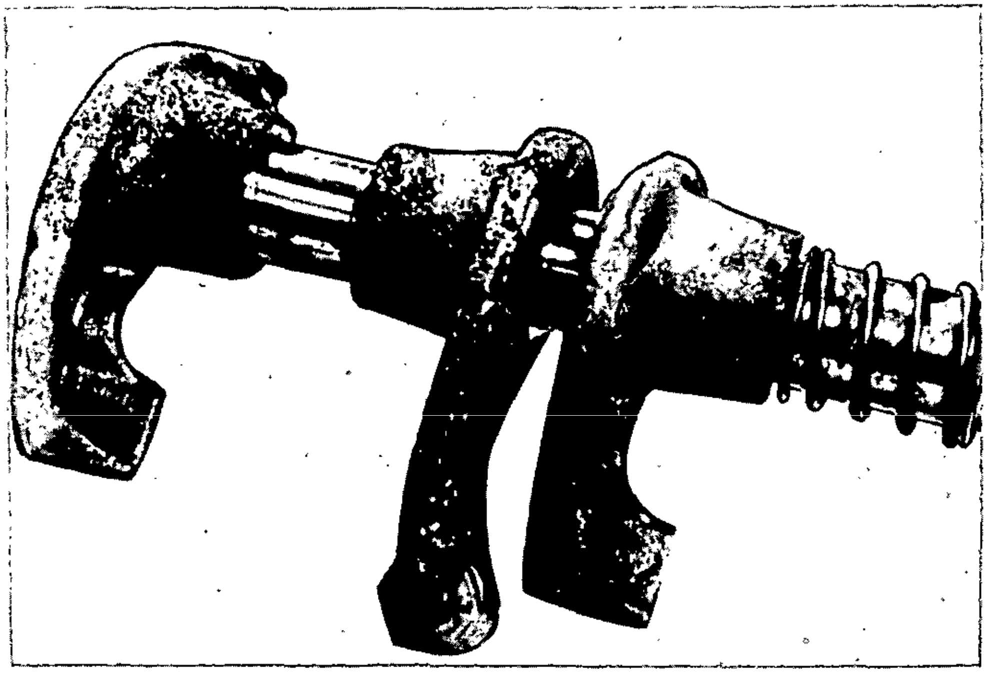


FIGURE 15. Rusted rocker arm of truck engine--after storage.

5.2.1.1 Moisture. Most metals corrode in the presence of moisture. The rate of corrosion is influenced by the manner in which the moisture is applied. Alternate wetting and drying, as created by a spray, cause rapid corrosion whereas immersion, as caused by condensation of a thin water layer, is even more destructive. A high relative humidity level is particularly harmful, resulting, for example, in an 80 percent increase in the corrosion rate of steel and a significant increase in the corrosion rate of zinc. Besides causing corrosion through simple chemical oxidation, moisture also causes corrosion by electrochemical action.

5.2.1.2 Chemical action. Corrosion of metals by reaction with chemical substances in the environment occurs under a variety of circumstances. Most chemical attacks depend on moisture to be effective. Airborne contaminants are an important part of the corrosion process, especially in areas subject to fog, because the water vapor acts as a vehicle to place the contaminant in contact with the package. The packaging engineer does not usually become concerned with protecting exclusively against corrosion resulting from direct chemical attack of active gases on metals. If corrosion caused by electrochemical action is eliminated or prevented through packaging, then direct chemical attack is also prevented. Salt water is particularly corrosive. Free acids and alkalis are encountered in airborne contaminants and in large concentrations in soil and natural waters. These three corrosive agents are described in the paragraphs which follow.

5.2.1.2.1 Salts. Salts in soil and water are the most widely distributed and troublesome of the corrosive chemical agents. The natural salts causing the greatest trouble are the chlorides (particularly sodium chloride because it is the most frequently encountered), nitrates, sulfates, phosphates, and occasionally carbonates. Salts of weak acids and strong bases or strong acids and weak bases hydrolyze, forming acids and bases, which result in the corrosion of metals by direct chemical action. Also, all salts do ionize in solution, causing corrosion by electrochemical action. The specific effect of a salt upon a metal depends on the chemical and electrochemical relationship between them. Iron and steel are affected primarily by sodium chloride salt spray. Aluminum is relatively immune to sodium chloride salt spray, but is readily attacked by the salts of strong bases and weak acids--such as the sodium, potassium, and ammonium salts of acetic, oxalic, and tartaric acids. The effects of salt solutions on various metals are given in tables IV and V.

TABLE IV. Corrosion rates of steel and cast iron in various salt solutions.

Salt Solution	Temperature		Duration of Test, Days	Corrosion Rate			
				Steel		Cast Iron	
	°C	°F		mdd*	ipy**	mdd*	ipy**
5% calcium chloride	16	60	--	35	0.006	48	0.009
30% calcium chloride	-12	10	355	--	--	34	0.006
30% calcium chloride (with $K_2Cr_2O_7$ inhibitor)	-12	10	372	--	--	2	0.0004
46% calcium chloride	180	360	11	28	0.005	--	--
6.6% ammonium thiocyanate	room	room	13-1/2	30	0.006	15.0	0.003
30% ammonium thiocyanate	68	154	17	442	0.08	520	0.10
5% ammonium sulfate	16	60	--	49	0.009	138	0.03
10% ammonium sulfate	16	60	--	50	0.009	151	0.03
25% ammonium sulfate	16	60	--	17	0.003	57	0.012

(Contributed by H.O. Teeple, International Nickel Co., Inc., New York, NY)

*Milligrams per square decimeter per day.

**Inches per year.

TABLE V. Corrosion of magnesium alloys in salt solutions.

Alloy - Mg: 6% Al, 1% Zn, 0.2% Mn
Specimen size: 7.5 x 2.5 x 0.15 cm (3 x 1 x 0.06 in.)
Surface preparation: NHO_3 pickled
Temperature: 35° C. (95° F.)
Volume of testing solution: 100 ml
Duration of test: 7 days
Test - alternate immersion: 30 sec in solution, 2 min in air
Concentration of solution: 3% by weight

Acid Salts	Corrosion Rate, mdd*	Neutral Salts	Corrosion Rate, mdd*	Alkaline Salts	Corrosion Rate, mdd*
		Nonoxidizing			
Aluminum sulfate	112	Sodium chloride	14	Sodium silicate, meta	0.7
Zinc chloride	770	Sodium bromide	6	Sodium sulfite	2
Sodium acid tartrate	155	Sodium iodide	29	Sodium borate, meta	5
Sodium dihydrogen phosphate	85	Sodium fluoride	3	Sodium phosphate	3
		Sodium sulfate	8		
		Sodium nitrate	5		
		Oxidizing			
Ammonium persulfate	465	Sodium chromate	2	Calcium hypochlorite	155
Sodium dichromate	4	Sodium chlorate	59	Sodium hypochlorite	5
Ferric sulfate	297	Sodium pyrophosphate	51	Sodium iodate	40

*Milligrams per square decimeter per day.

5.2.1.2.2 Acids and alkalis. Because of their high activity, free acids and bases are rarely encountered in natural environments. An important exception, however, is the high acid concentration in airborne contaminants. Industrial atmospheres are the worst offenders in this category. The high concentration of sulfur dioxide and carbon dioxide in industrial atmospheres form sulfurous acid and carbonic acid in the presence of water vapor. Carbonic acid is a fairly weak acid, resulting in minimal deterioration. Sulfurous acid, however, is a very strong acid and may even be oxidized under suitable circumstances to form the more powerful sulfuric acid. The latter two acids are extremely corrosive. In dilute solutions and hot concentrated solutions, these two acids attack iron, steel, copper and zinc compounds, and aluminum to some extent. Hydrogen sulfide is another sulfur compound frequently found in industrial atmospheres, though its corrosive effects are limited primarily to steel. The effects of the most prevalent industrial contaminants on metals are shown in table VI.

5.2.1.3 Electrochemical action. Attack by electrochemical (or galvanic) action accounts for more destruction of metals than any other form of corrosion. The deterioration process occurs in the manner described. Wherever two dissimilar metals are in contact and exposed to water or another electrolyte, a galvanic cell will be formed and current will flow. The rate of current flow depends on the potential difference, which in turn is dependent on the relative dissimilarity of the metals. Galvanic action usually results in the progressive corrosion of the more positive of the two metals with the action continuing as long as an electrolyte is present. There are usually sufficient differences between adjacent crystals of a metal for this action to take place. Where different metals such as aluminum and steel are coupled, the potential difference is greater and therefore the attack is accelerated. The electrochemical series listed in table VII reveals the relative electromotive potential of various metals. Usually, the greater the separation of two metals, the greater is the corrosion problem. However, corrosion is also a function of the concentration of the cations of the metal in solution and the presence of complexing agents. Corrosion may be either the surface type or intergranular--the latter being the more dangerous. Theoretically, as long as the relative humidity is kept below the saturation point, corrosion should not occur. But in practice, surface absorption and condensation of water vapor by particles of hygroscopic matter may produce liquid films or spots even though the air may be comparatively dry. To minimize the incidence of electrochemical attack, metallic components of items should be designed without recesses, cups, or traps where liquids can accumulate. Metals in contact should be chosen

TABLE VI. Resistance of metals to water solutions of airborne gases.

Metal	Carbon Dioxide(1) and Water		Sulfur Dioxide,(2) Air, and Water		Hydrogen Sulfide(3) and Water	
	Avg Wt Loss, gram	Avg ipy(4)(6)	Avg Wt Loss, gram	Avg ipy(4)	Avg Wt Loss, gram	Avg ipy(4)
Aluminum(2S)	0.0003	0.00004	0.150	0.0498	0.002	0.00028
Copper	--	--	0.681	0.0701	0.237	0.01030
Steel	0.2153	0.00977	8.583(5)	1.02(5)	1.366	0.06800

Notes:

(1) Metal specimens 1 x 4 x 1/16 in. (2.5 x 10.2 x 0.16 cm) were partially immersed (to a depth of 2 in.) (5.1 cm) in distilled water through which carbon dioxide and air were bubbled. The total period of exposure was 342 hours at room temperature.

(2) Metal specimens 1 x 4 x 1/16 in. thick were partially immersed (to a depth of 2 in.) in distilled water through which air and sulfur dioxide were bubbled. The total period of exposure was 135 hr at room temperature.

(3) Metal specimens 1 x 4 x 1/16 in. were partially immersed (to a depth of 2 in.) in distilled water through which hydrogen sulfide was bubbled. The total period of exposure was 320 hours at room temperature.

(4) This calculation was based on the assumption that all corrosion was confined to the immersed areas of the specimens.

(5) Steel specimen corroded completely through at the water line.

(6) ipy - inches per year.

TABLE VII. Electrochemical series.

Anodic (Positive) End	
Lithium	
Rubidium	
Potassium	
Calcium	
Sodium	
Strontium	
Barium	
Magnesium	
Beryllium	
Aluminum	
Manganese	
Zinc	
Chromium	
Gadolinium	
Iron (Fe^{++})	
Cadmium	
Indium	
Tellurium	
Cobalt	
Nickel	
Tin	
Lead	
Iron (Fe^{+++})	
Hydrogen	(neutral)
Antimony	
Bismuth	
Arsenic	
Copper	
Iodine	
Carbon (graphite)	
Silver	
Palladium	
Mercury	
Platinum	
Gold	
Cathodic (Negative) End	

as close toge 'er as possible in the electromotive force series. Exposed surfaces should be completely covered by some form of protective coating or surface plating. Corrosion inhibitors or preservative materials should be used whenever necessary or possible. Although moisture is the electrolyte in most galvanic action, salt solutions support even more vigorous deterioration. Extreme care must be exercised in the protection of metal items that may be transported by ship or stored in proximity of salt water. Slight alteration occurs in the electrochemical series when salts are present in the electrolyte. Table VIII lists the galvanic series for a variety of metals and alloys in sea water. Table IX gives the corrosive effects of this action on magnesium and other dissimilar metals in salt solution. The effects of distilled water on the same metal combinations are included for comparison.

5.2.1.4 Low temperatures. As the temperature decreases, most metals undergo transient changes in properties that make them susceptible to failure in areas of high stress concentration. The metals become stronger and stiffer but also more brittle at very low temperatures. Some of these transition temperatures are surprisingly high; for example, approximately 32° F. for some steels that are not thoroughly deoxidized. Although the packaging engineer can do nothing to prevent the occurrence of this transition, he/she should be aware of these properties of metals. In consultation with the item designer, he/she may perhaps recommend that certain metals or certain manufacturing processes not be used for cold-temperature use.

5.2.1.5 Corrosion prevention. For the packaging engineer, the problem is to eliminate hygroscopic matter and to maintain a relative humidity in which surface condensate will not form. Metal items must be thoroughly cleaned and dried before packaging, residual moisture must be removed as rapidly as possible after packaging, and a low relative humidity must be maintained for the life of preservation. Desiccants are frequently used for this purpose. But if hygroscopic matter and residual moisture are not removed before a package containing desiccant is sealed, they may start corrosion before they can be dried by the desiccant. Preservation may also be achieved by sealing dry inert gases within the package or by using controlled humidity warehouses. The destruction of metals can be reduced in the manufacturing stage through the use of corrosion-resistant coatings of metal, paint, and plastic, and by surface treatment of the metal with semipermanent corrosion preventive materials. These methods result in a significant increase in the service life of the metal. The use of these methods is described in the paragraphs which follow.

TABLE VIII. Galvanic series in sea water.

1. Magnesium
2. Magnesium alloys
3. Zinc
4. Galvanized steel
5. Aluminum (52SH, 61S, 3S, 2S, 53ST, in this order)
6. Aluminum clad, 24ST, 17ST
7. Cadmium
8. Aluminum (75ST, A17ST, 17ST, 24ST, in this order)
9. Mild steel
10. Wrought iron
11. Cast iron
12. Ni-Resist
13. 13% chromium stainless steel, type 410 (active)
14. 50-50 lead-tin solder
15. 18-8 stainless steel, type 304 (active)
16. 18-8-3 stainless steel, type 316 (active)
17. Lead
18. Tin
19. Muntz metal
20. Manganese bronze
21. Naval brass
22. Nickel (active)
23. Inconel (active)
24. Yellow brass
25. Admiralty brass
26. Aluminum bronze
27. Red brass
28. Copper
29. Silicon bronze
30. Ambrac
31. 70-30 copper nickel
32. Comp. G-bronze
33. Comp. M-bronze
34. Nickel (passive)
35. Inconel (passive)
36. Monel
37. 18-8 stainless steel, type 396 (passive)
38. 18-8-3 stainless steel, type 316 (passive)

TABLE IX. Corrosion of Mg - 6% Al, 3% Zn, 0.2% Mn alloys galvanically connected to other metals in various media.

Size of specimens: 4 x 1.3 x 0.2 cm (1.5 x 0.5 x 0.079 in.)
Relative areas: 1:1 (mounted face to face)
Surface preparation: Aloxite 150 ground
Temperature: room
Aeration: natural convection
Volume of testing solution: 100 ml
Velocity: quiescent
Duration of test: 3% NaCl, 3 hr; Midland tap water, 24 hours; Distilled water, 4 days

Dissimilar Metal	Corrosion Rate, mdd*				
	3% NaCl				Distilled Water
	Close Contact	Separation 0.35 cm	Separation 2.0 cm	Separation 10 cm	Separation 0.35 cm
Steel	23,400	25,500	8300	3900	18
24ST Aluminum	12,800	25,700	6800	3200	6
Nickel	18,800	22,400	6600	--	19
2S Aluminum	14,500	15,600	4100	--	4
Copper	8500	8200	3700	--	15
Brass	7100	4000	2500	1700	14
56S Aluminum	--	1900	--	--	3
Cd-Plated Steel	5200	2200	1000	--	14
Zinc	6200	1300	900	700	8
Mg-1.5% Mn	--	50	--	--	3
Mg-6% Al,3%Zn,0.2%Mn	--	200	--	--	3

*Milligrams per square decimeter per day.

5.2.1.5.1 Metal coating. Steel is most often protected by a corrosion-resistant metal coating. Cadmium, zinc, nickel, chromium, tin, and lead are the metals most frequently used for this purpose. All of these metals can be electroplated onto steel, although zinc, tin, and lead can also be applied by hot-dip. Cadmium and zinc protect steel and greatly reduce corrosion caused by the contact of steel with aluminum or magnesium alloys.

5.2.1.5.2 Paint. Paint is frequently employed to prevent corrosion by protecting the surface of the metal from moisture. To be really effective against the more severe environmental conditions such as salt spray and other chemical-laden fluids, a special corrosion-inhibiting primer must be applied to the metal surface prior to painting. These primers usually consist of liquid vehicle or binder and a corrosion-inhibiting pigment. The most common inhibitive pigments are red lead (lead oxide) and zinc yellow (zinc chromate). Red lead is popular for steel, but lighter zinc pigments must be used if weight is a factor. Table X lists several paint primers.

5.2.1.5.3 Semipermanent surface treatment. Chemical treatment of sheet metal to produce a corrosion-resistant surface is often used for aluminum and steel. Treatment of the metal surface with certain chemical solutions produces a thin corrosion-resistant film. Table XI lists the treatments used to protect aluminum; table XII lists the treatments used to protect steel. The temporary surface treatments which the packaging engineer uses for different item surfaces were reviewed earlier (see 5.2.1.5).

5.2.2 Deterioration of wood. Wood is subject to deterioration by the factors of climate, physical forces, chemical agents, and biological agents. Wood and wood products being organic in nature are highly susceptible to biological agents, especially microorganisms and insects. The deterioration of wood is particularly severe when suitable environmental conditions such as moisture and warmth favor the biological agents.

5.2.2.1 Microorganisms. Wood in contact with the ground is susceptible to attack by fungi and molds, particularly in a moist and warm environment. Most of these organisms cause decay which drastically reduces the structural properties of wood, whereas other do not damage the wood but quickly deteriorate certain plywood glues. Under humid conditions, molds and fungi can stain wood in a few days, even if the wood is supported off the ground, and can eventually cause decay. Use decay-resistant or decay-treated woods for items being shipped to areas where optimal conditions for decay are prevalent. Table XIII lists the decay resistance of some woods. Protection against microorganisms

TABLE X. Typical paint primers.

Type	Ingredients lb/100 gal paint								Properties					
	Zinc Yellow	Red Lead	Basic Lead Sulfate	Zinc Oxide	Iron Oxide	Inert Pigments	Other Pigments	Vehicle Solids	Thinners and Dryers	Phosphoric Acid (85%)	Wt/gal, lb	Red coating time, hr	Color	Suggested Use
Automotive	38			25	257	197		205(A)	393		11.2	18	Red	I
Automotive and equipment		1345 (95%)			448			344(A,O)	177		23	16	Brownish red	I, II
General purpose	149		447(B)	105		176		226(A)	355		14.6	12	Gray	I,II,III
Aircraft	280						50	265(A,P)	400		9.9	6	Yellow	II, III
Ship bottom	65					40		115(R)	610		8.1	18	Yellow	III, IV
Ship bottom			588(W)		591		295(C)	303(V)	383		21.5	12	Red	IV
Marine primer	71	391 (97%)		71	50	128		364(A,O,V)	269		13.5	4-8	Brownish red	III, IV
Wash primer	54					8		56(S)	630	28	7.5	1	Yellow	V

Vehicle

(A) Alkyd resin
(O) Oil, vegetable drying
(V) Varnish, oleoresinous
(P) Phenolic resin
(R) Vinyl resin
(S) Polyvinyl butyral resin

Pigment

(B) Blue lead sulfate
(W) White lead sulfate
(C) Lead carbonate

Usage

I Mild atmospheric exposure
II Severe atmospheric exposure
III Tidewater atmospheric exposure
IV Submerged-sea water
V Pretreatment coating

TABLE XI. Surface treatments for aluminum.

Type	Remarks
Anodic	---
Chemical conversion	Not for extremely severe exposure
Chromic acid wash	Used primarily on the more corrosion-resisting alloys and on electronics items
Alcoholic phosphoric acid wash	Same as above
Caustic etch	Electronics items only

TABLE XII. Surface treatments for steel.

Type	Most Common Usage
Phosphate (heavy)	Guns, some engine parts
Phosphate (paint base)	Noncritical steel parts, ground equipment
Phosphate (oiled)	Engine parts, guns, internal working surfaces where plating is impractical or undesirable
Black oxide	Parts continuously coated with oil

and most insects is obtained by the use of wood preservatives which make wood unpalatable or uninhabitable to wood-destroying organisms. Some of these substances are poisonous to the attacking organisms, while some are repellents. Still others form a physical barrier that prevents the organism from entering the wood or depositing eggs in its pores in the case of certain insects. Wood preservatives may make use of oil or water. Oil-borne preservatives are not washed away or leached out by water and, as a result, they make the wood moisture-repellent. The primary advantage of waterborne preservatives is that the water vehicle for the chemical substance is low cost. Table XIV lists various wood preservatives.

5.2.2.2 Insects. Wood in contact with the ground is subject to attack by many insects, particularly termites and powder-post beetles. Wood supported above the ground and kept dry is also subject to attack by these insects, although to a much lesser degree.

TABLE XIII. Heartwood decay resistance of some woods common in the United States.

Good(1)	Fair(1)	Poor(1)
Bald cypress	Douglas fir	Ashes(2)
Catalpas	Honey-locust(2)	Aspens
Cedars	Larch, western	Basswood
Chestnut	Oak, chestnut	Beech(2)
Junipers	Oak, white	Birches(2)
Locust, black	Pine, eastern white	Cottonwood
Mesquite	Pine, southern yellow	Firs (true)
Mulberry, red	Sassafras	Hemlocks(2)
Osage-orange		Maple, sugar(2)
Redwood		Oak, northern red(2)
Walnut, black		Spruces(2)
Yew, Pacific		Willows

Notes:
(1) The species in each group are listed alphabetically, since it is impractical to list them in order of relative decay resistance.
(2) These species may rate nearly as high in decay resistance as some of those in the next better group.

TABLE XIV. Wood preservatives.

Oil-Borne	Water-Borne
Coal-tar Creosotes	Cupric Chromate ("Celcure")
Creosote-coal Tar Solution	Chemonite
Croesote-petroleum Solution	Chromated Zinc Chloride
Wood-tar Creosote	"Wolman" Salt Tanalith
Lignite-tar Oil	Zinc Chloride
Copper Naphthalate	Zinc Metaarsenite
Pentachlorophenel	"Greensalt"
Zinc Naphthalate	"Erdalith"
	"Boliden Salt"
	"Minalith"
	"Pyresote"
	CZC (FR)

In this case, the subterranean termites have to build tubes up from the soil to reach the wood. Insect damage to crates supported above the ground is due primarily to powder-post beetles and dry-wood termites. The wood preservatives used to protect against microorganisms are also effective in combating insect infestation by coating the surface of the wood with an oil or paint film that will prevent the deposition of eggs in the wood pores.

5.2.2.3 Physical agents. Abrasion, weathering, and high temperatures all cause deterioration of wood products. Abrasion usually occurs during shipment and handling. Little can be done to combat this other than choosing a hard, abrasion-resistant wood, and reinforcing at the points where excess wear occurs. Long exposure to high temperatures causes gradual loss of strength with the rate of loss increasing with the temperature. Similar results occur when unfinished wood is exposed to the weather for an extended period of time. Alternate periods of rainfall and hot, dry weather produce cracks, splits, and general erosion of wood, eventually resulting in severe loss of structural properties. In extreme conditions where long life must be assured, wood products should be protected from the elements. Generally, this is of concern in reusable containers.

5.2.2.4 Chemical action. Wood products are readily destroyed by chemicals. The effects of various chemicals on some common woods are given in table XV. Where economics of the situation warrant, resistant wood should be selected for shipping containers that may be subjected to these conditions.

5.2.3 Deterioration of paper products. Paper products are often wood derivatives, hence they are subject to many of the deteriorating agents affecting wood.

5.2.3.1 Moisture. Moisture in the form of water or water vapor can cause deterioration of paper in two principal ways. When ordinary paper becomes wet, it loses its structural strength and falls to shreds because the moisture dissolves or softens the gelatinous binder intended to hold the fibers together. However, wet-strength papers are available to overcome this problem. An indirect but important effect of moisture on paper is to make the paper habitable for the growth of microorganisms, which results in decay.

5.2.3.2 Microorganisms. Under conditions of moisture and warmth, microbiological attack of paper, paperboard, and fiberboard deserves serious attention. Mildew, bacteria, and fungi are the chief offenders. Some microorganisms merely deface or

TABLE XV. Condition of woods after immersion in chemical solutions.

		Fir	Oak	Yellow Pine	Oregon Pine	Spruce	Redwood	Maple	Cypress
After 31 Days Immersion in Cold Solutions (examined after 7 days drying).*									
Hydrochloric acid	5%	NAC	NAC	NAC	SS	SS	SS	NAC	NAC
	10%	NAC	NAC	NAC	SS	SS	SS	NAC	NAC
	50%	SS,SB,SWF	SS,WF	S,WF	S,WF	S,WF	S,WF	S,WF	S,WF
Sulfuric acid	1%	NAC	NAC	NAC	SS	SS	NAC	NAC	SS,SB
	5%	SS	SS	SS	SS	SS,SB	SS,SB	NAC	SS,SB
	10%	S,FSD	S,FSD	S,FSD	S,FSD	S,FSD	S,FSD	S,FSD	S,FSD
	25%	SSp,FSD	SSp,FSD	SSp,FSD	SSp,FSD	SSp,FSD	SSp,FSD	SSp,FSD	SSp,FSD
Caustic soda	5%	S,NAC	MSh,SWp	SS	SS,FSD	SSp,FSD	SSp,FSD	MSh	SSp,FSD
	10%	S,FSD	MSh,WF	SS	SS,SB,FSD	SS,SB,FSD	SS,SB,FSD	MSh	S;SB,FSD
Alum	13%	NAC	NAC	NAC	NAC	NAC	NAC	NAC	NAC
Sodium carbonate	10%	S,GC	NAC	GC	SB,GC	SB,GC	SB,GC	GC	SB,GC
Calcium chloride	25%	NAC	NAC	NAC	NAC	NAC	NAC	NAC	NAC
Common salt	25%	NAC	NAC	NAC	SS,GC	SS,GC	SB,GC	NAC	NAC
Water		NAC	NAC	NAC	NAC	NAC	NAC	NAC	NAC
Sodium sulfide		SS,SB	MSh,WF	SB	SB	SB	SB	MSh,FSD	FSD
After 8 Hours in Boiling Solutions (examined after 7 days drying).*									
Hydrochloric acid	10%	SB,S	FSD	FSD	FSD	FSD	FSD	FSD	FSD
	50%	FD,Ch,B,S, NG	FS,Ch,B,S, NG	FD,Ch,B,S,NG	FD,Ch,B,S,NG	FD,Ch,B,S, NG	FD,Ch,B,S, NG	FD,Ch,B, S,NG	FD,Ch,B, S,NG
Sulfuric acid	4%	SB,GC	SB,GC	SB,GC	SB,GC	SB,GC	SB,GC	SB,GC	SB,GC
	5%	SS,GC	SB,GC	SB,GC	SB,GC	SB,FSD	SB,GC	SB,GC	SB,FSD
	10%	SS,GC	B,FD,Wpd,NG	Sp,FD,NG	B,Sp,FD,NG	B,Sp,FD,NG	SB,FSD	SB,FSD	B,FD
Caustic soda	5%	SS	MSh	S	GC	S,GC	S,GC	Sh	SSp
Alum	13%	SB,GC	NAC	NAC	SB,GC	SB,GC	SB,GC	NAC	SB,GC
Sodium carbonate	10%	SB,GC	GC	GC	GC	GC	GC	GC	SB,GC
Calcium chloride	25%	SB,GC	SB,SS,GC	NAC	SB,GC	SB,GC	NAC	NAC	SB,GC
Common salt	25%	NAC	NAC	NAC	SB,GC	NAC	SB,GC	NAC	NAC
Water		NAC	NAC	NAC	SB, GC	NAC	NAC	NAC	NAC

*Note:
The condition of eight varieties of wood used for tanks and other chemical-resistant uses is based on a report of James K. Stewart, consulting chemist to the Mountain Copper Co., Martinez, California. Tests were conducted on samples 1 x 4 x 1/4 in. in size, seasoned and chosen to be nearly as possible in the same physical condition as woods would be when used for equipment construction. Results of the tests are described by terms explained in abbreviation keys which follow:

B - Brittle
Ch - Charred
FD - Fiber Disintegrated
FSD - Fiber Slightly Disintegrated
GC - Good Condition
MSh - Much Shrunk
NAC - No Apparent Change
NG - No Good
S - Softer
SB - Slightly Brittle
Sh - Shrunk
Sp - Spongy
SS - Slightly Softer
SSp - Slightly Spongy
SWF - Slightly Weakened Fiber
SWp - Slightly Warped
WF - Weakened Fiber
Wpd - Warped

stain paper, but serious damage occurs when the cellulose content of paper is consumed. This can completely destroy the paper. Treatment of the paper with fungicides and mold-inhibiting solutions is the accepted preventive measure. Compounds used for treating paper are listed in table XVI.

5.2.3.3 <u>Insects</u>. Insects damage paper because they use it as food. Termites consume paper for its prime structural component, cellulose, whereas silverfish destroy paper by eating the starchy material, such as glue and sizing. Cockroaches feed on many materials, particularly book bindings. The cellulose-eating insects (termites and cockroaches) will attack sheet paper, pasteboard, composition board, fiberboard, labels, paper boxes, insulating paper, and tar paper. The time required for these insects to penetrate various materials is given in table XVII. Insecticides incorporated into the packaging material and sprayed or baited around storage areas are an effective means of controlling insect and rodent damage. Substances used for this purpose are listed in tables XVIII and XIX. The insecticides and repellents listed here are but a sampling of many kinds available for use today.

5.2.3.4 <u>Rodents</u>. Rodents damage paper products while gnawing in their search for food. Inasmuch as the paper particles are not swallowed, toxic agents are useless. The most effective preventive has been setting out poisoned bait. Table XX lists several effective baits. Attempts at impregnating materials with a repellent substance and making them impervious to gnawing have met with fair success, but the only highly effective repellent, actidione, is both expensive and highly toxic to man. Table XXI describes the habits and locales of several rodents.

5.2.3.5 <u>Sunlight</u>. Continued exposure to sunlight causes deterioration of cellulose, the main structural component of paper. The rate and severity of deterioration are dependent upon the kind of cellulose used in the paper and the impurities present therein. As far as paper used for packaging material is concerned, however, deterioration by sunlight is a minor problem.

5.2.3.6 <u>High temperatures</u>. Heat alone can weaken paper by altering its chemical structure but the main role of heat under normal circumstances is that of a catalyst in decay caused by microorganisms and moisture.

5.2.3.7 <u>Chemicals</u>. Most chemical deterioration of paper is due to the sulfur dioxide gas present in industrial atmospheres (see 5.2.1.2.2). The acids formed from sulfur dioxide attack the gel-like portion of the fibers but have a minor effect on the cellulose content. Deterioration varies according to the type of paper. Rag ledger paper and highly purified wood-fiber bond papers are least affected.

TABLE XVI. Treatment for microorganisms.

Treating Method or Compound Used	Treating Method or Compound Used
Acetone	Mercuric chloride
Acetylation	Mercuric salicylate
Asphalt	Mercurophen
Benzoates	2,2'-Methylenebis (4-chlorophenol)
Benzoic acid, solium-o-ethylmercuri mercapto	Microcrystalline wax
Betanaphthol	p-Nitrophenol
Bismuth benzoate	Paraffin
Borates	Pentachlorophenol or its sodium salt
Boric acid	Phenylmercury acetate
Bromobenzene, mono	Phenylmercury acetate plus calcium carbonate
Bromoform	Phenlymercury acetoxy octadecanoic acid
Calcium propionate	Phenylmercury oleate
Carbon disulfide	Phenylmercury saccharinate
Choloramine-T	o-Phenylphenol
Chlorobenzene, mono	Phenyl salicylate
Chlorocarvacrol	Polyester treatment
Choloroform	Quinoline, 8-hydroxy
Choloronaphthalene	Salicylanilide
Cholorphenol salts	Salicylic Acid
Chlorothymol	Silico fluoride, sodium
Chloroxylenols	Styrene
Copper naphthenate	Tetrachloroethane
Copper oleate	Tetrachlorophenol, sodium salt
Copper-8-quinolinolate	Toluol
Copper resinate	Tribromonaphthol
Copper sulfate	Trichlorophenol
m-Cresol, p-chloro-	Vinyl treatment
o-Cresol	Xylol
Cresote with copper oleate	Zinc chloride
Cuprammonium process	Zinc dimethyldithiocarbamate
Dichlorodimethyl succinate	Zinc naphthenate
Formaldehyde	Zinc oleate
GR-S rubber	Zinc resinate
Hexylresorcinol	Zinc sulfate
Hydrogen sulfide	
Mercuric benzoate	

TABLE XVII. Time required by certain insects to penetrate various papers and other bag materials.

Material (1)	Common Dampwood Termites	Nevada Dampwood Termites
Toweling	3-1/2 hours	3 hours
Asphalt bagging	7 days	8 days
Cellophane No. 300	4 days	5 days
50-lb kraft paper	1 day	1 day
50-lb kraft paper plus 50% sodium silicate solution	5 days	6 days
3/0 flint sandpaper (2)	more than 35 days	more than 35 days
3/0 flint sandpaper (3)	14 days	14 days
Cellophane No. 300 on 0.0006-in. lead foil (4)	more than 35 days	more than 35 days
No. 30 sulfite paper on 0.00035-in. lead foil (5)	10 days	10 days
0.00035-in. lead foil on No. 30 sulfite paper (6)	more than 35 days	more than 35 days

Notes: (1) Thickness, 0.0088 in.
(2) Rough side up
(3) Smooth side up
(4) Foil side up
(5) Paper side up
(6) Foil side up

TABLE XVIII. Insecticides.

Compound	Effective Against
Pyrethrum	All
Rotenone	All
DDT	Roaches, silverfish
Chlordane	All
Methoxychlor	(EPA use restricted)
Pentachlorophenol	Roaches, termites, firebrats
Tar derivatives	Drywood termites
Kerosene oil	Silverfish
Benezene hexachloride	Drywood termites
Heptachlor	Powder post and bark beetles
Dieldrin	All
Diazinon	Silverfish, firebrats
Dichlorvos	All

TABLE XIX. Repellents.

Compound	Effective Against
Thiocoumarin	Termites
Hexachlorocyclohexane	Termites
DDT	Termites
3,5-dinitro-o-cresol	Termites
Phenothiazine-3, 5-dinitro-o-cresylate	Termites
Phenothiazine	Termites
3,5-dinitro-o-cryslate	Termites
Lindane	Termites
Arason 75 (thiram)	Rodent
TNB-A (chemical)	Rodent
Improved Z.I.P. (ZAC)	Rodent
Diahacinona-paraffin	Rodent

TABLE XX. Toxic rodent baits.

Substance	Effectiveness
Warfarin	High
Sodium Fluoroacetate	High
Thallium Sulfate	Good
Red Squill	Good
ANTU	Good
Zinc Phosphide	Good
Strychnine	High
Endrin	High

TABLE XXI. Common types of small rodents.

Type	Range	Habits
Norway rat	Universal distribution throughout the world	Burrowing rodent; lives close to man; omnivorous
Roof rat	Warm climates, particularly along seacoast and rivers throughout the world	Adept climber, lives in trees and upper portions of buildings; prefers fruits and vegetables
House mouse	Universal distribution throughout the world	Capable of adaption to wide variety of conditions; lives close to man; almost omnivorous
Wood rat	Mountainous regions of eastern and western North America and Gulf States	Frequents cabins and camps; prefers green vegetation; seldom destructive
Field mouse	Universal throughout grassland areas of the world	Inhabits meadows and semi-swampy grassy areas; constructs distinct trails; feeds on green vegetation and tree roots
Woodland mouse	Practically all North America; similar forms in other countries	Lives in semiwooded areas; primarily a seed eater
Ground squirrel	Present in semiopen areas of western North America and other countries	Burrowing rodent; food includes grains, green vegetation, and insects

5.2.4 Deterioration of plastics. The wide variety of plastics makes it possible to choose a plastic material that is not affected by the particular environment conditions which it encounters. In general, most plastics have good resistance to corrosion and chemical action. Table XXII lists various plastics and their resistance to heat, acids and alkalis, organic solvents, and sunlight. The physical properties of plastics will be influenced by such factors as the manufacturing process and the reinforcements or fillers used.

5.2.4.1 Chemicals. Chemical deterioration of plastics results in loss of strength, erosion, warpage, cracking, and loss of transparency. Most physical changes are caused by loss of plasticizer. The resistance of several plastics to generalized classes of chemicals is given in table XXIII. The effects of specific chemical solutions upon plastics are detailed in table XXIV. Table XXV illustrates the relatively high resistance of acrylic plastics to various chemical solutions.

5.2.4.2 Microorganisms. A few plastics are susceptible to microbiological attack, although the deterioration rarely proceeds further than the surface. Table XXIV lists the relative resistance of several plastics to microorganisms.

5.2.4.3 Low temperatures. At typical arctic temperatures (-30° to -50° F.) (-34° to -46° C.), there are quite a few varieties of plastics that remain fairly flexible and retain their toughness. For example, in the ethylene polymer group, polyethylene is tough and durable. Its toughness is not seriously affected by low temperature. It remains fairly flexible but begins to stiffen slightly at -30° F. (-34° C.) and becomes brittle at -94° F. (-70° C.). Teflon and many other thermoplastics also maintain satisfactory pliability at low temperatures.

5.2.5 Deterioration of rubber. Rubber is subject to deterioration by a variety of chemical, biological, and physical agents often working in concert with each other. The generalized effects of some deleterious agents are shown in table XXVII. Detailed discussion of their effects are given below.

TABLE XXII. Deterioration resistance of plastics and rubbers.

Material	Water Abs, % (24 hr, on sample 1/8 in. thick)	Heat, °F. continuous	Resistance to(1)		
			Acids and Alkalis	Organic Solvents	Sunlight
Phenol-formaldehyde resin cast (no filler)	0.3-0.4	160	F	G	VG
Phenol-formaldehyde resin molded (woodflour filler)	0.3-1.0	300-350	F	E	VG
Phenol-formaldehyde resin molded (mineral filler)	0.01-0.3	230-450	F	E	VG
Phenol-furfural resin (woodflour filler)	0.2-0.6	300	F	E	VG
Phenol-furfural resin (mineral filler)	0.2-1.0	350-400	F	E	VG
Urea-formaldehyde resin (cellulose filler)	0.4-0.8	170	F	VG	E
Melamine-formaldehyde resin (cellulose filler)	0.1-0.6	210-250	G	E	VG
Melamine-formaldehyde resin (asbestos filler)	0.08-0.14	250-400	G	E	VG
Aniline-formaldehyde resin	0.01-0.08	180-190	F	VG	VG
Glyceryl phthalate (alkyd)	--	250	G	G	VG
Silicone rubber (mineral filler)	0.25-1.0	350	VG	VG	E
Ethyl cellulose	0.8-1.8	115-185	VG	widely soluble	VG
Cellulose acetate (molding)	1.9-6.5	140-220	F	widely soluble	VG
Cellulose acetate (high acetyl)	2.2-3.1	150-220	F	widely soluble	VG
Cellulose acetate-butyrate	1.1-2.2	140-220	F	widely soluble	VG
Cellulose nitrate	1.0-2.0	ca. 140	F	widely soluble	VG
Casein plastics	7-14	275	P	E	VG

TABLE XXII. Deterioration resistance of plastics and rubbers. - Continued

Material	Water Abs,% (24 hr, on sample 1/8 in. thick)	Heat, °F. continuous	Resistance to(1)		
			Acids and Alkalis	Organic Solvents	Sunlight
Shellac compound	--	150-190	VP	G	E
Cold-molded plastics	0.6-0.2	500	F	G	E
Polyvinyl chloride-acetate (rigid)	0.07-0.08	130	E	F	VG(2)
Polyvinyl chloride-acetate (flexible)	0.40-0.65	150	VG	F	VG(2)
Polyvinyl chloride (plasticized)	0.1-0.6	150-175	VG	F	VG(2)
Polyvinylidene chloride (molding)	<0.1	160-200	E	E	VG(2)
Polyvinyl formal	0.6-1.3		G	G	VG(2)
Polyvinyl butyral (rigid)	1.0-3.0	115	G	F	VG(2)
Polyvinyl butyral (flexible)	1.0-2.0		G	G	VG(2)
Polyvinyl carbazole	0.1		G	F	VG(2)
Allyl resins (cast)	03-0.44	212	VG	E	VG
Polyester resins (rigid)	0.15-0.60	250	VG	VG	VG
Polyester resins (flexible)	0.1-2.4	250	VG	VG	VG
Polymethyl methacrylate (cast)	0.3-0.4	140-160	VG	F	VG
Polymethyl methacrylate (molded)	0.3-0.4	155-185	VG	F	VG
Polystyrene	0.03-0.05	150-205	G	F	VG
Polyethylene	<0.01	212	E	VG	VG(2)
Polytetraflouroethylene	0.00	400	E	E	E

TABLE XXII. Deterioration resistance of plastics and rubbers. - Continued

Material	Water Abs,% (24 hr, on sample 1/8 in. thick)	Heat, °F. continuous	Resistance to(1)		
			Acids and Alkalis	Organic Solvents	Sunlight
Nylon (molded)	1.5	300	F	E	VG
Butadiene-styrene		250-300	VG	G	VG
Butadiene-acrylonitrile		250-300	VG	VG	VG
Polyacrylic ester		250-350	VG	G	VG
Poysulfide		200-300		E	VG
Isobutylene-isoprene			E	VG	E

Notes:

(1) Code: P = Very poor, P = Poor, F = Fair, G = Good, VG = Very good, E = Excellent.

(2) These compounds exhibit this degree of sunlight resistance when they are protected with the proper stabilizers.

TABLE XXIII. Average properties of some plastic materials.

Material	Resistance to Weak Mineral Acids	Strong Mineral Acids	Oxidizing Acids	Weak Alkalis	Strong Alkalis	Organic Solvents	Weathering
Acrylic acid resins	G	G	P	G	G-F	P	F
Casein	F	P	P	P	P	F	P
Cellulose acetate	F	P	P	F	P	P	F
Cellulose acetate butyrate	F	P	P	F	P	P	F
Cellulose nitrate (pyroxylin)	F	P	P	F	P	P	P
Ethyl cellulose	F	P	P	G	F	P	F
Phenolics, cast, electrical, and mechanical grades	F	F	F-P	P	P	F	F
Phenolics, laminated, paper-base	G	F	F	P	P	F-G	F
Phenolics, molded, fabric-filled	G	G	P	F	P	G	F
Phenolics, molded, mineral-filled	G	G	P	F	P	G	F
Phenolics, molded, woodflour-filled	F	P	P	P	P	G	F
Styrene resins	G	F	P	G	G	F-P	F
Urea resins	F	P	P	F	P	F	F
Vinyl resins	G	G	F	G	G	F-P	F-P
Vinylidene chloride resins	G	G-F	F	G	F	F-P	G-F

Chemical Properties: P = Poor, F = Fair, G = Good.

TABLE XXIV. Effect on plastics by immersion for 7 days in chemical reagents at 25° C.

Item	Urea-Formaldehyde Laminated	Vinyl Chloride-Acetate Resin	Vinyl Butyral Resin	Methyl Metha-crylate Resin	Styrene Resin Molded
30% Sulfuric acid	Surface attacked	None	None	None	None
3% Sulfuric acid	Surface attacked	None	Cloudy	None	None
10% Nitric acid	Delaminated	None	Cloudy	None	None
10% Hydrochloric acid	Delaminated	None	Cloudy	None	None
5% Acetic acid	None	None	Cloudy	None	None
Oleic acid	None	None	Tacky	None	None
10% Sodium hydroxide	Surface attacked	None	None	None	None
1% Sodium hydroxide	None	None	Slightly cloudy	None	None
10% Ammonium	None	None	Opaque	None	Discol-ored
2% Sodium carbonate	None	None	Slightly cloudy	None	None
10% Sodium chloride	None	None	None	None	None
3% Hydrogen peroxide	Delaminated	None	Cloudy	None	None
Distilled water	None	None	Cloudy	None	None
50% Ethyl alcohol	None	None	Swollen; rubbery	Slightly swollen	None
95% Ethyl alcohol	None	None	Dissolv-ed	Surface attacked	None
Acetone	None	Dissolved	Swollen; opaque	Dissolved	Dissolved
Ethyl acetate	None	Decomposed	Decom-posed	Dissolved	Dissolved
Ethylene chloride	None	Dissolved	Decom-posed	Dissolved	Dissolved
Carbon tetrachloride	None	None	Swollen; rubbery	Surface attacked	Dissolved
Toluene	None	Soft, rubbery	Swollen; rubbery	Dissolved	Dissolved
Gasoline	None	None	None	None	Partly dissolved

TABLE XXIV. Effect on plastics by immersion for 7 days in chemical reagents at 25° C. - Continued

Item	Cellulose Nitrate	Cellulose Acetate	Ethyl Cellulose No. 1	Cold-Molded Phenolic	Casein Plastic
3% Sulfuric acid	None	softened Swollen	None	None	Swollen; rubbery
10% Nitric acid	None	Decomposed	None	None	Swollen; cracked
10% Hydrochloric acid	None	Decomposed	None	Cracked on drying	Swollen; cracked
5% Acetic acid	None	Swollen	None	None	Rubbery; split
Oleic acid	None	None	Decom-posed	None	None
10% Sodium hydroxide	Crazed	Decomposed	None	Decomposed	Decom-posed
1% Sodium hydroxide	Crazed	Surface attacked	None	Decomposed	Broken up
10% Ammonium hydroxide	Crazed; discol-ored	Opaque; soft	None	None	Swollen; split
2% Sodium carbonate	None	Swollen	None	None	Swollen; rubbery
10% Sodium chloride	None	None	None	None	None
3% Hydrogen peroxide	None	None	None	None	Swollen; rubbery
Distilled water	None	None	None	None	Swollen; rubbery
50% Ethyl alcohol	None	Partly dissolved	Swollen; cracked	None	Swollen; rubbery
95% Ethyl alcohol	Dissolved	Partly dissolved	Dissolved	None	None
Acetone	Dissolved	Dissolved	Dissolved	None	None
Ethyl acetate	Dissolved	Dissolved	Dissolved	None	None
Ethylene chloride	Partly dissolved	Soft; swollen	Dissolved	None	None
Carbon tetrachloride	None	None	Dissolved	None	None
Toluene	Partly dissolved	None	Dissolved	None	None
Gasoline	None	None	Swollen; cracked	None	None

TABLE XXIV. Effect on plastics by immersion for 7 days in chemical reagents at 25° C. - Continued

Item	Phenol-Formaldehyde Molded	Phenol-Formaldehyde Cast	Phenol-Formaldehyde Laminated	Urea-Formaldehyde Molded
30% Sulfuric acid	Surface roughened	None	Edges swollen	Surface roughened
3% Sulfuric acid	Surface roughened	None	Edges swollen	Surface roughened
10% Nitric acid	Surface roughened	None	Edges swollen	Surface roughened
10% Hydrochloric acid	Surface roughened	None	Edges swollen	Surface roughened
5% Acetic acid	None	None	Edges swollen	None
Oleic acid	None	None	None	None
10% Sodium hydroxide	Decomposed	Decomposed	Delaminated	None
1% Sodium hydroxide	Surface roughened	Decomposed	Edges swollen	None
10% Ammonium hydroxide	Surface dulled	Discolored	Discolored edges swollen	None
2% Sodium carbonate	None	Discolored	Discolored	None
10% Sodium chloride	None	None	Edges swollen	None
3% Hydrogen peroxide	None	Discolored	None	Surface dulled
Distilled water	None	None	None	None
50% Ethyl alcohol	None	None	None	None
95% Ethyl alcohol	None	None	None	None
Acetone	None	Softened	Blistered	None
Ethyl acetate	None	None	None	None
Ethylene chloride	None	None	None	None
Carbon tetrachloride	None	None	None	None
Toluene	None	None	None	None
Gasoline	None	None	None	None

TABLE XXV. Effect of total immersion on acrylic plastics.

Solution(2)	% Wt Gain(3)
30% Sulfuric acid	0.6
3% Sulfuric acid	1.0
10% Hydrochloric acid	0.7
10% Sodium hydroxide	0.8
1% Sodium hydroxide	1.0
10% Nitric acid	0.9
5% Acetic acid	1.0
2% Sodium carbonate	1.0
10% Sodium chloride	0.9
10% Ammonium hydroxide	0.9
3% Hydrogen peroxide	1.0
100% Distilled water	0.9

Notes: (1) Approved tests of the Committee on Plastics of the American Society for Testing and Materials using pieces of material 1 x 3 x 0.125 in. totally immersed in the various chemical solutions for 192 hours 25° C. Data supplied for Plexiglas by Rohm and Haas Co., Philadelphia, Pa.

(2) All concentrations given in percentage by weight in distilled water.

(3) A gain in weight of 1% or less is considered negligible except in unusual applications. None of the above solutions appreciably affects the appearance or strength characteristics.

TABLE XXVI. Resistance of plastics to attack by microorganisms.

Material	Resistance
Acrylics	
Polymethylmethacrylate	Good
Polyacrylonitrile ("Orlon")	Good
Acrylonitrile-vinyl chloride copolymer ("Dynel")	Good
Cellulose derivatives	
Cellulose acetate(1)	Good, poor
Cellulose acetate-butyrate	Good
Cellulose acetate-propionate	Good
Cellulose nitrate	Poor
Ethyl cellulose	Good
Rayons	
Acetate rayon ("Estron")	Good
Saponified acetate rayon	Slightly more resistant than cotton
Cuprammonium rayon	Poor
Viscose rayon	Poor
Phenol-formaldehydes	
Phenol-formaldehyde(2)	Good
Phenol-aniline-formaldehyde	Poor
Resorcinol-formaldehyde	Good
Melamine-formaldehydes	
Melamine-formaldehyde(3)	Good, poor
Urea-formaldehydes	
Urea-formaldehyde(3)	Good
Protein-formaldehydes	
Zein-formaldehyde ("Vicara")	Good
Casein-formaldehyde	Poor
Polyamides	
Nylon(4)	Good
Polyesters	
Ethylene glycol terephthalate ("Terylene") ("Fiber V")	Good
Polyethylenes	
Polyethylene(5)	Good

TABLE XXVI. Resistance of plastics to attack by microganisms. - Continued

Material	Resistance
Polytetrafluoroethylene ("Teflon")	Good
Polymonochlorotrifluoroethylene	Good
Polyisobutylene	Good
Styrenes	
Polystyrene	Good
Polydichlorostyrene	Good
Vinyls and vinylidenes	
Polyvinyl chloride	Good
Polyvinyl acetate	Poor
Polyvinyl chloride-acetate	Good
Polyvinylidene chloride	Good
Polyvinyl butyral	Good
Glyptal resins (Alkyd resins)	Poor, moderate
Silicone resins	Good

Notes:

(1) Fully acetylated cotton is resistant, but there are acetylated cottons in which the percentage of acetate is not high enough to impart complete resistance.

(2) Some cases are on record in which phenol-formaldehydes have been listed as poor. This difference in opinion probably arises from testing samples containing susceptible fillers since the resin itself is considered as having rather good fungus resistance.

(3) White and Siu, in tests on cotton fabrics impregnated with urea-formaldehyde and melamine-formaldehyde resins, found that a high degree of fungal resistance was imparted to the cotton by the resins. It was not conclusively shown, however, whether the resistance was due to the resins as such or to the possible presence of free formaldehyde.

(4) Some tests have indicated nylon to be attacked in soil burial, but most evidence shows it to be immune.

(5) Klemme and Watkins in 1950 reported that the susceptibility of polyethylene and polyisobutylene resins to fungus growth decreases as the average molecular weight increases. Ethylene materials of molecular weights above 10,000, and a butylene sample of 100,000 mw, were found to be fairly resistant. Polytrifluorochloroethylene ("Kel-F") shows a nutritive inertness comparable to the high-molecular-weight polyethylene.

TABLE XXVII. Physical properties of synthetic and natural rubbers.

Material	Effect of Heat	Abrasion Resistance	Effect of Sunlight (under tension)	Effect of Aging
Chemigum, oil-resistant	Stiffens	Excellent	Equal to rubber	Stiffens
Chemigum, tire	Stiffens	Good	None	Better than rubber
GR-I (Butyl)	Stiffens slightly	Excellent	None	Highly resistant
GR-M (Neoprene)	Stiffens slightly	Excellent	None	Highly resistant
GR-N (Perbunan)	Stiffens	Excellent	Slight	Highly resistant
GR-P (Thiokol FA)	Hardens slightly	Fairly good	None	None
GR-P (Thiokol ST)	Hardens slightly	Good	None	None
GR-S (Buna S), hard	--	--	--	Highly resistant
GR-S (Buna S), soft	Stiffens	Excellent	Deteriorates	Highly resistant
Hycar OR-15, soft	Stiffens	Excellent	Slightly better than natural rubber	Highly resistant
Hycar OR-25, soft	Stiffens	Excellent	Slightly better than natural rubber	Highly resistant
Hycar OR-15, hard	--	--	--	Highly resistant
Hycar OR-10, soft	Stiffens	Excellent	Deteriorates	Highly resistant
Koroseal, soft	Softens	Good	None	Highly resistant
Koroseal, hard	Softens	Excellent	None	Highly resistant
Pliolite, No. 40	Softens	--	None	None
Resistoflex	Softens	Good	None	None
Tygon T	Softens	Good	None	--
Vistanex, medium	--	--	None	Better than rubber
Vistanex, high	--	--	None	Better than rubber
Natural rubber, hard	--	--	--	Highly resistant
Natural rubber, soft	Softens	Excellent	Deteriorates	Moderately resistant

5.2.5.1 Chemicals. The most serious deterioration in rubber is caused by the ozone present in the atmosphere. Ozone causes rubber to become brittle, and may produce fissures over its surface. The severity of attack varies greatly according to the type of rubber. Oxygen has similar effects but they are subordinate in importance to those caused by ozone. Neoprene, butyl, Thiokol, silicone, Hypalon, and polyacrylate rubbers are more resistant to ozone than polymers based on butadiene or isoprene such as GR-S, nitrile rubber, or natural rubbers. Natural rubbers swell when in contact with liquid hydrocarbons such as oil, gasoline, and benzene. Disintegration and aging occur from prolonged contact. Several synthetic rubbers have been developed which are oil resistant. These products are substituted for natural rubbers when contact with oil or chemicals is expected. Neoprene, Thiokol, butadiene-acrylonitrile vulcanizates, some polyacrylic ester compounds, and chlorinated rubber are often used for these purposes. Table XXVIII lists various rubber compounds and their chemical resistance.

5.2.5.2 Temperature effects. A number of changes take place in rubbers, particularly carbon-based types, under the influence of low temperatures. All of these changes are reversible, however, and the material recovers its original properties as temperatures return to normal. As the temperature is decreased, the rubber becomes more difficult to bend or stretch. Below a certain subzero temperature, this stiffness increases to a maximum, at which the rubber becomes brittle and will shatter under suddenly applied loads. Longtime exposure is sometimes accompanied by crystallization and the plasticizer-time effect. Crystallization results in an increase in stiffness but not necessarily in brittleness. The plasticizer-time effect results in a portion of the plasticizer being thrown out of solution, which may result in a loss of flexibility above the brittle temperature and also cause this temperature to be raised. The various commercial rubbers differ appreciably as to the temperature ranges in which they pass through these various stages. At high temperatures, both natural and synthetic rubbers become gummy, take on a permanent set, and decrease in tensile strength. The temperatures at which various types of rubber become unusable are shown in table XXIX.

5.2.5.3 Microorganisms. Certain rubber compounds are susceptible to microbiological deterioration. The reaction is fairly slow, however, and requires an environment containing moisture and warmth.

TABLE XXVIII. Chemical resistance of natural rubber compounds.

Item	Concentration by Weight	Maximum Temperature °F.	Degree of Vulcanization	Design of Compound
Solutions of Inorganic Acids				
Arsenic acid	Any concentration	150	Soft	Specific
			Hard	General
Carbonic acid	Up to saturation at atmospheric pressure	150	Soft or hard	General
Chlorine water (hypochlorous acid)	Up to saturation at atmospheric pressure	100	Soft	Specific
		150	Hard	Specific
Fluoboric acid	Any concentration	150	Soft or hard	General
Fluosilicic acid	Any concentration	150	Soft or hard	General
Hydrobromic acid	Any concentration	100	Soft	Specific
		150	Hard	Specific
Hydrofluoric acid	Up to 50%	150	Soft or hard	General
Hydrogen sulfide water	Up to saturation at atmospheric pressure	150	Hard	General
Hydrochloric acid	Any concentration	150	Soft or hard	General
Phosphoric acid	Up to 85%	150	Soft	Specific
			Hard	General
Sulfuric acid	Up to 50%	150	Soft or hard	General
Sulfurous acid	Up to saturation at atmospheric pressure	150	Hard	Specific
Solutions of Inorganic Salts and Alkalis				
Aluminum chloride	Up to saturation	150	Soft or hard	General
Aluminum sulfate	Up to saturation	150	Soft or hard	General
Alums	Up to saturation	150	Soft or hard	General
Ammonium chloride	Up to saturation	150	Soft or hard	General
Ammonium hydroxide	Up to saturation	100	Hard	General

TABLE XXVIII. Chemical resistance of natural rubber compounds. - Continued

Item	Concentration by Weight	Maximum Temperature °F.	Degree of Vulcanization	Design of Compound
Solutions of Inorganic Salts and Alkalis				
Ammonium persulfate	Up to saturation	100	Soft	General
		150	Hard	General
Ammonium sulfate	Up to saturation	150	Soft or hard	General
Barium sulfide	Up to saturation	150	Soft or hard	General
Calcium bisulfite	Up to saturation	150	Hard	Specific
Calcium chloride	Up to saturation	150	Soft or hard	General
Calcium hypochlorite	Up to saturation	150	Soft	Specific
			Hard	General
Sodium hydroxide	Up to saturation	150	Soft or hard	General
Potassium hydroxide	Up to saturation	150	Soft or hard	General
Copper chloride (cupric)	Up to saturation	150	Hard	General
Copper cyanide (in solution with alkali cyanides)	Up to saturation	150	Soft or hard	General
Copper sulfate (cupric)	Up to saturation	150	Soft or hard	General
Ferric chloride	Up to saturation	150	Soft	Specific
			Hard	General
Ferrous sulfate ("copperas")	Up to saturation	150	Soft or hard	General
Nickel acetate	Up to saturation	150	Hard	Specific
Plating solutions: Brass, Cadmium, Copper, Gold, Lead, Nickel, Silver, Tin, Zinc	--	150	Soft or hard	General

TABLE XXVIII. Chemical resistance of natural rubber compounds. - Continued

Item	Concentration by Weight	Maximum Temperature °F.	Degree of Vulcanization	Design of Compound
Solutions of Inorganic Salts and Alkalis				
Potassium cuprocyanide	Up to saturation	150	Soft or hard	General
Potassium dichromate	Up to saturation	150	Hard	General
Sodium (or potassium) antimonate	Up to saturation	150	Soft or hard	General
Sodium (or potassium bisulfite	Up to saturation	150	Hard	General
Sodium (or potassium) acid sulfate	Up to saturation	150	Soft or hard	General
Sodium (or potassium chloride	Up to saturation	150	Soft or hard	General
Sodium (or potassium) cyanide	Up to saturation	150	Soft or hard	General
Sodium (or potassium) hypochlorite	Up to saturation	150	Soft Hard	Specific General
Sodium (or potassium) sulfide	Up to saturation	150	Soft or hard	General
Sodium (or potassium) sulfite	Up to saturation	150	Soft or hard	General
Sodium (or potassium) thiosulfate	Up to saturation	150	Soft or hard	General
Silver nitrate	Up to saturation	150	Soft	Specific*
Tin chloride (either stannous or stannic)	Any aqueous solution	150	Hard Soft or hard	General General
Zinc chloride	Up to saturation	150	Soft or hard	General
Zinc sulfate	Up to saturation	150	Soft or hard	General

*If discoloration is to be avoided.

TABLE XXVIII. Chemical resistance of natural rubber compounds. - Continued

Item	Concentration by Weight	Maximum Temperature °F.	Degree of Vulcanization	Design of Compound
Organic Materials				
Acetic acid	Any concentration	150	Hard	Specific
Acetic anhydride	--	150	Hard	Specific
Acetone	Any concentration	150	Soft	Specific
			Hard	General
Amyl alcohol	Any concentration	150	Soft	Specific
			Hard	General
Aniline hydrochloride	Any concentration	150	Soft or hard	General
Butyl alcohol	Any concentration	150	Soft	Specific
			Hard	General
Casein	Any concentration	150	Soft or hard	General
Castor oil	--	150	Hard	Specific
Citric acid	Up to saturation	150	Soft	Specific
Coconut oil	--	150	Hard	Specific
Cottonseed oil	--	150	Hard	Specific
Dyestuffs	--	150	Hard	Specific
Ethyl alcohol	Any concentration	150	Soft	Specific
			Hard	General
Ethylene glycol	Any concentration	150	Soft or hard	General
Formaldehyde (formalin)	40% aqueous solution	100	Hard	Specific
Formic acid	Any concentration	100	Hard	Specific
Furfural	--	100	Hard	Specific

TABLE XXVIII. Chemical resistance of natural rubber compounds. - Continued

Item	Concentration by Weight	Maximum Temperature °F.	Degree of Vulcanization	Design of Compound
Organic Materials				
Gallic acid	Up to saturation	150	Soft or hard	General
Glucose	Any concentration	150	Soft or hard	General
Glue	Any concentration	150	Soft or hard	General
Glycerin	Any concentration	150	Soft or hard	General
Lactic acid	Any concentration	150	Hard	Specific
Malic acid	Up to saturation	150	Soft or hard	Specific
Methyl alcohol	Any concentration	150	Soft	Specific
			Hard	General
Mineral oils	--	100	Hard	Specific
Propyl alcohol	Any concentration	150	Soft	Specific
			Hard	General
Soaps	Any concentration	150	Soft or hard	General
Tannic acid	Up to saturation	150	Soft or hard	General
Tartaric acid	Up to saturation	150	Soft	Specific
			Hard	General
Triethanolamine	Any concentration	150	Soft or hard	General
Vinegar	--	150	Hard	Specific

TABLE XXIX. Degradation of rubber by high temperatures.

Type of Rubber	Highest Usable Temperature, °F. (°C.)
Silicone	500 (260)
Polyacrylic	350 (177)
Buna-N	340 (171)
Neoprene	315 (157)
Butyl	300 (149)
Buna-S	280 (138)
Natural	260 (127)
Thiokol	250 (121)

5.2.5.4 Sunlight. Decomposition of rubber by sunlight is due mainly to the blue and ultraviolet wavelengths. These rays cause the rubber to liberate gases as the rubber decomposes. The surface of rubber undergoing solar deterioration exhibits resinification of the surface and an irregular pattern of very fine cracks. The effects of sunlight on various rubbers are included in table XXVII. Preventive measures include coloring the rubber to decrease the effect of the damaging wavelengths, application of plastic coatings to tire surfaces, and incorporation of antiozonants in initial rubber formulation. Storage in darkness, however, is the most effective measure.

5.2.6 Deterioration of textiles. Textiles are subject to deterioration by the principal forces of weather and biological agents. Textiles are particularly susceptible to destruction by microorganisms since the materials are usually of vegetable or animal origin, and, therefore, serve as food.

5.2.6.1 Microorganisms. Warmth and wetness facilitate the development of a flourishing and diversified collection of bacteria, molds, and fungi which destroy materials of vegetable or animal origin. Fabrics of cotton, linen, and some rayons are vigorously attacked. Microbiological deterioration causes odors, spotting, loss of water repellency, loss of strength, and a decrease in flexibility. The growth of microorganisms on textiles is invariably preceded by contact with soil or a moist, tropical environment. The standard preventive is to treat textiles with a fungicide. The fungicides most often employed are copper naphthalate, copper 8-quinolinolate, and 2,2'-methylenebia (4-chlorophenol). The last fungicide mentioned is widely used as Compound G-4.

5.2.6.2 Excessive drying. Generally, moisture is an active chemical and physical agent of deterioration. Ordinarily, the more severe the moisture conditions, the more rapid the degradative effect. But where deterioration of textiles is concerned, there is one peculiar feature worth noting. In a negative sense, moisture can contribute to the breakdown of some textiles by its very absence. As for most materials, there is some optimum moisture content for the maintenance of useful properties. Textiles that have lost their properties through lack of humidity can be returned to use if they are returned to the proper humidity.

5.2.6.3 Sunlight. Sunlight is responsible for most of the non-biological deterioration of textiles. The deterioration results from changes in the cellulose content of the textile fiber caused by solar radiation. Table XXX lists the effects of sunlight on various textile fibers. Certain dyestuffs reduce the deleterious effects of sunlight. Anthraquinone vat dyes and substantive azo dyes protect cotton, while Monostral Fast Blue protects woven cotton duck. Green, blue, and brown dyes generally retard solar deterioration, whereas orange and yellow dyes generally accelerate deterioration.

5.3 Methods of preservation.

5.3.1 Methods. Methods of preservation for military packaging as specified in MIL-P-116 are used as a convenient form for describing the various combinations of packaging operations involved prior to insertion of packed items into their shipping or intermediate containers. These operations include cleaning and drying (see 5.4), preservative selection and application (see 5.5), selection of greaseproof and cushioning wraps and barriers (see 5.6), and selection of containers (see 5.7). The basic methods of preservation (figure 16 and table XXXI) prescribed in MIL-P-116 are:

a. Method I: Preservative coating (with greaseproof wrap as required).

b. Method IA: Watervaporproof inclosure (with preservative as required).

c. Method IB: Strippable compound coating (hot or cold dip).

d. Method IC: Waterproof or waterproof greaseproof inclosure (with preservative as required).

TABLE XXX. Effect of sunlight on fibers.

Fiber	Type of Chemical	Reported Effect(a)	Reported Effect(b)	Reported Effect(c)
Cotton	Cellulosic	Loss of strength, tendency to yellow	Loss of tensile strength, tendency of white to yellow	--
Silk	Protein	--	Loss of tensile strength, affected more than cotton	--
Wool	Protein	Loss of strength, some effect on dyeing properties	Loss of tensile strength, dyeing affected, less affected than cotton	--
Viscose rayon	Regenerated cellulose	Loses tensile strength after prolonged exposure, very light discoloration	Loss of tensile strength	Loss of strength with direct exposure but superior to acetate
Cuprammonium rayon	Regenerated cellulose	Loses strength on prolonged exposure	Loss of tensile strength	--
Acetate	Cellulose acetate	Slight loss of tensile strength, no discoloration	Loss of tensile strength	Loss of strength with direct exposure
Nylon	Adipic acid and hexamethylene diamine	Loses strength on prolonged exposure, no discoloration, bright yarn more resistant than semi-dull	Some loss of tensile strength, no discoloration	Slow loss of strength with direct exposure
"Bobina-Perlon"	Caprolactam	--	--	Similar to nylon(1)
"Rhovyl"	Vinyl chloride	--	--	Not degraded(2)

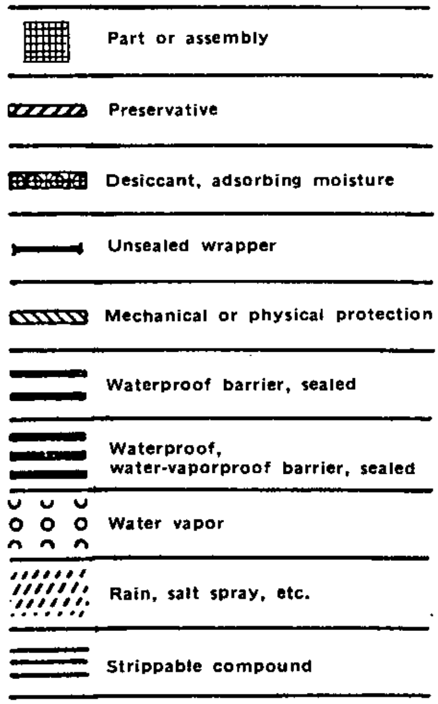
TABLE XXX. Effect of sunlight on fibers. - Continued

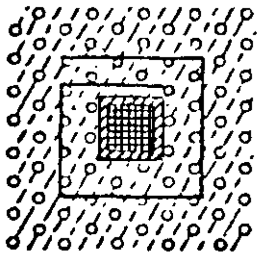
Fiber	Type of Chemical	Reported Effect(a)	Reported Effect(b)	Reported Effect(c)
"Thermovyl"	Vinyl chloride	--	--	Not degraded(2)
"Vinyon"	Vinyl chloride and vinyl acetate	None	None	Not degraded
"Saran"	Vinyl chloride and vinylidene chloride	Darkens slightly	Darkens slightly	--
"Velon"	Vinyl chloride and vinylidene chloride	--	Darkens slightly	--
"Tygan"	Vinyl chloride and vinylidene chloride	--	--	Not degraded(3)
"Dynel"	Vinyl chloride and acrylonitrile	Darkens somewhat after prolonged exposure with some loss of tensile strength	Some loss of tensile strength	Not degraded
"Vinyon N"	Vinyl chloride and acrylonitrile	Darkens somewhat after prolonged exposure with some loss of tensile strength	Darkens slightly, some loss of tensile strength	--
"Orlon"	Acrylonitrile	Very resistant to degradation by ultraviolet light and atmosphere	Very high resistance to sunlight deterioration	Not degraded
"Acrilan"	Acrylonitrile	Very resistant to degradation by ultraviolet light and atmosphere	--	--
"X-51"	Acrylic ester	--	--	Not degraded

TABLE XXX. Effect of sunlight on fibers. - Continued

Fiber	Type of Chemical	Reported Effect (a)	Reported Effect (b)	Reported Effect (c)
"Dacron"	Terephthalic acid and ethylene glycol	Loss of strength on prolonged exposure. No discoloration. Much more resistant behind glass than in direct sunlight	Some loss in strength. No discoloration. Much more resistant behind glass than in direct sunlight	--
"Terylene"	Terephthalic acid and ethylglycol	--	--	Very slow loss of strength with direct exposure
--	Poyethylene	Prolonged exposure decreases tensile strength	Some loss of tensile strength for clear, much less for pigmented; no darkening	
Polythene	Polyethylene	--	--	Very slight degradation(4)
"Azlon"	Protein	Very slow deterioration and loss of strength	--	--
"Vicara"	Protein	--	Slow deterioration and loss of strength	--
"Ardil"	Protein	--	--	Very slow loss of strength with direct exposure(5)
Glass	Inorganic	None	None	Not degraded
Asbestos, chrysotile	Inorganic	--	--	Not degraded

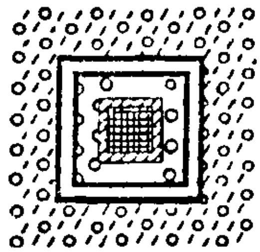
Notes:
(a) Textile World's Synthetic - Fiber Table, 1951.
(b) Modern Plastics Encyclopedia and Engineer's Handbook, 1952.
(c) The Rubber Age and Synthetics, May 1953.
(1) Also named "Rilsan," "Grillon," "Phrilon."
(2) Also named "Pe Ce," "Isovyl," "Fibrovyl."
(3) Also named "Lumite," "Parmalon," "Harlon."
(4) Also named "Courlene."
(5) Also named "Lanital."





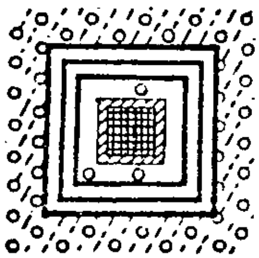
METHOD I

Preservative coating applied. Wrapper not sealed. Water as liquid or vapor and corrosive atmosphere has relatively free contact with the preserved part.



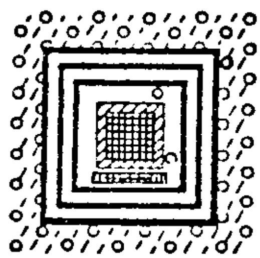
METHOD IC

Preservative coating applied. as required. Waterproof or water-resistant barrier sealed. Only water-vapor penetration to preserved part. Thermoformed packaging transparent vacuum formed.



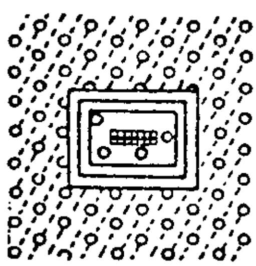
METHOD IA

Preservative coating applied as required. Water-vaporproof barrier sealed. Only traces of water-vapor penetration to part possible.



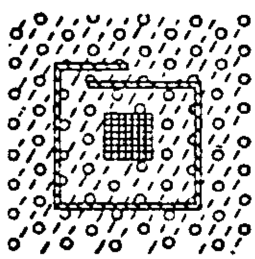
METHOD II

Preservative coating applied as required. Waterproof, water-vaporproof barrier sealed. Only traces of water-vapor penetration to part and this is adsorbed by desiccant.



METHOD IB

Part, wrapped or unwrapped, enclosed within coating of strippable compound. No penetration of liquid and only traces of water-vapor to part.



METHOD III

No additional preservative on part. Packaged for physical and mechanical protection only. Relatively free access of liquid or water-vapor to part.

FIGURE 16. Characteristics of basic methods.

TABLE XXXI. Summary of MIL-P-116.

Preservation Methods	
Method I: Preservative Coating (with greaseproof wrap as required)	IC-4: Rigid Container Other Than All Metal, Sealed
Method IA: Watervaporproof Enclosure (with preservative as required)	IC-7: Blister Pack - Single or Multiple Compartment, Individually Sealed
IA-5: Rigid Metal Container, Sealed	IC-9: Skin Pack - Greaseproof, Vacuum Formed
IA-6: Rigid Container (items immersed in preservative, oil type), Sealed	IC-10: Skin Pack - Waterproof, Vacuum Formed
IA-8: Watervaporproof Bag, Sealed	Method II: Watervaporproof Enclosure With Desiccant (with preservative as required)
IA-13: Rigid Container Other Than All Metal, Sealed	IIa: Floating Bag, Sealed
IA-14: Container, Bag, Sealed, Container	IIb: Container, Bag, Sealed
IA-15: Container, Bag, Sealed	IIc: Watervaporproof Bag, Sealed
IA-16: Floating Bag, Sealed	IId: Rigid Metal Container, Sealed
Method IB: Strippable Compound Coating (hot or cold dip)	IIe: Container, Bag, Sealed
IB-1: Direct Application of Strippable Compound	IIf: Rigid Container, Other Than All Metal, Sealed
IB-2: Aluminum Foil Wrap, Strippable Compound	Method III: Physical and Mechanical Protection Only
Method IC: Waterproof or Waterproof Greaseproof Enclosure (with preservation as required)	
IC-1: Greaseproof, Waterproof Bag, Sealed	
IC-2: Container, Bag, Sealed	
IC-3: Waterproof Bag, Sealed	

TABLE XXXI. Summary of MIL-P-116. - Continued

Cleaning Methods	Drying Methods	Preservatives
C-1: Any Applicable Process	D-1: Prepared Compressed Air	P-1: Thin Film Preservative (hard drying, cold application)
C-3: Solvent Cleaning	D-2: Oven	P-2: Thin Film Preservative (soft film, cold application)
C-5: Solvent Cleaning Followed by Fingerprint Remover	D-3: Infrared Lamps	P-3: Thin Film Preservative, Water Displacing (soft film, cold application)
C-7: Vapor Degreasing	D-4: Wiping	P-6: Light Preservative Compound (soft film, hot application)
C-8: Perspiration and Fingerprint Removal	D-5: Draining	P-7: Medium Preservative Oil (cold application)
C-9: Alkaline Cleaning		P-9: Very Light Preservative Oil (cold application)
C-11: Electrocleaning		P-10: Engine Preservative Oil
C-12: Emulsion Cleaning		P-11: Preservative Grease (application as required)
C-14: Steam Cleaning		P-14: Corrosion Preventive (food handling machinery and equipment, nontoxic)
C-15: Abrasive Blast		P-15: Hydraulic Preservative Oil
C-16: Abrasive Blast (Honing Process)		P-17: Instrument Bearing Preservative Oil
C-17: Soft Grit Blast		P-18: Volatile Corrosion Inhibitor
C-18: Vapor-Degreasing Followed by Fingerprint Removal		P-19: Thin Film Preservative (transparent, nontacky)
C-19: Ultrasonic Cleaning		P-20: Lubricating Oil, Contact and Volatile Corrosion Inhibitor Treated
		P-21: Thin Film Preservative, Water Displacing (soft film, cold application, low pressure, steam removable)

e. Method II: Watervaporproof barrier with desiccant (with preservative as required).

f. Method III: Physical and mechanical protection only.

5.3.2 Submethods. Basically, all submethods within a specific method are equal in at least one important characteristic. However, the submethods within a basic method are not equal in other important respects. Differences among submethods exist in characteristics such as strength of barriers, physical protection afforded both item and package, labor and material costs involved, cube and weight of resulting package, and storage and transportation costs.

5.3.3 Adherence and uniformity of methods. Adherence to these prescribed methods of preservation is extremely important since requirements established during the package-engineering phase of package development are usually applicable throughout the supply system. Consequently, the manner in which an item is to be preserved and packed at the time of procurement must be recognizable as to methods and materials by any recipient in the supply system. The use of unknown methods and materials could result in repackaging within the supply system if there were any question as to the adequacy of the methods and materials used. Equally important is the requirement for uniformity of methods and materials whether an item is packed by a manufacturer or at a military or defense depot.

5.3.4 Method determination. Selection of the proper method of preservation is one of the most important decisions that a packaging engineer must make. The primary consideration in making this decision is the degree of physical and environmental protection required, which depends upon the susceptibility of the item to damage from the physical and chemical environment the package will experience until the item is used. Once the required degree of protection has been established, further analysis is required to determine the specific submethod and combination of packaging materials to be used. This analysis takes into consideration, as a minimum, the following factors:

a. Labor costs.

b. Material costs.

c. Transportation costs (relative to cube and weight).

d. Storage space and cost.

Only when all of these factors are considered can the packaging engineer be sure that he/she has selected a method and materials that not only provide the required degree of protection, but provide them at minimum overall cost. If only some of the pertinent factors are considered, erroneous conclusions could be drawn regarding the comparative costs of the methods. All factors affecting cost must be considered in the analysis if the results are not to be suspect.

5.4 Cleaning and drying.

5.4.1 General. To obtain maximum benefits from the various methods of preservation, the item must be perfectly clean in order to prevent any chemical action that might result in corrosion or other forms of deterioration. Because cleaning is the first step in the process of preservation, it must be performed thoroughly to insure both the effectiveness of the subsequent operations and the usefulness of the packaged item. Five general requirements for cleaning are:

a. It must be thorough.

b. Process must not injure item.

c. Disassembly should be limited.

d. Fingerprints must be removed from critical surfaces.

e. Items must pass required tests.

The purpose of this section is to aid the packaging engineer in prescribing and designating cleaning and drying methods and materials. MIL-P-116 establishes the basic cleaning requirements to be met when packaging for the military and gives information on the techniques and equipment to be used with the cleaners and cleaning processes covered.

5.4.2 Contamination. Water soluble, oily, and solid contaminants which are commonly deposited on military items being packaged include fingerprints and perspiration, inorganic residues, organic residues, and water or other liquids. Table XXXII lists the cleaners that are most frequently used to remove these contaminants.

TABLE XXXII. Specific cleaners for various types of contamination.

Type of Contamination	Type of Surface	Cleaner Specification
Fingerprints and perspiration	Metal surfaces	MIL-C-15074, Corrosion Preventive, Fingerprint Remover
Organic Residues		
Oils and greases	Metal surfaces	O-T-236, Tetrachloroethylene (Perchloroethylene). Technical
Oils and greases	Metal surfaces	O-T-634, Trichloroethylene, Technical
Carbon	Metal surfaces	MIL-G-5634, Grain, Abrasive, Soft, for Carbon Removal
Oils, greases, asphalts, and tars	Copper alloys (brass, bronze) and ferrous surfaces	O-C-1824, Cleaning Compound, Solvent, Heavy Duty
Oils, greases, asphalts, and tars	Metallic and painted surfaces	MIL-C-11090, Cleaning Compound, Degreasing and Depreserving Solvent, Self-Emulsifying
Oils, greases	Rubber, plastics, canvas, and metallic	MIL-D-16791, Detergent, General Purpose (Liquid, Nonionic)
Inorganic Residues		
Rust removal	Ferrous metal surfaces	MIL-C-14460, Corrosion Removing Compound, Sodium Hydroxide Base; for Electrolytic or Immersion Application
Soils	Ferrous metal surfaces	P-C-535, Cleaning Compound, Platers' Electrocleaning, for Steel
Grease, oil, dirt	Various surfaces, if compatible	P-C-444, Cleaning Compound, Solvent, Grease Emulsifying

TABLE XXXII. Specific cleaners for various types of contamination. - Continued

Type of Contamination	Type of Surface	Cleaner Specification
All Contamination		
Rust removal and metal etch conditioning	Metal surfaces	MIL-M-10578, Metal Conditioner and Rust Remover (Phosphoric Acid Base)
Preparation prior to application of organic or in-organic sur-face castings.	Aluminum, magne-sium, and other metallic surfaces	MIL-M-7752, Metal Cleaner Silicate-Soap
Cleaner as brightner - aircraft	Aluminum surfaces	MIL-C-5410, Cleaning Compound, Aluminum Surface, Non-Flame-Sustaining
	Ferrous and non-ferrous alloy parts	P-C-436, Cleaning Compound Alkali, Boiling Vat (Soak) or Hydrosteam
	Ferrous and non-ferrous surfaces	P-C-437, Cleaning Compound, High Pressure (Steam) Cleaner

5.4.3 Choosing a cleaning process and cleaner. The selection of a cleaning process depends upon the characteristics of the item, the nature of the contaminants, availability of cleaning materials and equipment, and the safety hazards involved. Figure 17 lists the considerations involved when prescribing a cleaning process and cleaner.

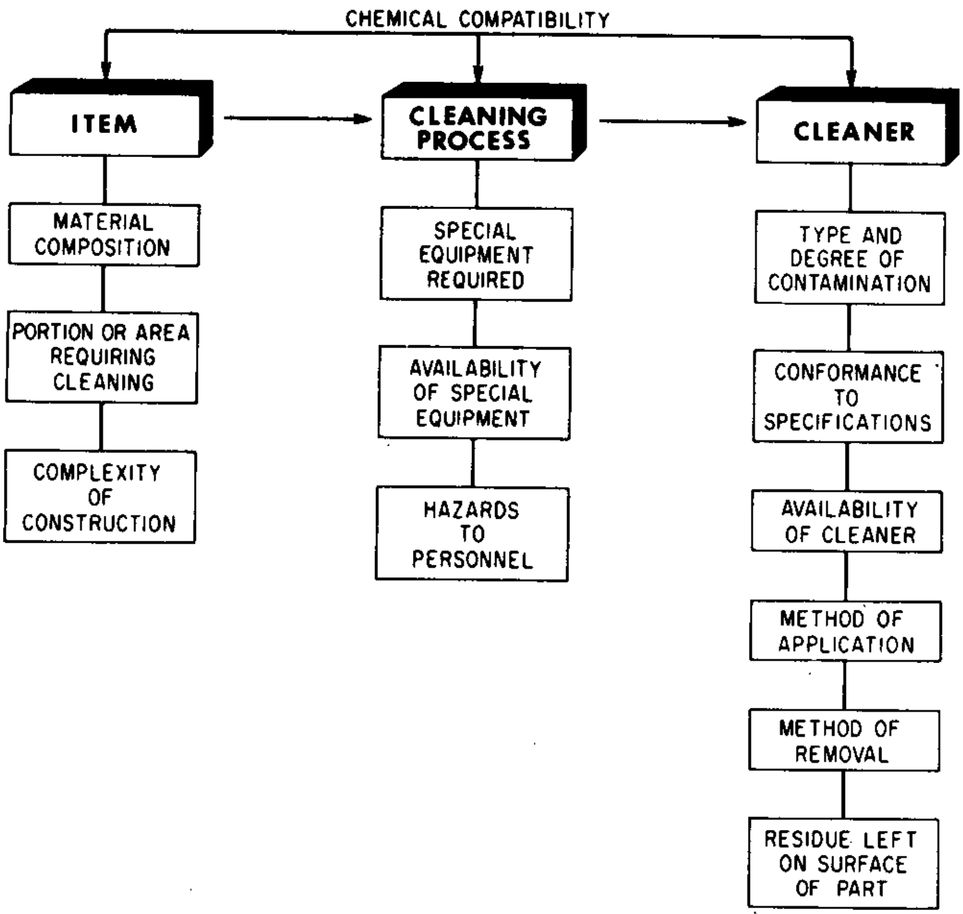


FIGURE 17. Choosing a cleaning process and cleaner.

5.4.3.1 Item considerations.

a. Composition of the item. The composition of the item limits the choice of the cleaning process. Aluminum or zinc items should not be cleaned in highly alkaline cleaners because of the detrimental effect of the cleaner. Nonmetallic items of rubber, fabric, cork, or other organic composition should not be cleaned haphazardly in organic or water-soluble alkaline cleaners. If solvent cleaning is applied to such items, the solvent exposure must be brief and scrubbing action limited when dimensions and use conditions of the item are critical. Petroleum solvents are detrimental to most rubber and synthetic rubber materials. If metallic and nonmetallic materials are combined in an assembly, the cleaning process must be carefully considered and the choice of the process governed by the nature of the materials combined in the assembly.

b. Portion or area requiring cleaning. When only portions of an item require cleaning, either the entire item or just the critical surfaces may be subjected to the cleaning process. In either case, the cleaner and process selected must not adversely affect any of the materials of which the item is made.

c. Complexity of construction. If it is feasible, complex items should undergo some disassembly before cleaning. In all cases, the selected cleaning process must adequately clean all protrusions, crevices, and grooves; the cleaner should either not collect in grooves or crevices, or be easily removed from such places if it does collect.

5.4.3.2 Cleaning process considerations.

a. Special equipment required. The packaging engineer must be aware of all special equipment required when prescribing a particular cleaning process. Special equipment used must not harm the item or unduly increase the cleaning costs.

b. Availability of special equipment. If special equipment is required, it must be available at the cleaning location to be suitable for use with the particular item being cleaned, or be capable of being adapted or modified so as to be suitable for use with the item. If the required equipment is not available, the desirability of using the particular process must be weighed against the cost and possible delay in obtaining the equipment.

c. Hazards to personnel. Packaging engineers should not overlook the problems associated with hazardous cleaning processes (and cleaners). Considerations involved include costs of special protective equipment or devices, personnel training required, insurance costs, the time factor involved, and possible residual hazards. All cleaning processes have health and safety hazards that must be recognized. These cleaning processes must comply with the requirements of the Occupational Safety and Health Act (OSHA) of 1970, or Executive Order 11612, as applicable.

5.4.3.3 Cleaner considerations.

a. Type and degree of contamination. The cleaner selected should be effective, economical, and suited to the particular residue being removed. Packaging engineers should become familiar with the chemical characteristics of cleaners under consideration. Associated information concerning the item must be available for checking on compatibility.

b. Conformance to specifications. All cleaners shall conform to Federal or military specifications. However, if an approved cleaner is not available or if an item requires special attention, deviations may be made.

c. Availability of cleaners. The availability of the cleaner and other required reagents must be ascertained before a decision is made for use.

d. Method of application. In many cases, the choice of a cleaning process establishes the method of application. In other instances, material composition of the part or its configuration may dictate the manner in which the cleaner is to be applied. In any case, the method used must accomplish cleaning of all required portions of the item without adversely affecting the item.

e. Removing cleaner residues. Cleaning should be carried out in a manner which leaves no residual cleaning material. In those instances where some cleaning residue remains, e.g., on a complex item that cannot undergo disassembly, care should be taken that the cleaner is of a type that will not cause subsequent corrosion of the item or will not reduce the effectiveness of any preservative that might be used on the item. On highly critical surfaces, the cleaner selected should always be of a type that leaves no residue. The best way of meeting and overcoming such situations is through early consultation with item design personnel.

5.4.4 Cleaner selection chart. Table XXXIII presents data to aid in the selection of an appropriate cleaning process and cleaner for a particular application. Data are also included on the characteristics and uses of each cleaner, as well as on any special considerations involved, such as hazards to personnel. It should be noted that in some cases the specifying of cleaning requirements involves more than just selecting a cleaning product and a cleaner, e.g., an item that must be cleaned and packed in a dust-free environment, thus necessitating the use of special "clean room" facilities. The advent of sophisticated subassemblies and components for aerospace and other modern military applications has created new requirements for absolute cleanliness in assembly and packaging operations. With tolerances often held to within millionths of an inch, contamination, even in minute quantities, may cause malfunctions. To avoid such contamination, precise assembly work must be performed in a controlled environment or "clean room." Air entering the room is filtered and conditioned to control its oil and moisture content, thus creating favorable environmental conditions in the clean room. Microminiaturized components and subassemblies go through rigid cleaning procedures before entering the clean room for final assembly and packaging. Procedures entail cleaning in ultrasonic baths or spray cleaning with solvents to remove contaminants.

5.4.5 Cleaning procedures for special items. For some special types of items, specific cleaning procedures are covered in specifications. These procedures may give complete cleaning instructions, or may augment and supplement MIL-P-116. For example, the cleaning of optical elements and lenses is covered in MIL-P-14232. Figure 18 illustrates cleaning processes for the removal of perspiration and fingerprints, and in the use of petroleum solvents. Before choosing a cleaner and cleaning process, first determine that a specific cleaning process for the item does not exist.

TABLE XXXIII. Cleaner selection chart.

Cleaning Process	Cleaner Specification	Cleaner Characteristics	Chemical Properties	General Uses and Special Considerations
Any Applicable Process (C-1)*	O-C-1824 Cleaning Compound Solvent, Liquid, Heavy Duty	Grease removal solvent of organic composition	When the compound is diluted 1 to 1 by volume with distilled water at 25° C., it shall have a pH of not less than 11.0 Flash point 180° F.	Removal of oil, grease, asphalt, tar, and some rust preventive compounds from ferrous and copper alloy surfaces. Not designed for the removal of rust or corrosion. Do not use on aluminum or zinc.
	MIL-C-5410 Cleaning Compound Aluminum Surface, Non-Flame-Sustaining Type I	Nonflammable; phosphoric-acid base Viscous emulsion used full strength	Viscosity: 120 $\pm$ 1 Krebs Unit (K.U.) Phosphoric-acid content (P_2O_5): $\leq$5.5% by weight	Overhaul of unfinished aluminum surfaces.
	Type II	Nonflammable; Phosphoric-acid base Clear liquid used full strength or diluted with mineral spirits and water	Phosphoric-acid content (P_2O_5): $\leq$14.7% by weight	Maintenance of transport aircraft.
	MIL-D-16791 Detergent, General Purpose Liquid, Nonionic		Cloud point: 120° to 160° F.	Preparation of cleaning solutions effective in and rinsable with either fresh or sea water.

*C-Numbers refer to Cleaning Methods as defined in latest revision of MIL-P-116.

TABLE XXXIII. Cleaner selection chart. - Continued

Cleaning Process	Cleaner Specification	Cleaner Characteristics	Chemical Properties	General Uses and Special Considerations
Any Applicable Process (Continued)	MIL-D-16791 Detergent, General Purpose Liquid, Nonionic (Continued)			
	Type I	Water-soluble clear liquid	pH: 6.0 to 8.0 at 25° C.	
	Type II	Oil-soluble	Saponification No. 5	
	MIL-M-7752 Metal Cleaner Silicate-Soap	Granular powder	Sodium metasilicate- (40.5 to 41.5%) Sodium trisilicate- (53.5 to 54.5%) Synthetic Soap- (4.9 to 5.1%) pH: 11.0 to 12.5	Cleaning of aluminum, magnesium, and other metallic surfaces.
	MIL-M-10578 Metal Conditioner and Rust Remover (Phosphoric Acid Base)		All types: flash point (min) 135° F. (57° C.)	Rust remover for ferrous metal parts and as metal conditioners for ferrous and nonferrous metals prior to application of paints and/or corrosion preventives.
	Type I	Wash-off	Phosphoric acid; 68 g/100ml min	
	Type II	Wipe-off	Phosphoric acid; 20-25 g/100ml min	

TABLE XXXIII. Cleaner selection chart. - Continued

Cleaning Process	Cleaner Specification	Cleaner Characteristics	Chemical Properties	General Uses and Special Considerations
Any Applicable Process (Continued)	MIL-M-10578 Metal Conditioner and Rust Remover (Phosphoric Acid Base) (Continued)			
	Type III	Inhibited	Phosphoric acid; 49 g/100ml min	
	Type IV	Nonfoaming	Phosphoric acid; 68 g/100ml min	
	Type V	Immersion-tank	Phosphoric acid; 68 g/100ml min	
	MIL-C-14460 Corrosion Removing Compound, Sodium Hydroxide Base; for Electrolytic or Immersion Application	Supplied in the form of dry, fine granular, or dry, fine, flake material		
	Type I		Type I Trisodium salt of N-Hydroxyethyl-enedia-minetri-acetic acid - 13% min; Sodium Gluconate - 25% min; Sodium Hydroxide - 54% max; Others 7.0% max	Removal of rust and scale from iron and steel surfaces.
	Type II		Type II Chelate or Sequestrant Compound 25 to 35% Sodium Hydroxide 35% min Sodium Cyanide 25 to 35% Others including foamers 4% max	Type II contains sodium cyanide and is, therefore, classified as poisonous.

TABLE XXXIII. Cleaner selection chart. - Continued

Cleaning Process	Cleaner Specification	Cleaner Characteristics	Chemical Properties	General Uses and Special Considerations
Any applicable Process (Continued)	MIL-C-11090 Cleaning Compound, Degreasing and Depreserving Solvent, Self-Emulsifying	Self-emulsifying degreasing solvent	Flash point (min): 100° F. (38° C.) Viscosity (Centistokes) max: 15.0 at 10° F. Emulsion stability (10 parts compound to 90 parts water, for a min of 6 hrs)	Removal of oils, greases, asphalt tar, and rust preventive compounds from metallic and painted surfaces. Do not use for removal of wax-type rust preventive compounds.
Dry Cleaning Solvent (C-3)	P-D-680 Dry Cleaning Solvent			Cleaning of metal parts Surfaces where tolerances are critical. Cleaning of metal parts prior to plating, painting, or preservation. Used in spray, brush and dip-soak operations. Deteriorates natural and some synthetic rubbers.
	Type I	100° F. Solvent (Stoddard Solvent)	Flash point (min): 100° F. Distillation Range: Init boiling point (min): 300° F. Min 50% distilled: 350° F. End point (max): 410° F.	
	Type II	140° F. Solvent	Flash point (min): 138° F. Distillation Range: Init boiling point (min): 350° F. Min 50% distilled: 375° F.	

TABLE XXXIII. Cleaner selection chart. - Continued

Cleaning Process	Cleaner Specification	Cleaner Characteristics	Chemical Properties	General Uses and Special Considerations
Dry Cleaning Solvent (C-3) (Continued)	P-D-680 Dry Cleaning Solvent (Continued)		End point (max): 415° F.	
	TT-T-291 Thinner; Paint Volatile Spirits (Petroleum Spirits)	Petroleum distillate	Aniline point: 59° to 65° C. (138° to 149° F.) Flash point: 38° C. (100° F.)	Used as thinners and/or solvents for paints. Used to remove P-type preservatives from metallic surfaces.
	Type 1	Regular mineral spirits	Distillation: Init boiling point: 150° C. (302° F.) End point: 210° C. (410° F.)	
	Type 2	Highflash (or 60° C.) mineral spirits	Aniline Point: 59° C. to 65° C. (138° F. to 149° F.) Flash point: 52° C. min (126° F.) Distillation: Init boiling point: 171° C. (340° F.) min End point: 252° C. (486° F.) max	
	Type 3	Odorless mineral spirits	Aniline Point: 83° to 87° C. (181° to 189° F.)	

TABLE XXXIII. Cleaner selection chart. - Continued

Cleaning Process	Cleaner Specification	Cleaner Characteristics	Chemical Properties	General Uses and Special Considerations
Dry Cleaning Solvent (C-3) (Continued)	TT-T-291 Thinner; Paint Volatile Spirits (Petroleum Spirits) (Continued)		Flash point: 57° C. min (135° F.) Distillation: Init boiling point: 168° C. (334° F.) min End point: 210° C. (410° F.)	
	MIL-C-4036 Cleaner, Vapor Pressure, Spray Rinse			Used as a portable combination vapor and high-pressure rinse, gasoline-engine-operated cleaner.
	Style 1	Mounted on 4 industrial-type, pneumatic tired wheels, with towing handle, designated Type B-2C		Intended for use in washing and cleaning of aircraft engines and accessories, vehicles, and miscellaneous ground equipment.
	Style 2	Mounted on a 2-wheel, automotive-type trailer, with towbar and a folding leg for balance		
	MIL-D-12491 Degreasers, Solvent, Tank Immersion	Mechanized method and apparatus for applying solvents		Used for removal of grease and dirt from parts associated with maintenance shop operations.

TABLE XXXIII. Cleaner selection chart. - Continued

Cleaning Process	Cleaner Specification	Cleaner Characteristics	Chemical Properties	General Uses and Special Considerations
Petroleum Solvent Cleaning (C-5) followed by fingerprint removal	Items shall be cleaned in accordance with process C-3 followed by process C-8			
Vapor Degreasing (C-7)	O-T-634 Trichloroethylene, Technical Type II	Vapor degreasing	Distillation range: Init boiling point (min): 86.0° C. Minimum 95% distilled (max): 87.5° C. Dry point (max): 90.0° C. (194.0° F.)	Vapor degreasing of metals. Adequate ventilation required for use. Extreme care must be exercised when used. Proper equipment required.
	O-T-236 Tetrachloroethylene (Perchloroethylene) Technical	Vapor degreasing	Specific gravity: 1.620 - 1.630 Acidity .0005% Distillation Range: Init boiling point: 120° F. End point: 122° C. (251.6°)	Removal of oil, grease, and similar contaminants. Vapor degreasing. Adequate ventilation required for use. Temperature at which solvent is used must not injure them.
Perspiration and Fingerprint Removal (C-8)	MIL-C-15074 Corrosion Preventive, Fingerprint Removal		Flash point: 100° F. (min) Viscosity: 30 Centistokes (max) at 100° F.	Fingerprint contamination removal for metallic items. Corrosion preventive for metal parts.

TABLE XXXIII. Cleaner selection chart. - Continued

Cleaning Process	Cleaner Specification	Cleaner Characteristics	Chemical Properties	General uses and Special Considerations
Perspiration and Fingerprint Removal (C-8) (Continued)	MIL-C-15074 Corrosion Preventive, Fingerprint Removal (Continued)			Removal of fresh fingerprint residues. Suppression of corrosion that has developed as a result of fingerprint residues. Must be followed by a thorough rinse in P-D-680 or TT-T-291 grade 1.
Hot Soak Tank Cleaning (C-9)	P-C-436 Cleaning Compound, Alkali, Boiling Vat (Soak) or Hydrosteam	Alkali cleaning compound Granular, free flowing, uniform	Sodium metasilicate anhydrous 31.3% Primary sodium phosphate 12.3% Trisodium phosphate 24.8% Nonionic surfactant 7.9% Anionic surfactant 23.7%	Hot soak tank cleaning of ferrous and nonferrous alloy parts. Removal of asphalt, mineral oil, grease, and road dirt from metal parts.
Immersion in solution electrically charged. (C-11)	P-C-535 Cleaning Compound, Platers' Electrocleaning, for Steel	Heavy-duty anodic electrocleaner	Composition: Silicate (SiO_2): 10-35% Phosphate (P_2O_5): 5% min Organic detergent: 0.4% min Caustic soda: remainder	Removal of soils from ferrous metallic surfaces before electroplating.

TABLE XXXIII. Cleaner selection chart. - Continued

Cleaning Process	Cleaner Specification	Cleaner Characteristics	Chemical Properties	General Uses and Special Considerations
Immersed in Emulsion (C-12)	P-C-444 Cleaning Compound, Solvent, Grease Emulsifying	Solvent emulsifying type cleaning compound	Flash point: 110° F. (43° C.) Pour point (max): 35° F. (2° C.)	Removal of grease, oil, dirt, by solvent action.
	Type I	Nonphenolic		General cleaning.
	Type II	Phenolic		Heavy duty - extreme caution.
Steam Generated By a Steam Cleaning Machine (C-14)	P-C-437 Cleaning Compound, High Pressure (Steam) Cleaner		Manufacturers' discretion with the exception prohibitions detailed in the specification pH: 10.5 to 11.4 (1/2% solution at 25° C.)	Cleaning of ferrous and nonferrous faces
Abrasive Blast (C-15)	MIL-S-851 Steel Grit, Shot, and Cut Wire Shot; and Iron Grit and Shot - Blast Cleaning and Peening	Grit and shot Type I - Cast Steel (grit and shot) Type II - Cast Iron (grit and shot) Type III - Steel Cut Wire (shot only)	Grit For general blast cleaning Shot For peening and blast cleaning	Used for blast cleaning of castings and forgings, and for removal of sand, slag, rust, and marine incrustations. Where cutting action of grit is undesirable.

TABLE XXXIII. Cleaner selection chart. - Continued

Cleaning Process	Cleaner Specification	Cleaner Characteristics	Chemical Properties	General Uses and Special Considerations
Abrasive Blast (honing process) (C-16)	Cleaning shall be effected by subjecting the item to a high velocity stream of atomized water combined with a fine particle size abrasive and suitable corrosion inhibitor.			
Soft Grit Blast (C-17)	MIL-G-5634 Grain, Abrasive, Soft, for Carbon Removal Type I	Apricot pits	Water content - 10% (max) Specific gravity - 1.2 to 1.4	Removal of carbon from surfaces (aircraft jet engine). Used in blasting machines.
	Type II	Pecan shells	Water content - 10% (max) Specific gravity - 1.2 to 1.4	
	Type III	Black walnut shells	Water content - 10% (max) Specific gravity - 1.2 to 1.4	Aircraft jet engine and general purpose only.

TABLE XXXIII. Cleaner selection chart. - Continued

Cleaning Process	Cleaner Specification	Cleaner Characteristics	Chemical Properties	General Uses and Special Considerations
Soft Grit Blast (C-17) (Continued)	MIL-G-5634 Grain, Abrasive, Soft, for Carbon Removal (Continued) Type IV	Corn cobs	Water content - 10% (max) Specific gravity - 1.2 to 1.4	
	Type V	Rice hulls	Water content - 10% (max) Specific gravity - 1.1 to 1.55	
	Type VI	English walnut shells or apricot pit shells or mixture of two	Water content - 10% (max) Specific gravity - 1.2 to 1.4	Aircraft jet engine only.
	Type VII	Peach pits	Water content - 10% (max) Specific gravity - 1.2 to 1.4	Aircraft jet engine.
Vapor Degreasing Followed by Fingerprint Removal (C-18)	Items shall be cleaned in accordance with process C-7 followed by C-8.			
Ultrasonic Cleaning (C-19)	Cleaning shall be effected by subjecting the item(s) suspended in a cleaning agent, to the force of high frequency sound waves (ultrasonic)			Nonabsorbent materials and electronic devices.

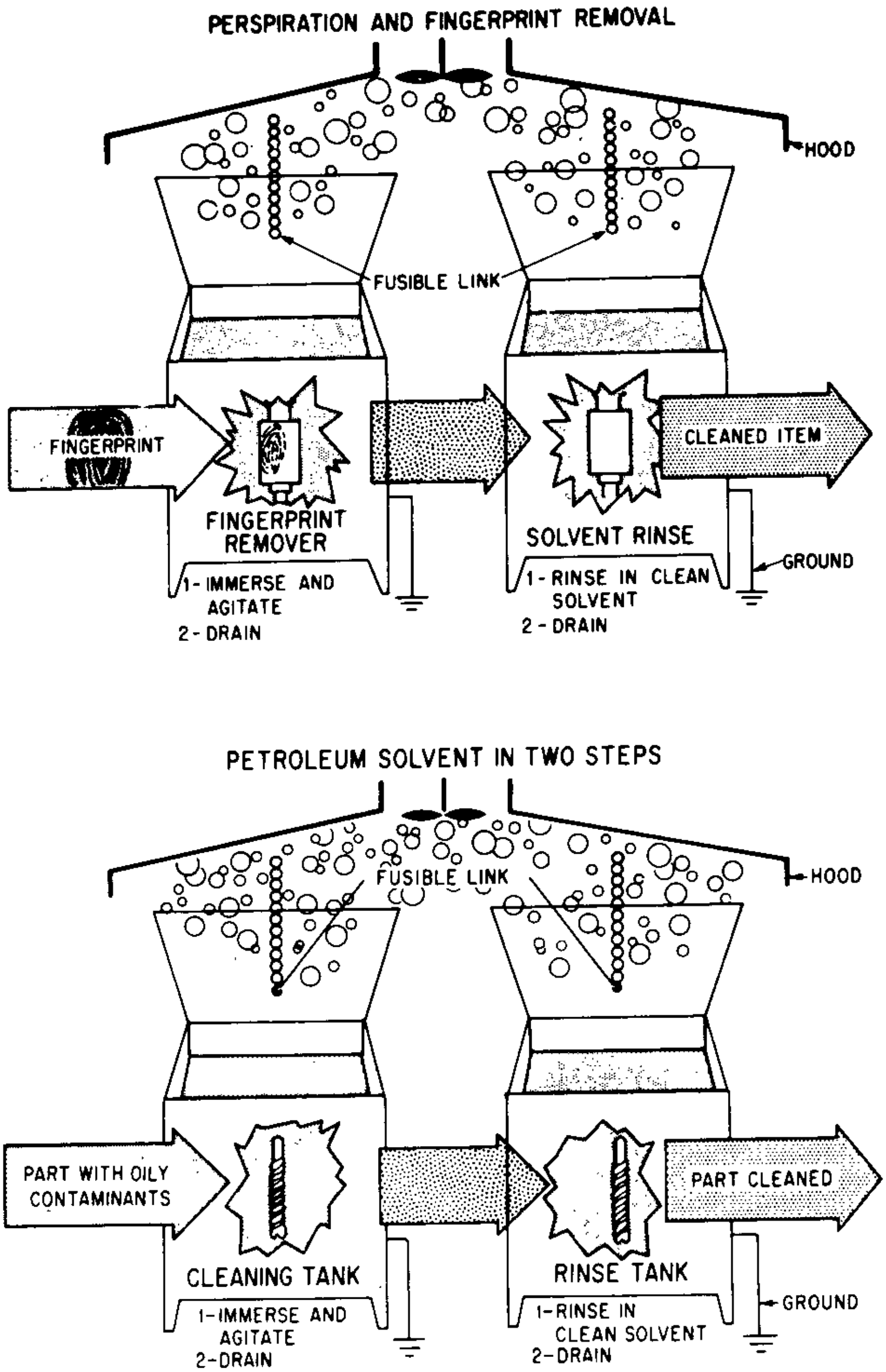


FIGURE 18. Cleaning processes.

5.4.6 Testing of cleanliness. To insure that all contamination has been removed, the item should be tested immediately after cleaning. Tests performed may include visual tests, cloth tests, litmus tests, or any other test specified by the packaging engineer to determine if the item has been cleaned effectively. In performing the tests, care must be exercised to insure that the item is not recontaminated.

5.4.7 Drying. Items should be dried immediately after it has been determined that they are clean. Drying processes and the considerations to be observed in their use are given in table XXXIV. Typical drying procedures are illustrated in figure 19.

5.5 Preservatives.

5.5.1 General. This section provides information on selection of preservatives. Included in this section are considerations in choosing a preservative and data on preservative types, characteristics, and general uses. Also discussed is the situation where contact-type preservatives are not used but rather a barrier or some other protection such as vapor phase inhibitors or volatile corrosion inhibitors are used. The types of preservatives must be correlated with the barrier used to offset the limitations of each. Closely related, therefore, to the materials discussed in this section are Methods of Preservation (section 5.3), Barrier Materials and Cushioning Materials (section 5.6), and Methods of Humidity Control (section 5.12).

5.5.2 Preservation after cleaning. Protection of items after cleaning is required. When specifying processes for cleaning, requirements should be established to provide for the temporary protection of the item pending preservation and packaging or immediate accomplishment of the subsequent packaging operations.

5.5.3 Considerations in choosing a preservative. Because of the nature of the various materials used as preservatives, the packaging engineer must consider factors such as the following before selecting the specific preservative most appropriate to the item:

a. What degree of protection does the item require?

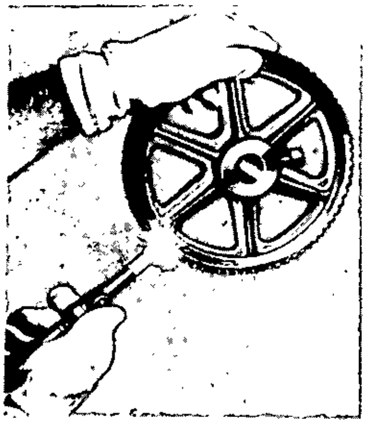
b. Should the item be placed in a waterproof or water-vaporproof package with a light oil-type preservative?

c. Can the item be protected by a thin-film or compound-type preservative without additional barrier protection?

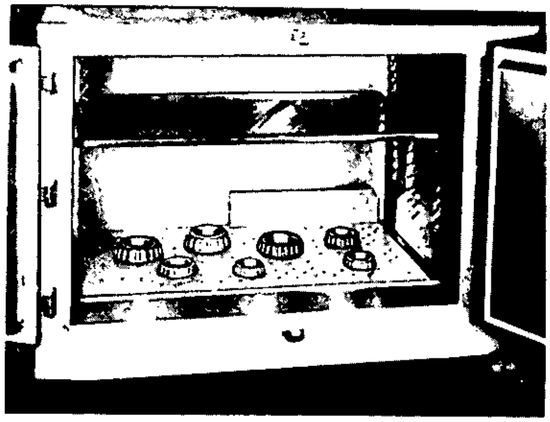
TABLE XXXIV. Drying methods and procedures.

Drying Process	Procedure	Special Considerations
Prepared compressed air (D-1)*	Item is subjected to a blast of clean, dry compressed air.	Air must reach all portions of item requiring drying. Any obstructions to air flow must be removed or bypassed. Air must not spray cleaner residue on incompatible portion of item.
Oven (D-2)	Item is dried within a ventilated and temperature-controlled oven.	Items must not be adversely affected by heat.
Infrared Lamps (D-3)	Item is exposed to heat rays from a bank of infrared lamps.	Item must not be adversely affected by heat resulting from the infrared radiation.
Wiping (D-4)	Item is wiped with a clean, dry lint-free cloth.	Cloth must be changed when it becomes damp or slightly contaminated.
Draining (D-5)		Used when the final step in cleaning is a petroleum solvent, or when cold application solvent cutback preservatives are employed.

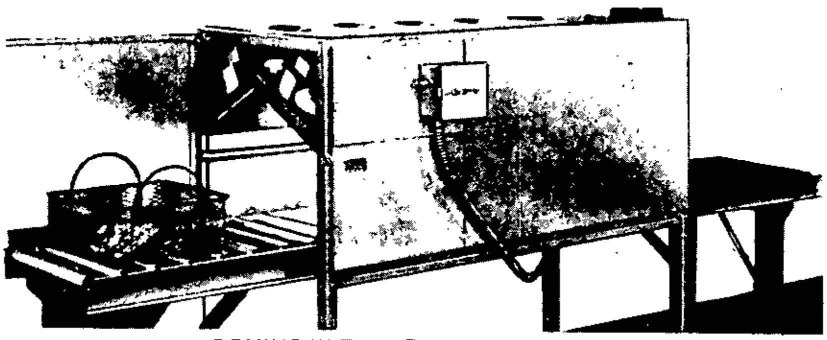
*D-Numbers refer to drying methods as defined in latest revision to MIL-P-116.



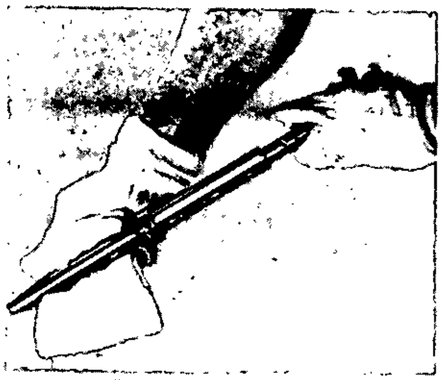
DRYING WITH COMPRESSED AIR



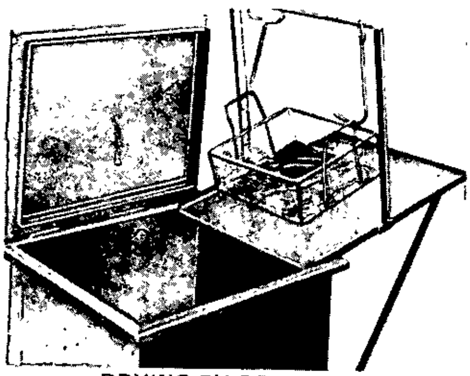
DRYING BY HEATED OVEN



DRYING WITH INFRA RED LAMPS



DRYING BY WIPING



DRYING BY DRAINING

FIGURE 19. Typical drying procedures.

d. Do any characteristics of the item indicate that no contact preservative should be employed or that one type would be more compatible with the nature of the item than another?

e. Will removal of the preservative prior to use of the item present any special problems?

f. Can a dual-purpose material which functions as both preservative and lubricant be used?

g. After consideration of the six factors above, which preservative material will be most appropriate from the standpoint of production and least costly after consideration of all pertinent factors? (See figure 20.)

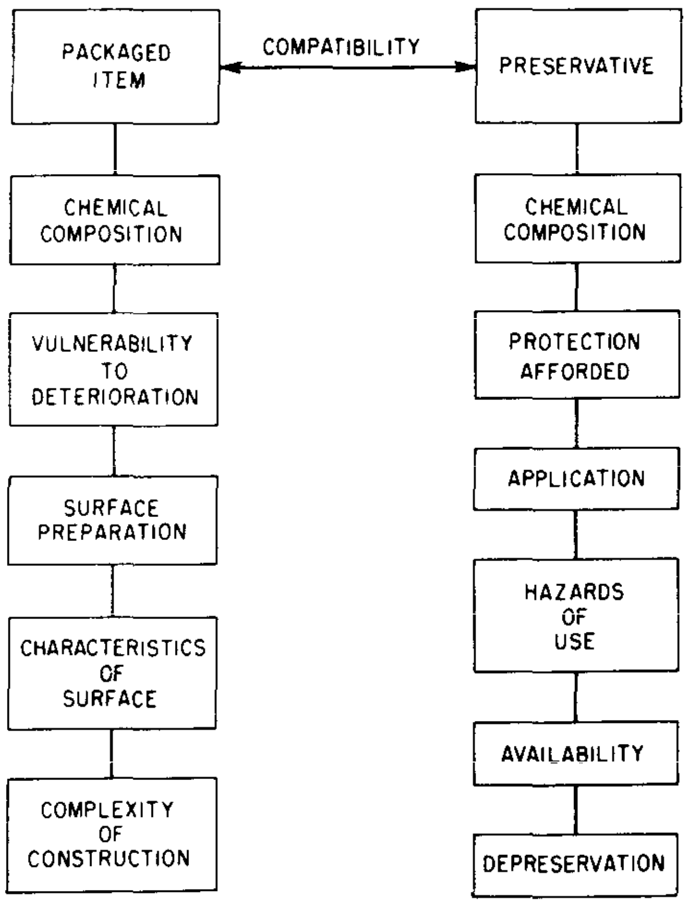


FIGURE 20. Considerations for choosing a preservative.

5.5.3.1 Item characteristics. The item characteristics that must be considered when choosing a preservative are:

a. Chemical composition. The preservative material and the packaged item must be compatible to protect against deterioration and prevent harmful interaction between the item and the preservative.

b. Vulnerability to deterioration. The major types of deterioration and the degree to which the item is vulnerable must be known in order for the preservative to provide adequate protection.

c. Surface preparation. The item must be cleaned and dried before application of the preservative to prevent contaminants from counteracting the effects of the preservative. Other problems associated with the lack of cleanliness or complete drying include nonadherence of the preservative to the item surface and interaction between the contaminant and the preservative.

d. Characteristics of item surface. When an item consists of different types of material, some of which do not require a preservative, the preservative must protect the critical surfaces and be compatible with the portions of the item not requiring preservative. In addition, the surface of the item may have a close tolerance or high polish, thus requiring a preservative that leaves no residue and is nonabrasive. Many preservatives cannot be used if the surface has any crevices or indentations that may be filled during the preservation process and thus require extensive depreservation.

e. Complexity of construction. The preservative must be capable of adequately covering all parts of the items requiring such preservation. Complex items or items with moving parts may require disassembly in order to apply the preservative to all the parts.

5.5.3.2 Preservative considerations. The preservative characteristics that must be considered when choosing a preservative are:

a. Chemical composition. The preservative and the packaged item must be compatible to protect against deterioration and to prevent harmful interaction between the item and the preservative.

b. Protection afforded. The protection afforded by the preservative must be commensurate with the major types of deterioration to which the item is vulnerable. If the exact environmental conditions are not known, the preservative must be capable of protecting the item under all normal conditions of shipment and storage.

c. Application. The effects of the application process on the item--such as the use of heat, pressure, and moisture--must be determined. Items must not suffer damage to mechanism or structure, or be subject to malfunction or unsafe operating conditions because of the application or removal of a preservative compound. Examples of vulnerable items are optical instruments, cameras, and fire control units. Figure 21 illustrates some preservative applications.

d. Hazards of use. The safety of the packaging personnel and subsequent handlers of the item must be considered when a hazard exists if the use of the preservative must take into consideration the availability of proper equipment and trained personnel.

e. Availability. The availability of the preservative must be known. If special equipment is required for applying or removing the preservative, it must be available and suitable for use with the item.

f. Depreservation. The need for removal of the preservative must be established. Some preservatives do not require removal; thus the item functions normally with the preservative retained on the surface of the item. The effect of the depreservation process on the item also must be determined. Wherever possible, either preservatives that do not have to be removed or those that are easily removed should be used.

5.5.4 Types of preservatives. The principal types of preservatives and their specifications are given in table XXXV. This table lists the types of materials, characteristics, methods of application and removal, uses, and special considerations.

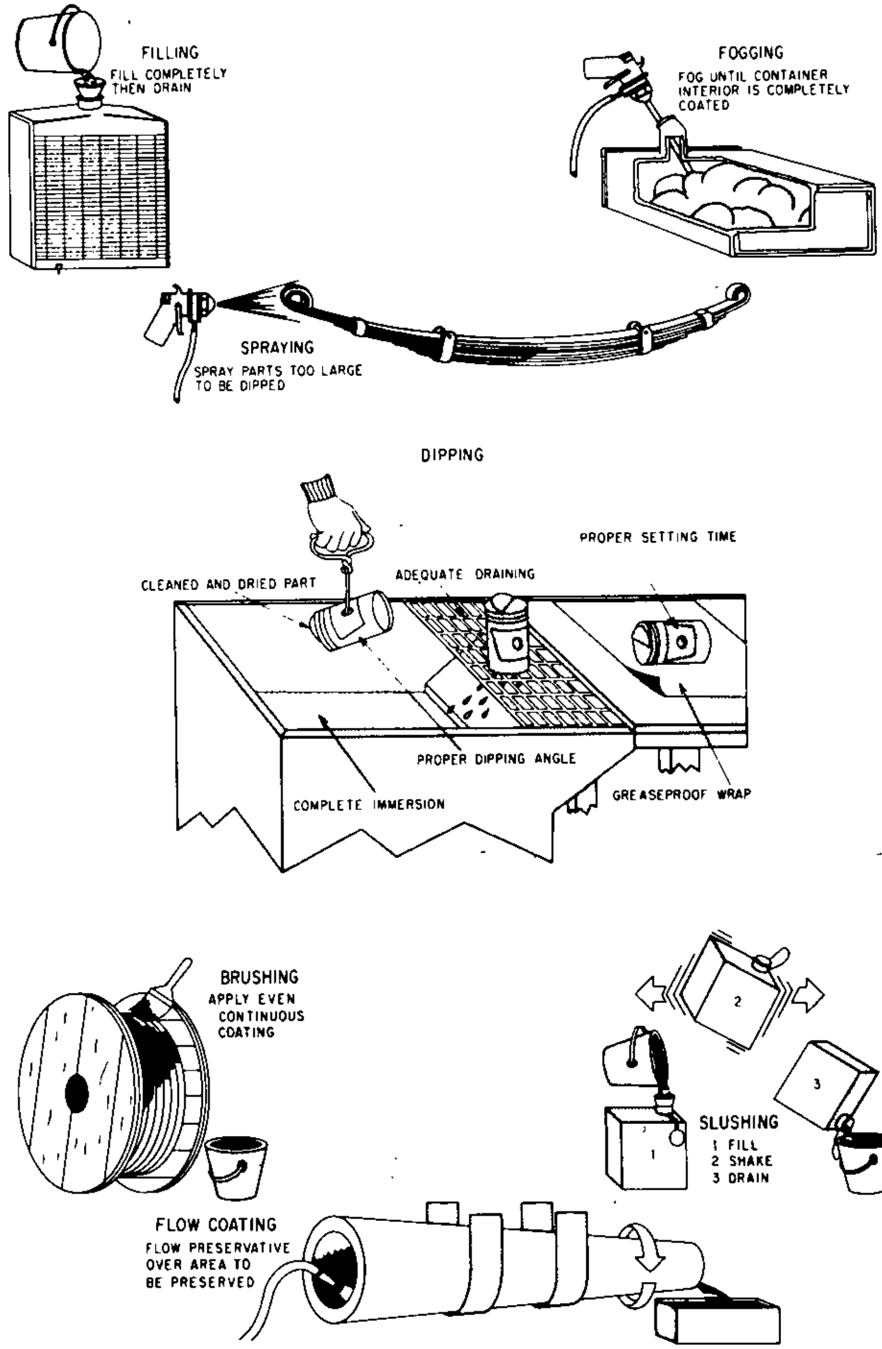


FIGURE 21. Preservative applications.

TABLE XXXV. Types of preservatives.

Specification No.	Type and P-No.	Flow Point, °F.	Flash Point, °F.	Melting Point, °F.	Pour Point, °F.	Method and Temperature of Application	Method of Removal	Uses
MIL-C-16173 CORROSION PREVENTIVE COMPOUND, SOLVENT CUTBACK, COLD-APPLICATION	Grade 1 Hard Film (P-1)*	175	100			Dipping, spraying or brushing at room temperature.	Not usually required. Can be accomplished by vapor degreasing or with petroleum solvents.	Protection of noncritical metal items that are stored outdoors or where a "dry-to-touch" film is desired. Should not be used on items requiring removal of film for operation. Used on bolts, chains, bale hooks, and similar items.
	Grade 2 Soft Film (P-2)		100			Dipping, spraying or brushing at room temperature.	Petroleum solvents or vapor degreasing	Extended under cover protection to interior or exterior surfaces of machinery, instruments, bearings or material with or without use of supplementary barrier materials, for outdoor use for limited periods where metal temperature does not prevent film flow.

*P-Numbers refer to preservation methods defined in latest revision of MIL-P-116.

TABLE XXXV. Types of preservatives. - Continued

Specification No.	Type and P-No.	Flow Point, °F.	Flash Point, °F.	Melting Point, °F.	Pour Point, °F.	Method and Temperature of Application	Method of Removal	Uses
	Grade 3 Water Displacing. Soft Film (P-3)		100			Dipping, brushing, spraying of exterior; flushing, filling or slushing of interiors at room temperatures.	Vapor degreasing or petroleum solvents.	Used where fresh or salt water must be displaced from corrodible surfaces and the corrosion prevented or stopped; for protecting interior surfaces of machinery, instruments, or material under cover for limited periods and for protecting critical bare steel or phosphated surfaces for extended periods when satisfactorily packaged.
MIL-C-11796 CORROSION PREVENTIVE COMPOUND PETROLATUM, HOT APPLICATION	Class 3 Soft Film Compound (P-6)	130	350	135		Applied either by brushing or swabbing at room temperatures, or by dipping in the molten state at temperatures not to exceed 180° F.	Vapor degreasing or petroleum solvents.	Preservation of antifriction bearings for use on machined surfaces for which a protective material that is brushable and easily removable at room temperature is required.

TABLE XXXV. Types of preservatives. - Continued

Specification No.	Type and P-No.	Flow Point, °F.	Flash Point, °F.	Melting Point, °F.	Pour Point, °F.	Method and Temperature of Application	Method of Removal	Uses
MIL-L-3150 LUBRICATING OIL PRESERVATIVE, MEDIUM	One Grade only; viscosity same as SAE 30 (P-7)		300		20	Applied at room temperature by any applicable method except fogging.	Vapor degreasing or petroleum solvents.	For lubricating and preserving internal surfaces of machine assemblies (other than internal combustion engines), for artillery and small arms, transmissions, differentials, and fuel tanks. Used as a temporary preservative on items and equipment awaiting processing for long-term storage and for maintaining supplies and equipment in the reserve fleet.
VV-L-800 LUBRICATING OIL, GENERAL PURPOSE, PRESERVATIVE, (Water Displacing Low Temperature).	One grade only. (P-9)		275 min.	NOTE: The oil loses its newtonian properties at very low temperatures; its use	-70° or lower	Any method at room temperature.	Petroleum solvents or vapor degreasing	For use in lubrication and protection against corrosion of certain small arms, automatic weapons, fuze mechanisms,

TABLE XXXV. Types of preservatives. - Continued

Specification No.	Type and P-No.	Flow Point, °F.	Flash Point, °F.	Melting Point, °F.	Pour Point, °F.	Method and Temperature of Application	Method of Removal	Uses
VV-L-800 (Cont)				at temperatures below -40° F. is limited by a number of machine design factors and should be proved for any specific item application by test before adoption.				components of internal combustion engines, and wherever a general purpose low temperature lubricating oil is required.
MIL-L-21260 LUBRICATING OIL, INTERNAL COMBUSITON ENGINE, PRESERVATIVE AND BREAK-IN	Type I & Type II (P-10) Grade 10		400		-25	Any method at room temperature	Petroleum solvents. Removal before use is generally not required.	Type I. For lubrication of spark ignition type of reciprocating internal combustion engines, operating below 150 p.s.i., BMEP, for preservation, use, for engine break-in and for operation until the first scheduled oil change.
	Grade 30		425		0			
	Grade 50 (Type I only) (P-10)		450		15			

TABLE XXXV. Types of preservatives. - Continued

Specification No.	Type and P-No.	Flow Point, °F.	Flash Point, °F.	Melting Point, °F.	Pour Point, °F.	Method and Temperature of Application	Method of Removal	Uses
MIL-L-21260 (Cont)								Type II. Same usage as Type I, except for supercharged compression-ignition engines operating at approximately 150 p.s.i., BMEP, and above.
MIL-C-6529 CORROSION PREVENTIVE, AIRCRAFT ENGINE. (For Aeronautical Applications See P-10 MIL-C-8188 below)	Type I Concentrated Material (P-10)		400		10	Brush, dip, spray, flow-coating, slushing, filling, or flushing and fogging.	Petroleum solvents vapor degreasing (Removal not usually required.)	Corrosion preventive for piston engines when used in MIL-L-6082 oil and for jet engines when used in MIL-O-6081 oil.
	Type II Ready mixed for reciprocating aircraft engines.		400		10			Corrosion-preventive lubricant for reciprocating aircraft engines.

TABLE XXXV. Types of preservatives. - Continued

Specification No.	Type and P-No.	Flow Point, °F.	Flash Point, °F.	Melting Point, °F.	Pour Point, °F.	Method and Temperature of Application	Method of Removal	Uses
MIL-C-6529 (Cont)	Type III Ready mixed for turbo jet aircraft engines.		400		10			Corrosion-preventive lubricant for jet aircraft engines which require use of MIL-O-6081 oil.
MIL-C-8188 CORROSION-PREVENTIVE OIL, GAS TURBINE ENGINE, AIRCRAFT, SYNTHETIC BASE (For Processing Army Helicopter Engines).	Grade A High Temperature Oil. Grade B Low Temperature Oil.		400		-75	Filling.	Draining.	For preservation of turboprop and turbojet engines using MIL-L-7808 oils. Use should not exceed 20 hours as an aircraft engine lubricant. Will be used for both preservation and final acceptance runs of aircraft engines requiring the use of specification MIL-L-7808 oils.
MIL-G-23827 GREASE, AIRCRAFT AND INSTRUMENT,	One grade only. (P-11)					Brush, swab or grease gun at room temperature.	Toluene, benzene or hot SAE oil followed	For ball, roller and needle bearings and gears; and on sliding

TABLE XXXV. Types of preservatives. - Continued

Specification No.	Type and P-No.	Flow Point, °F.	Flash Point, °F.	Melting Point, °F.	Pour Point, °F.	Method and Temperature of Application	Method of Removal	Uses
MIL-G-23827 (Cont) GEAR AND ACTUATOR SCREW. (For Aeronautical Applications)							by solvent. Removal not generally required.	and rolling surfaces of such equipment as instruments, cameras, electronic gear and aircraft control systems, during high and low temperature operations.
MIL-G-10924 GREASE, AUTOMOTIVE AND ARTILLERY.	One grade only (P-11)					Brush, grease gun or swabbing at room temperature.	Toluene, benzene or hot oil followed by agitated petroleum solvent rinse (removal not usually required).	For lubrication of automotive and artillery equipment operating temperature range of -65° F. to +175° F.
MIL-G-81322 GREASE, AIRCRAFT, GENERAL PURPOSE WIDE TEMPERATURE RANGE	One grade only (P-11)					Brush or grease gun.		In applications where operation at temperatures as low as -65° F. (-54° C.) and as high as 350° F. (117° C.) may be required.

TABLE XXXV. Types of preservatives. - Continued

Specification No.	Type and P-No.	Flow Point, °F.	Flash Point, °F.	Melting Point, °F.	Pour Point, °F.	Method and Temperature of Application	Method of Removal	Uses
MIL-G-81322 (Cont)								It is specifically designed for wheel bearings in internal brake wheel assemblies, anti-friction bearings, gear boxes, and plain bearings.
MIL-C-10382 CORROSION, PREVENTIVE, PETROLEUM, SPRAYING APPLICATION, FOR FOOD HANDLING MACHINERY AND EQUIPMENT.	One grade only (P-14)		100 min.	150 min.		Spraying at room temperature.	Hot water 160° F.	For use on food handling machinery and equipment. The residual material after evaporation shall be harmless if inadvertently ingested by personnel.
HYDRAULIC PRESERVATIVE OILS (These oils have not been listed because of variations in systems requirements.)	(P-15)							

TABLE XXXV. Types of preservatives. - Continued

Specification No.	Type and P-No.	Flow Point, °F.	Flash Point, °F.	Melting Point, °F.	Pour Point, °F.	Method and Temperature of Application	Method of Removal	Uses
MIL-L-6085 LUBRICATING OIL, INSTRUMENT, AIRCRAFT, LOW VOLATILITY	One grade only. (P-17)		365		-70	Applied by dipping, spraying, or squirt oiler.	Removal not required. But, if necessary, solvent rinse should be sufficient.	For use in aircraft instruments, electronic equipment, or where a low evaporation oil is required for both high and low temperature application, and where oxidation and corrosion resistance are desired.
MIL-P-3420 PACKAGING MATERIALS, VOLATILE CORROSION INHIBITOR TREATED, OPAQUE	Type 1 (P-18)					Surface covered with a carrier, (with a volatile corrosion inhibitor) at room temperature in accordance with MIL-I-8574.	Any safe method at room temperature.	Type I. For general protection against corrosion of ferrous aluminum, aluminum base alloys. Also, zinc plate, cadmium, lead-base alloys, and zinc-base alloys. See MIL-I-8574.
	Type II							Type II. Shall not be used where equipment and parts include nonmetallic

TABLE XXXV. Types of preservatives. - Continued

Specification No.	Type and P-No.	Flow Point, °F.	Flash Point, °F.	Melting Point, °F.	Pour Point, °F.	Method and Temperature of Application	Method of Removal	Uses
MIL-P-3420 (Cont)	Type II							components and where plastic barrier materials are involved.
MIL-F-22019 FILM, TRANSPARENT, FLEXIBLE, HEAT-SEALABLE, VOLATILE CORROSION INHIBITOR TREATED.	(P-18)					Applied as a barrier material in accordance with applicable submethods set forth in MIL-P-116.		Where transparency is desired to facilitate inspection of the item without disturbing the package. Also intended for shipboard use.
MIL-B-22020 BAGS, TRANSPARENT, FLEXIBLE, SEALABLE, VOLATILE CORROSION INHIBITOR TREATED.	(P-18)							Same as above. Note. Maximum weight of the contents in each bag should not exceed 5 pounds.
MIL-I-22110 INHIBITORS, CORROSION, VOLATILE, CRYSTALLINE.	Type I, For general application (low volatility). (P-18)							A preservative for ferrous aluminum, aluminum-base alloys, and components containing zinc plate, cadmium zinc-base alloys, magnesum-base alloys, lead-base alloys, and alloys of other metals (including solders and brazing alloys having less than 30% of zinc

TABLE XXXV. Types of preservatives. - Continued

Specification No.	Type and P-No.	Flow Point, °F.	Flash Point, °F.	Melting Point, °F.	Pour Point, °F.	Method and Temperature of Application	Method of Removal	Uses
MIL-I-22110 (Cont)								and 9% of lead. Direct contact with nonferrous metals, except aluminum and aluminum-base alloys, shall be avoided. Direct contact with nonmetals shall be avoided, unless the specific inhibitor has passed the compatibility test specified in MIL-I-8574.
	Type II For limited application (high volatility).							Same use as Type I, except that it must be used in sealed water-vaporproof containers.
MIL-P-16173 CORROSION PREVENTIVE COMPOUND SOLVENT, CUT-BACK, COLD-APPLLICATION.	Grade 4 Transparent Non-Tacky Film (P-19)	175	100			Dipping and brushing at room temperature.	Petroleum solvents or vapor degreaser.	General purpose indoor and limited outdoor preservation or corrodible metals with or without an overwrap where tack-free and transparent coating is required; nonmiscible with lubricating oil.

TABLE XXXV. Types of preservatives. - Continued

Specification No.	Type and P-No.	Flow Point, °F.	Flash Point, °F.	Melting Point, °F.	Pour Point, °F.	Method and Temperature of Application	Method of Removal	Uses
MIL-I-23310 INHIBITORS, CORROSION, VOLATILE, OIL TYPE (For Navy use.)	Grade 1 Low Viscosity Oil. (P-20)		300		-20	Fogging.	Removal from combustion chamber not required.	Use as a preservative in "closed" systems constructed essentially of ferrous alloys, with components containing aluminum and aluminum-base alloys.
	Grade 2 Medium Viscosity Oil. (P-20)		300		0			
MIL-P-46002 PRESERVATIVE OIL, CONTACT AND VOLATILE CORROSION INHIBITED	Grade 1 Light Viscosity Oil. (P-20)		240		-50	Filling. Note. This oil is not effective unless an adequate reservoir of oil can be maintained. A minimum of 0.15 quart for Grade 1 and 0.25 quart for Grade 2 should be used for each cubic foot or area to be protected.		Use in the preservation of inclosed systems where the volatile components will provide protection above the oil level. May also be effectively used as a contact preservative. Is not intended for use as an operational preservative oil and should not be used in applications where
	Grade 2 Medium Viscosity Oil. (P-20)		250		-10			

TABLE XXXV. Types of preservatives. - Continued

Specification No.	Type and P-No.	Flow Point, °F.	Flash Point, °F.	Melting Point, °F.	Pour Point, °F.	Method and Temperature of Application	Method of Removal	Uses
MIL-P-46002 (Cont)								magnesium, cadmium plated, or rubber components are present.
MIL-C-16173 CORROSION PREVENTIVE COMPOUND, SOLVENT, CUTBACK, COLD APPLICATION	Grade 5 Pressure Steam Removable Film (P-21)		100° F.			Dipping, brushing, spraying of exterior surfaces and flashing, tilling, or slushing of interior surfaces at room temperature (40° F. or higher).	Vapor degreasing solvent, hot water or low pressure steam.	Where fresh or salt water must be displaced from corrodible surfaces; for protecting interior surfaces of materiel under cover for limited periods; and for protection of critical bare steel or phosphated surfaces for extended periods when packaged with satisfactory barrier materials. Used in lieu of grade 3, MIL-C-16173, where chemical boilout cannot be used for removal.

NOTE. Hydraulic preservative oils have not been listed because of variations in system requirements. Hydraulic preservatives used shall be subjected to approval by the procuring agency.

5.5.4.1 Contact-type preservatives. Contact-type preservatives are generally used when the surface of the item is of such a chemical nature that the use of a preservative will provide a protective barrier between the item surface and the environment that surrounds it. These contact preservatives provide effective protection because of their ability to flow over and into all accessible areas of exposed surfaces and because they resist the corroding effect of moisture. These preservatives retard the effects of corrosive elements of the atmosphere until chemical or physical breakdown occurs. Contact preservatives are four basic types: (1) thin-film, solvent cutback, cold application; (2) petroleum base, hot application; (3) oils, rust inhibited, cold application; (4) special purpose, cold application. All of these preservative materials have their peculiar characteristics and are capable of protecting for varying periods of time and under a wide range of severity of exposure conditions.

5.5.4.2 Volatile corrosion inhibitors (VCI). Materials described as vapor phase inhibitors were developed to protect ferrous alloys during storage and shipment. These were a class of substituted ammonium nitrites, with a significant but controlled vapor pressure, whose vapors possess definite corrosion inhibitive characteristics. Such materials are stable chemical salts usually formed from a volatile acid and a volatile base. The resulting vapor pressure may vary considerably between salts, but is ordinarily low in order to assure reasonable persistence in a nonhermetic closure. The mechanism of the vaporization of the salt appears to involve its hydrolysis in the presence of moisture and an equilibrium recombination within and on surfaces in the enclosure. In general, good chemical stability appears to depend on a reasonable balance of volatility between the acid and base involved; certain amine nitrites are particularly effective. VCI protection is equal to, or better than, that provided by the more commonly used P-type preservative compounds. VCI provides good protection to areas of an item where it would be impossible or impractical to apply a grease- or oil-type preservative. This material has been successfully used in the prevention of ferrous parts of assemblies under controlled conditions of application. VCI packaging materials have also been used for the preservation of parts of assemblies containing cadmium, lead, zinc, or magnesium of less than 15 percent alloying content. Oil with VCI is available for use as a preservative in enclosed systems where the VCI will provide protection above the oil level. MIL-P-46002 covers one such application. VCI oil can also be effectively used as a contact preservative. It should not be used in applications where magnesium, cadmium-plated, or rubber components are present. Information on the use of VCIs is not yet complete enough to permit general uncontrolled use of this material, although the successful use of the material eliminates the need for difficult and expensive depreservation when putting the item in use. VCIs, which should be applied only to specific items, are subject to the limitations of MIL-I-8574. Care must be taken in relation to assemblies which may contain plastics, painted parts, or components of natural or synthetic rubber. Assemblies should not be packaged with VCI if any of the parts are made of these materials until proof is established that they have passed the compatibility test required by MIL-I-8574. In addition to the previously stated limitations, VCI methods should not be used on the following general types of items until the protection problems have been resolved.

a. Items made of, or containing, a substantial percentage of copper.

b. Optical items, unless specifically authorized by service or agency concerned.

c. Categories of items not specifically approved by service or agency concerned.

VCI materials are supplied in the form of coated and impregnated wrapping papers, barrier materials, fiberboard laminates, flexible transparent films, crystalline solids, fabricated bags, treated lubricating oils, and other forms.

5.6 Barrier materials and cushioning materials. This section provides data to aid the packaging engineer in the selection of barrier and cushioning materials. As discussed in sec 5.1, packaging materials must be selected in accordance with the method of preservation prescribed.

5.6.1 Barriers. The design of packages intended to conform to DOD policy considers, in the majority of cases, the use of one or more barriers.

5.6.1.1 Types and purposes. The properties of the principal types of barriers are given in table XXXVI. Included are dual purpose materials that also serve as cushioning. Table XXXVII gives properties of packaging films, while table XXXVIII relates the wrapping and marking characteristics of packaging films. Barriers fall into the following four general classifications:

a. Greaseproof. These barriers are used when the item being packaged has been treated with a transferable grease, oil, or compound. Greaseproof barriers may be wraps, or where economy and adequacy dictate, envelopes or bags. To retain the preservative in intimate contact with the item and prevent other components of the package from absorbing the preservative, these barriers are interposed between the preservative-coated item and the package.

b. Neutral and cushioning wraps. Although these materials are not true barriers, they are many times treated as such. Used as a barrier, they are employed to prevent surfaces of packaged items from coming into contact with elements of the package which by their chemical nature could cause corrosion. Where no grease- or water-proofness is required, these wraps are the most economical.

c. Waterproof and greaseproof barriers. These are used when waterproofness is a requirement and when the nature of the item being packed is not critical enough to require a moisture-vaporproof barrier. Barriers in this group may range from plastic-coated kraft papers to semirigid metal and fiber cans.

d. Greaseproof, waterproof, moisture-vaporproof barriers. These are used when maximum protection of the item is required. Included in this group are plastic-foil-scrim-plastic, plastic-foil-kraft-paper, metal-end-fiber cans, and rigid metal containers. Greaseproof barriers are selected for preservative retention as their principal function. Waterproof barriers are used for a variety of items--paper gaskets, metallic components having finishes and surface treatments rendering them comparatively immune to corrosion, or where a moderate amount of corrosion can be tolerated. Moisture-vaporproof barriers are used where the lighter preservatives must be used on highly finished surfaces and also where, because of the nature of the items, no preservative can be used. In such cases, the ultimate package is usually desiccated to attain and maintain a low enough relative humidity to prevent any corrosion that would affect the use of the item (see 5.12).

5.6.1.2 Selection. Although many considerations must be applied in the selection of a proper barrier, the following factors usually apply:

a. The barrier must provide neutrality, grease-, water-, watervapor-, or gas-proofness indicated by the submethod of packaging being designed.

b. The type, grade, class, and amount of the barrier selected must be of sufficient strength and quantity to protect the item.

c. After determination of the barrier, strength, and any cushioning factor used, the most economical material having the desired qualities shall be selected (see fig 22).

TABLE XXXVI. Specification requirements for barrier materials.

Specification	Type	Characteristics			Other	General Use
		Bursting Strength (points)	Mimimum Tearing Strength (grams)	Minimum Tensile Strength (lb/in. width)		
MIL-B-121 BARRIER MATERIAL, GREASEPROOFED, WATERPROOFED, FLEXIBLE	Type 1 - Heavy Duty					Flexible, greaseproof, waterproof barrier material for the protection of military supplies and equipment during transportation and storage under all climatic conditions. Grade A, Class 1 material is primarily used to fabricate greaseproof, waterproof bags. It may also be used as intimate wrap. Grade A, Class 2 material is used as intimate wrap to protect preservatives, and to insulate metal surfaces from hygroscopic materials. Grade C material is primarily used as an outer wrap and sealed by wax dip, used as intimate wrap only for critical items with soft preservatives.
	Grade A-Greaseproofed, waterproofed and noncorrosive.					
	Class 1--Heat sealable, nonstretchable.	45	150	25		
	Class 2--Nonheat sealable, stretchable.	45	150	23		
	Grade C-Greaseproofed, waterproofed, noncorrosive, moldable and self-adhering.					
	Class 1--Self-adhering coating applied on nongreaseproof side only.	45	500	20		

TABLE XXXVI. Specification requirements for barrier materials. - Continued

Specification	Types	Characteristics: Bursting Strength (points)	Characteristics: Minimum Tearing Strength (grams)	Characteristics: Minimum Tensile Strength (lb/in. width)	Other	General Use
MIL-B-121 (Cont)	Class 2--Self-adhering coating applied on both sides.	45	500	20		
	Type II - Medium Duty					
	Grade A-Greaseproofed, waterproofed, and noncorrosive.					
	Class 1--Heat sealable, nonstretchable.	30	100	17		
	Class 2--Nonheat sealable, stretchable.	25	100	15		
MIL-P-130 PAPER, WRAPPING, LAMINATED	Type I - Heavy Duty	40	250	40		Protective cover or wrapper over greaseproof wrappers. Added protection against mechanical damage.
	Type II - Medium Duty	35	200	30		

TABLE XXXVI. Specification requirements for barrier materials. - Continued

Specification	Types	Characteristics: Bursting Strength (points)	Characteristics: Minimum Tearing Strength (grams)	Characteristics: Minimum Tensile Strength (lb/in. width)	Other	General Use
MIL-P-130 (Cont)	Type III - Light Duty	30	150	20		
MIL-B-131 BARRIER MATERIAL. WATER-VAPORPROOF, FLEXIBLE, HEAT SEALABLE	Class 1-- Plastic and nonwoven. General use.			50	Good resistance to delamination.	Where heat sealable, flexible barrier is required. Water-vaporproof.
	Class 2-- Kraft, limited use.			25	Good resistance to delamination.	For use where weight inside barrier does not exceed 10 pounds with combined dimension not to exceed 42 inches. Not to be used in floating bag applications, packaging below 32° F. where manipulation is required, or where double seam junctions are required.
	Class 3-- Scrim (woven fabric), general use.					Where a scrim (woven fabric) backing is required.

TABLE XXXVI. Specification requirements for barrier materials. - Continued

Specification	Types	Characteristics: Bursting Strength (points)	Characteristics: Minimum Tearing Strength (grams)	Characteristics: Minimum Tensile Strength (lb/in. width)	Other	General Use
MIL-P-17667 PAPER, WRAPPING, CHEMICALLY NEUTRAL (NONCORROSIVE)	Type I - Flat (Basic weight 500 sheets 24"x36")				Water resistance (dry indicator)	Initial wrap of items requiring a noncorrosive, dust protective wrap applied prior to or as part of unit packaging where a greaseproof wrap is not needed.
	15 lb	10	15	5	3 sec	
	20 lb	21	45	10	15 sec	
	55 lb	39	100	20	40 sec	
	80 lb	56	160	35	50 sec	
	Type II - Creped					
	Class 1--Creped in 1 direction					
	35 lb	14	90	8	15 sec	
	50 lb	20	130	10	25 sec	
	70 lb	27	160	18	40 sec	
	Class 2--Creped in 2 directions					
	20 lb	14	40	3	5 sec	
	40 lb	22	90	6	25 sec	
	73 lb	30	150	11	40 sec	
MIL-F-22019 FILM, TRANSPARENT, FLEXIBLE, HEAT	One type only	60 psi	20 (Elmendorf)			For use in short-term storage of items where transparency is desired

TABLE XXXVI. Specification requirements for barrier materials. - Continued

Specification	Types	Characteristics: Bursting Strength (points)	Characteristics: Minimum Tearing Strength (grams)	Characteristics: Minimum Tensile Strength (lb/in. width)	Other	General Use
MIL-F-22019 (Cont) SEABLE, VOLATILE CORROSION INHIBITOR						to facilitate inspection.
MIL-B-22191 BARRIER MATERIAL, TRANSPARENT, FLEXIBLE, HEAT SEALABLE	Type I - Watervaporproof, Waterproof, Greaseproof				WVTR: 0.05 gm/ 100 sq in./24 hr, max.	For use in applications where water-vapor impermeability is required.
	Type II - Waterproof, Greaseproof					For use in applications where greaseproofness and waterproofness are required.
	Type III - Waterproof					For use in applications where protection against water or solid contamination is required.
NNN-P-40 PAPER, LENS	Type I - Wrapping and cleaning lenses and other glass and highly polished surfaces.					

TABLE XXXVI. Specification requirements for barrier materials. - Continued

Specification	Types	Characteristics			Other	General Use
		Bursting Strength (points)	Minimum Tearing Strength (grams)	Minimum Tensile Strength (lb/in. width)		
NNN-P-40 (Cont)	Class 1--Lightweight 5.5 lb/24"x 36"--500 sheets.	30 (10 sheets)			pH 5.0 to 7.5	Cleaning and protecting lenses and other glass and highly polished surfaces.
	Class 2--Heavyweight 8.5 lb/24"x 36"--500 sheets.			450 gm/ 15-mm width	pH 5.0 to 7.5	
	Class 3--Heavyweight silicone treated 11.8 lb/24"x36"--500 sheets.	40 (10 sheets)			pH 5.0 to 7.5	
	Class 4--Heavyweight, wet strength--10.4 lb/24"x 36"--500 sheets.			1800 gm/ 15-mm (dry, length) 600 gm/ 15-mm (dry, width) 450 gm/ 15-mm (wet, length)	pH 5.0 to 7.5	

TABLE XXXVI. Specification requirements for barrier materials. - Continued

Specification	Types	Characteristics			Other	General Use
		Bursting Strength (points)	Minimum Tearing Strength (grams)	Minimum Tensile Strength (lb/in. width)		
NNN-P-40 (Cont)	Class 5--Lightweight, wet strength--7.0 lb/24"x 36"--500 sheets.			700 gm/ 15-mm (dry, length) 100 gm/ 15-mm (dry, width) 150 gm/ 15-mm (wet, length)	pH 4.5 to 7.5	
	Type II - Wrapping and cleaning of all coated optics--11.5 lb/24"x36"--500 sheets	50			pH 6.0 to 7.0	
UU-P-268 PAPER, KRAFT, UNTREATED, WRAPPING, (24" x 36"--500)	Grade A-No. 1 kraft paper					Used where a chemically neutral or greaseproof and waterproof barrier is not required.
	35 lb	32	85			
	60 lb	54	150			
	80 lb	72	210			
	Grade B-No. 2 kraft paper					

TABLE XXXVI. Specification requirements for barrier materials. - Continued

Specification	Types	Characteristics: Bursting Strength (points)	Characteristics: Minimum Tearing Strength (grams)	Characteristics: Minimum Tensile Strength (lb/in. width)	Other	General Use
UU-P-268 (Cont)	30 lb	21	50			
	40 lb	28	75			
	50 lb	35	100			
	60 lb	42	130			
	70 lb	49	160			
	80 lb	56	190			
L-P-378 PLASTIC SHEET AND STRIP (POLYOLEFIN)	Type I - Normal Impact Strength Polyethylene			1700 psi	WVTR: 10 gm/100 sq in./24 hr, max.	For use in general purpose packaging where a high degree of moisture resistance, moderate vapor resistance, and dust protection is required. Not intended for use where special grease or oil resistant properties are required.
	Type II - High Impact Strength Polyethylene			1700 psi	WVTR: 10 gm/100 sq in./24 hr, max.	
	Type III - Polypropylene			4500 psi		
	Type IV - Heat Shrinkable Polyethylene			1700 psi		
	Type V - Heat Shrinkable Weatherable Polyethylene			1900 psi		

TABLE XXXVI. Specification requirements for barrier materials. - Continued

Specification	Types	Characteristics			Other	General Use
		Bursting Strength (points)	Minimum Tearing Strength (grams)	Minimum Tensile Strength (lb/in. width)		
PPP-B-1055 BARRIER MATERIAL, WATERPROOF, FLEXIBLE	B-1--Baling and interior wraps.			18		For use in a packaging application which requires waterproofness plus a high degree of resistance to permeation by water vapor.
	B-2--Baling and interior wraps.			12		
	B-3--Baling and interior wraps.			12		
	C-1--Interior wraps.			20		
	C-2(a)--Crate liners and interior wraps.			36		
	E-1--Interior wraps and crate liners.			36		
	E-2--Interior wraps, crate liners, shrouds and balancing.			36		
	H-2--Case liners.		400	25		
	H-3(a)--Case liners.			32		
	H-4--Case liners.			28		
	H-5--Case liners, shrouds and crate liners.		400	12		

TABLE XXXVI. Specification requirements for barrier materials. - Continued

Specification	Types	Characteristics			Other	General Use
		Bursting Strength (points)	Minimum Tearing Strength (grams)	Minimum Tensile Strength (lb/in. width)		
PPP-B-1055 (Cont)	L-2(b)--Case liners and crate liners.			36		
	L-4--Temporary tarpaulin.			36		
	M-1--Case liners, shrouds and crate liners.					
	P-1--Ammunition container.		400	40		
QQ-A-1876 ALUMINUM FOIL	Type I - Rolls Type II - Interfolded Flat Sheets					Grade A for food handling and processing applications. Grade B for applications other than food handling or processing.
	Class 1--Flat sheets, 12"x10 3/4" Class 2--Flat sheets, 9"x10 3/4"					Used in place of Grade A (MIL-B-121) only after approval of processing agency of a noncorrosive barrier between a preserved surface and a surface that may cause corrosion. Direct contact with metals other than cadmium, magnesium,

TABLE XXXVI. Specification requirements for barrier materials. - Continued

Specification	Types	Characteristics: Bursting Strength (points) min	Characteristics: Bursting Strength (points) max	Characteristics: Minimum Tearing Strength (grams)	Characteristics: Minimum Tensile Strength (lb/in. width)	Other	General Use
QQ-A-1876 (Cont)							or zinc should be avoided where water is present to prevent electrolytic action.
	Type III - Single-ply Flat Sheets; thickness inch	min	max				
	.0008	8	23				
	.0010	11	31				
	.0015	22	35				
	.0020	40	90				
	.0030	75	150				
	.0040	110	222				
	.0050	140	280				

TABLE XXXVII. Properties of packaging films.

Material ➡		Nylon 6	Nylon 66	Nylon 610	Nylon 12	Polycarbonate	Polyester [a]	Polystyrene (oriented)
GENERAL CHARACTERISTICS	ASTM							
Method of Production	—	Extr	Extr	Extr	Extr	Extr, cast	Extr	Extr
Forms Available	—	Sheets, rolls, tapes	—	—	Sheet, rolls, tapes	Sheet, rolls	Sheet, rolls	Sheet, rolls
Clarity	—	Transp	Transp	Transp, transl	Transp, transl	Transp, transl	Transp, opaque	Trp, trl, opaque
Min Thickness, in.	—	0.0005	—	—	0.0005	0.0005	0.00015	0.001
Max Width, in.	—	120	—	—	120	54	55	40
Area Factor, 1000 sq in./lb/mil	—	24.5	24.3	25	27.3	23.1	20	26.1
PHYSICAL AND MECHANICAL PROPERTIES								
Specific Gravity	D792	1.12	1.14	1.11	1.01	1.20	1.39	1.05–1.07
Tensile Strength, 1000 psi	D882	9–13	12	10	7-9	8	17–18	7–12
Elongation, %	D882	>400	>250	>250	120-350	85–105	70–130	3–10
Burst Str (Mullen), psi	D774	—	—	—	—	25–35	45	30–60
Tear Str (Elmendorf), gm/mil	D689	50	50	70	—	10–16	18	2–8
Fold Endurance	D643	Exc	Exc	Exc	Exc	250–400	Exc	—
Heat Sealing Range, F	—	400–450	490–540	420–470	350–400	400–430	490	220–300
Water Absorp (24 hr), %	D570	8.0	1.5	0.4	0.25	0.35	Nil	0.04–0.06
Water Vapor Perm, gm/100 sq in./24 hr/mil	E96	18.0 [b]	—	—	3.6-4.6	8.0	1.8	6.2
Gas Perm, cu cm/100 sq in./24 hr/mil	—							
Oxygen		2.6	2.5	4.5	51-89	142	5.7	213
Nitrogen		—	0.7	—	13-18	28	0.9	42
Carbon Dioxide		—	11	—	152-330	680	17.5	926
ELECTRICAL PROPERTIES								
Dielec Str (77F, 60 cps), v/mil	D149	480	385	470	—	3200	7500	400–600
Dielec Const (77F, 60 cps)	D150	4.8	4.0	3.6	4.2	3.09	3.25	2.4–2.7
Dissip Factor (77F, 60 cps)	D150	0.014–0.040	—	—	0.009	0.0003	0.0021	0.005
Surface Res, ohm	D257	—	—	—	6×10^{13}	1.4×10^{12}	$>1 \times 10^{17}$	—
CHEMICAL RESISTANCE								
Strong Acids	D543 or D1239	Poor	Poor	Poor	P–G	Good	Exc	Good
Strong Alkalis	—	Exc	Exc	Exc	Exc	Poor	Exc	Exc
Greases and Oils	—	Exc	Exc	Exc	Exc	Good	Exc	Good
Solvents	—							
Ketone and Ester		Exc	Exc	Exc	Exc	Fair	Exc	Poor
Chlorinated		—	—	—	Poor	Poor	Exc	Good
Hydrocarbon		Exc	Exc	Exc	Exc	Fair	Exc	Good
ENVIRONMENTAL PROPERTIES								
Max Cont Service Temp, F	—	380	300	300	230	270–280	250	160–180
Min Service Temp, F	—	<−100	<−100	<−100	−100	<−212	−80	—
Resistance to Sunlight	—	Fair	Fair	Fair	Fair	Fair	Fair	Fair
Dimensional Change, %	—	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Storage Stability	—	Exc	Exc	Exc	Exc	Exc	Exc	Good
Rate of Burning	—	Self-ext	Self-ext	Self-ext	Self-ext to slow burn	Slow	Self-ext	Slow

[a] Polyethylene terephthalate. [b] Procedure E.

TABLE XXXVII. Properties of packaging films. - Continued

Type ➡		Cellophane		Fluorocarbon			Polypropylene	
		Plain	Coated	CTFE	FEP	PVF	Set Cast	Biaxially Oriented
GENERAL PROPERTIES	**ASTM**							
Method of Production[a]		Extr	Extr	Extr	Extr	Extr	Extr, calndr	Extr
Forms Available		Sheet, rolls, tapes	Sheet, rolls	Rolls	Rolls	Rolls	Sheets, rolls, tapes	Sheets, rolls
Clarity[b]		Trp	Trp	Trp	Trp	Trp	Trp	Trp
Min Thickness, in.		0.0009	0.0009	0.0005	0.005	0.0005	0.00075	0.0005
Max Width, in.		60	46	48	48	48	60	72
Area Factor, 1000 sq in./lb/mil		12-22	12-25	13.5	13	7	31	31
PHYSICAL PROPERTIES								
Specific Gravity	D792	1.45	1.40-1.55	2.1	2.15	1.5	0.90	0.90
Ten Str, 1000 psi	D882	8-19	7-16	5-8	3-3.5	7-18	4-10	18-32
Elong, %	D882	15-25	15-50	50-150	300-400	115-250	>400	40-80
Burst Str (Mullen), psi	D774	45-70	45-70	23-31	10-15	19-70	—	—
Tear Str (Elmendorf), gm/mil	D689	2-10	2-15	10-26	100-150	12-100	20-100	5-10
Fold Endurance	D643	7000-22,000	—	Good	4000	—	Excellent	Excellent
Heat Seal Range, F		Not sealable	200-350	370-500	600-700	—	320	—
Water Absorp (24 hr), %	D570	High	High	Negligible	0.01	0.05	Negligible	Negligible
Water Vapor Perm, gm/100 sq in./24 hr/mil	E96	High	0.2-1.0	0.025	0.40	—	0.4-1.0	.25-.5
Gas Perm, cu cm/100 sq in./24 hr/mil								
Oxygen		2	Low	7-12	950	3.2	150	150
Nitrogen		3	Low	2.5	360	0.3	—	—
Carbon Dioxide		39	Low	16-40	1850	11.1	—	—
CHEMICAL RESISTANCE								
Strong Acids	D543 or D1239	Poor	—	Excellent	Excellent	Excellent	Excellent	Excellent
Strong Alkalis		Poor	—	Excellent	Excellent	Excellent	Excellent	Excellent
Greases and Oils		Excellent	—	Excellent	Excellent	Excellent	Good	Good
Solvents								
Ketone and Ester		Excellent	—	Good	Good	Excellent	—	—
Chlorinated		Excellent	—	Good	Good	Excellent	—	—
Hydrocarbon		Excellent	—	Excellent	Excellent	Excellent	Good	—
PERMANENCE								
Max Cont Svc Temp, F		375	300-375	300-390	400	225	285	—
Min Svc Temp, F		0	0	−320	−400	−100	—	<−40
Resistance to Sunlight		Good	Good	Excellent	Excellent	Excellent	Fair	Fair
Dimensional Change, %		3-5	2-5	Nil	Nil	Nil	Nil	—
Storage Stability		Good	Good	Excellent	Excellent	Excellent	Excellent	Excellent
Flammability (rate of burning)		Fast	Fast	Nil	Nil	Slow	Slow	Slow

[a] Key: cast = casting; calndr = calendering; extr = extrusion. [b] Key: trp = transparent; trl = translucent.

TABLE XXXVII. Properties of packaging films. - Continued

Material→	ASTM	Polyethylene Type I	Polyethylene Type II	Polyethylene Type III	Polyvinyl Chloride (incl copolymers) Rigid	Polyvinyl Chloride (incl copolymers) Nonrigid	Rubber Hydro-chloride	Polyimide
GENERAL CHARACTERISTICS								
Method of Production	—	Extr, calndr	Extr, calndr	Extr	Cast, calndr, extr	Cast, calndr, ext	Cast	Cast
Forms Available	—	Sheets, rolls, tapes, tubes	Sheets, rolls, tapes	Sheets, rolls, tapes	Sheets, rolls, tapes	Sheets, rolls, tapes, tubes	Sheets, rolls, tapes	Sheets, rolls, tapes
Clarity	—	Transp, transl, opaque	Transp, transl, opaque	Transp, transl	Transp, transl, opaque	Transp, transl, opaque	Transp, transl, opaque	Transp
Min Thickness, in.	—	0.00075	0.00075	0.00075	0.001	0.005	0.0004	0.0005
Max Width, in.	—	72	60	60	54	104	60	—
Area Factor, 1000 sq in./lb/mil	—	30	30	29	19.5–22.5	20–23	24	19.4
PHYSICAL AND MECHANICAL PROPERTIES								
Specific Gravity	D792	0.92	0.935–0.938	0.940–0.945	1.36–1.50	1.15–1.50	1.12–1.15	1.42
Tensile Strength, 1000 psi	D882	1.6–3.0	2.5–3.5	3.5–8.0	6.5–8.5	1–5	5–6	24–25
Elongation, %	D882	300–800	>200	50–400	5–25	50–500	350–500	65–70
Burst Str (Mullen), psi	D774	10–15	—	—	—	9–20	—	75
Tear Str (Elmendorf), gm/mil	D689	100–125	93–97	10–350	20–150	30–1400	1000–1500	—
Fold Endurance	D643	Good	Good	Good	Poor	Good	—	Good
Heat Sealing Range, F	—	400–450	250–375	250–375	260–400	200–400	225–350	Not poss
Water Absorp (24 hr), %	D570	0.01	Neglig	Neglig	Neglig	Neglig	Neglig	2.9
Water Vapor Perm, gm/100 sq in./24 hr/mil	E96	1.5	0.5–0.7	0.3–0.4	0.5 (0.005 in.)	0.7 (0.005 in.)	0.5–15.5	5.4
Gas Perm, cu cm/100 sq in./24 hr/mil	—							
Oxygen		5.50 (1 mil)	280 (1 mil)	200 (1 mil)	3 (0.005 in.)	—	2–405	25
Nitrogen		300 (1 mil)	—	42 (1 mil)	—	—	—	6
Carbon Dioxide		2500 (1 mil)	990 (1 mil)	580 (1 mil)	11 (0.005 in.)	—	36–2616	45
ELECTRICAL PROPERTIES								
Dielec Str (77 F, 60 cps), v/mil.	D149	450	450	500	250–1300	250–1300	—	7000
Dielec Const (77 F, 60 cps)	D150	2.3	2.3	2.3	3.0–8.0	3.0–8.0	—	3.5 (1000 cps)
Dissip Factor (77 F, 60 cps)	D150	0.0005	0.0005	0.0005	0.009–0.16	0.009–0.16	—	0.003 (1000 cps)
Surface Res, ohm	D257	$>10^{16}$	$>10^{16}$	$>10^{16}$	—	—	—	$>10^{16}$
CHEMICAL RESISTANCE								
Strong Acids	D543 or D1239	Exc	Exc	Exc	Exc	Exc	Good	Exc
Strong Alkalis	—	Exc	Exc	Exc	Exc	Exc	Good	Poor
Greases and Oils	—	Fair	Fair	Fair	Good	Fair	Exc	Exc
Solvents	—							
Ketone and Ester		Good	Good	Good	Poor	Poor	Fair	Exc
Chlorinated		Fair	Fair	Fair	Fair	Fair	Fair	Exc
Hydocarbon		Fair	Fair	Fair	Exc	Good	Exc	Exc
ENVIRONMENTAL PROPERTIES								
Max Cont Service Temp, F	—	180	230	250	200–220	150–180	205	550
Min Service Temp, F	—	—70	<—100	<—100	—70	—50	—20	—450
Resistance to Sunlight	—	Fair	Fair	Fair	Good	Good	Fair	Exc
Dimensional Change, %	—	Nil	Nil	Nil	Nil	Nil	Slight	Nil
Storage Stabiltiy	—	Exc	Exc	Exc	Exc	Exc	Good	Exc
Rate of Burning	—	Slow	Slow	Slow	Self-ext	Self-ext	Self-ext	Self-ext

TABLE XXXVIII. Wrapping and marking characteristics of packaging films.

	Workability	Marking Ease	Sealing Method	Heat Shrinkable
Cellophane				
Plain	Excellent	Good	Adhesives	No
Coated	Excellent	Good	Heat or adhesives	No
Fluorocarbon				
CTFE	Good	Good[1]	Heat	No
FEP	Good	Good	Heat or adhesives[1]	No
PVF	Good	Good	Adhesives	Yes
Nylon	Good	Good	Heat	No
Polypropylene				
Set cast	Fair to good	Good	Heat	No
Biaxially oriented	Fair to good	Good	Heat or adhesives	Yes
Polycarbonate	Good	Good	Heat or adhesives	No
Polyester	Good	Good	Heat[2] or adhesives	Some types
Polystyrene (oriented)	Good	Good	Heat or adhesives	Yes
Polyethylene	Fair to good	Good[1]	Heat	Some types
Polyvinyl Chloride	Fair	Good[1]	Heat or adhesives	Some types
Rubber Hydrochloride	Fair	Good	Heat	Some types

[1]Requires special ink or must be specially treated.
[2]Requires special coating.

5.6.1.3 Item characteristics. The item characteristics that must be considered when choosing a barrier material are:

a. Chemical composition. The barrier material and the packaged item must be compatible to protect against deterioration and to prevent harmful interaction between the item and the barrier material.

b. Vulnerability to deterioration. The major types of deterioration and the degree to which the item is vulnerable must be known in order for the barrier material to provide adequate protection. The vulnerability of the barrier material must also be considered.

c. Construction. The major dimensions of the item must be known for determining the amount of barrier material and the type, sheet, bag form, or rigid container form that is required.

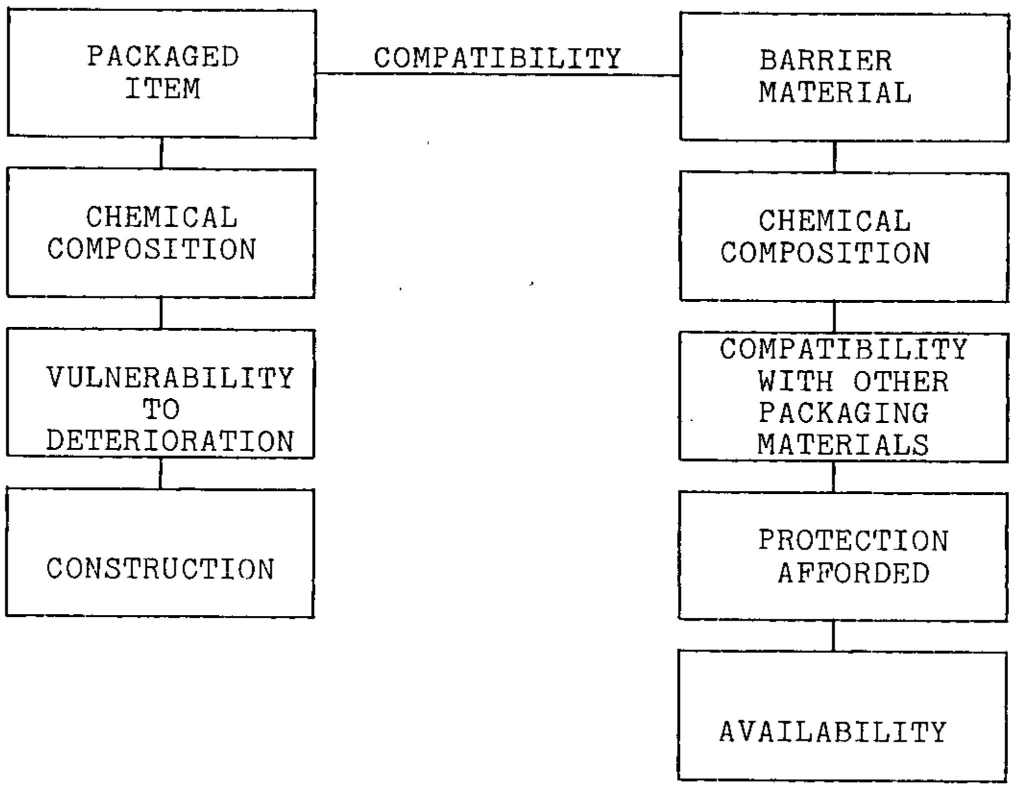


FIGURE 22. Selecting a barrier material.

5.6.1.4 Barrier material characteristics. The barrier material characteristics that must be considered when choosing a barrier material are:

a. Chemical composition. The barrier material and the packaged item must be compatible to protect against deterioration and to prevent harmful interaction between the item and the barrier material.

b. Compatibility with other packaging materials. The barrier material must be compatible with all other packaging materials with which it may come in contact, including preservatives and the outer wrap to prevent harmful interaction that may affect the integrity of the package.

c. Protection afforded. The protection afforded by a barrier material must be commensurate with the types of deterioration to which the item is vulnerable.

d. Availability. The availability of the barrier material must be known. If special equipment is required for applying the barrier material, it must be available and suitable for use with the item.

5.6.1.5 Static conductivity in plastic films. Unpleasant and sometimes dangerous electrostatic charges can build up on flexible plastic films. These charges are generated by friction from the film rubbing either against itself or against other non-metallic materials. This may occur during or after packaging. Static charges on large sheets of film can result in dangerous sparking, attraction, and holding of dust or other undesirable particles, or merely nuisances such as unpleasant shocks and difficulty in handling the film because of clinging. Electrical discharge should be a prime factor when considering barrier materials in the packaging of sensitive electronic devices, highly flammable materials, explosive chemicals, or munitions. Generally, some nonplastic barrier material should be used in these cases. Conductive plastic films and barriers made with such films are now commercially available and may be used in some applications where requirements for electrostatic-free packaging exist. Highly sophisticated parts such as are used in missile or electronics systems are especially susceptible to foreign particles which may adhere to films. When plastic films are used, special precautions should be taken to insure their cleanliness.

5.6.2 Cushioning. If items are subject to damage from impact, vibration, or simply from abrasion, they will require protection within the shipping container. There are numerous types of cushions ranging from excelsior and cellulosic wadding to springs and elaborate mechanical shock mounts. The paragraphs which follow discuss the functions of cushioning, the materials commonly used as cushions, and their applications.

5.6.2.1 Purpose. The purpose of cushioning is to insure adequate protection of the contents of a pack under particular circumstances such as:

a. Protection of delicate and fragile items against the effects of shock and vibration occurring during handling and transportation.

b. Protection of delicate and highly finished surfaces against abrasion.

c. Protection of small projections on items.

d. To prevent rupture or severe abrasion of greaseproof or waterproof barriers at points of contact with solid blocks or braces.

e. Protection of moisture-vaporproof barriers, at points of contact, from sharp edges of the item itself, packing materials, or container.

f. Protection at points of contact with wood blocking or bracing, and protection of strippable compound coating applied to large or heavy items.

g. To absorb liquids.

5.6.2.2 Properties.

5.6.2.2.1 Shock absorption and resilience. The properties of shock absorption and resilience vary for specific materials (see fig 23). One material may be an excellent cushion when used to protect small, light, fragile items, but this same material may be unsatisfactory when used to protect small, heavy, fragile items. The cushioning material must be able to absorb a series of shocks and must have ability to return to its original size and shape after each deformation. Cushioning material that settles down so that looseness develops is not entirely satisfactory. The tendency for a material to become permanently compressed under initial loadings can be offset to some extent by precompressing it when the item is packed.

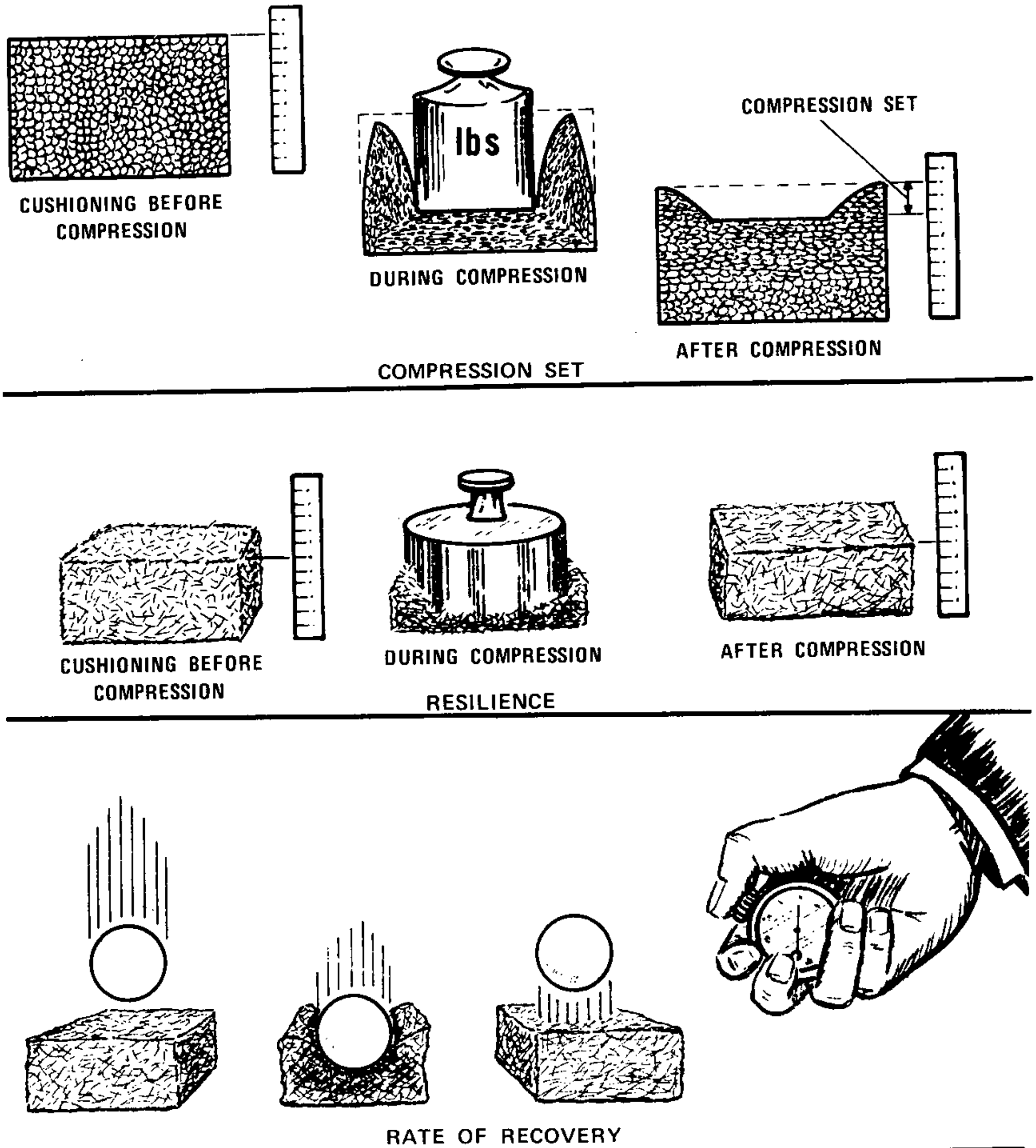


FIGURE 23. Characteristics of cushioning materials--compression set, resilience, and rate of recovery.

5.6.2.2.2 Texture and workability. The ability of cushioning materials to protect finished surfaces against abrasion is dependent on the texture of the materials. Materials such as creped cellulose wadding or cotton wadding are soft textured and can generally be placed in contact with easily marred surfaces. Generally, materials supplied in roll form are sufficiently pliable to be used without difficulty to cushion irregularly shaped items. These materials are readily used to make irregular surfaces regular and are used for wrapping small miscellaneous parts.

5.6.2.2.3 Water resistance. Generally, hygroscopic cushioning materials will have less protective or cushioning value at high moisture content than at low moisture content. For this reason, absorbent materials must be protected from long exposures to high humidities by means of a sealed watervaporproof barrier. Water-resistant materials respond less rapidly to moisture changes and should always be used when the application of a watervaporproof or waterproof barrier is not feasible. Most cushioning, when wet, will cause corrosion of contacting metal surfaces. Grease-proof or watervaporproof barriers are recommended to separate cushioning materials from metal surfaces.

5.6.2.2.4 Resistance to dust. Small particles become detached, during use, from most cushioning materials. Items having operational functions that can be harmed by dust particles should be wrapped or protected by other means against the entrance of dust. Items that will not be protected when in service need not be protected against dust particles when packaged for shipment.

5.6.2.2.5 Fungus resistance. Many cushioning materials can be made fungus-resistant by means of chemicals introduced during the manufacturing process. Materials so treated generally will not be affected by microorganisms during exposure to atmospheric conditions in which fungi usually flourish. Treated materials, however, are often very corrosive to metal surfaces and need to be isolated from them.

5.6.2.3 Selecting the cushioning material. There are several factors that need to be considered in selecting the appropriate cushioning material for a specific application. To design the cushioning requirements rationally, the fragility of the item must be known or estimated and the level of performance in rough handling must be established for the item. Since little is commonly known about the actual fragility of many military items, estimates must sometimes be used. For strategic military materiel, it is necessary to design for nearly 100 percent damage-free shipment. Because information is not available on the height of drop, kind of dropping surface, or probability of flat or edge drops that the item is likely to be subjected to during transportation, a height of drop is chosen for specifying the level of performance in handling operations based in general on item weight. Light, fragile instruments usually require the use of low density cushioning several inches thick having high resilience. The cushioning materials for heavy articles, however, need to be more dense and firm. Harsh abrasive materials should never contact highly finished surfaces. Such surfaces should be isolated from the cushioning with a barrier. Also, cushioning must be separated from corrodible surfaces. When cushioning must be inclosed within moisture-vaporproof barriers, cushioning with a low moisture content should be used. Cushioning used outside the barrier must retain a large portion of its cushioning properties when completely wet.

5.6.2.4 Types. Table XXXIX provides data on selected cushioning materials while table XL gives specifications for cushioning materials. Various cushioning materials, their advantages, and limitations are discussed in the paragraphs which follow.

5.6.2.4.1 Flexible corrugated paper. Flexible corrugated paper is economical, easy to obtain, moldable, and provides good cushioning for some lightweight objects. The cushioning effect is provided by the corrugations being crushed. However, if loaded to the extent that the corrugations are completely crushed on a single drop, most of its ability to protect the item in subsequent drops is lost.

5.6.2.4.2 Wool felt. Felt material is available in a variety of thicknesses and densities, and can be used for most cushioning applications. It is especially adaptable for padding hold-down cradles and braces to the item being secured. Generally, the felt materials are resilient and will withstand repeated deformations and abrasions without disintegrating. The material may be procured in rolls of flat or die-cut pads of various shapes and thicknesses.

5.6.2.4.3 Glass-fiber. Glass-fiber cushioning materials may be procured in densities ranging from a fraction of a pound per cubic foot to 12 to 15 pounds per cubic foot. Many thicknesses of sheets or die-cut pads are available in the various densities. This inorganic material is one of the more resilient cushioning materials and is nonhygroscopic; fire-, mold-, and fungus-resistant, as well as being resistant to most acids and alkalis. Although the fine fibers are easily handled, some grades are highly abrasive and susceptible to dusting, therefore requiring isolation from finished surfaces and item opening when critical. NOTE. Gloves must be worn to protect workers' skin from harmful effect of glass fibers. In some cases, dust masks may be needed.

TABLE XXXIX. General properties of selected cushioning materials.

Material	Compression set	Damping shock absorption[1]	Denisty	Dusting	General corrosive effect	Moisture absorption	Moisture content	Fungus resistance[4]	Low-temperature function
Animal hair, bonded sheet molded	Slight	Good	Varies	Slight	Slight	Slight	High	Poor	Fair[5]
Foam rubber, molded	Slight	Good	High	Some	Slight	Much	High	Poor	Good
Blown vinyl flexible foam	Some	Good	High	None	Slight	Much	Low	Good	Poor
Air pillow-vinyl cradle	None	Fair	Low	None	None	None	None	Excellent	Good
Vinyl cradles in suspension	None	Fair	Low	None	None	None	None	Excellent	Good
Springs	Neglig	Poor	---	None	None	None	None	Excellent	Good
Canvas slings	Neglig	Fair	---	None	None	Some	Varies	Poor	Good
Honeycomb, kraft paper	Much[3]	Excellent[3]	Low	None	Slight	Medium	Low	Poor	Good
Excelsior[6]	Much	Excellent	Average	Very high	Much	High	High	Poor	Poor
Shredded paper[6]	Much	Excellent	Average	Very high	Much	High	Varies	Poor	Good
Corrugated fiberboard[2]	Much	Excellent[3]	Low	Slight	None	High	Varies	Poor	Good
Plastic foams: Polyethylene, molded	Slight	Excellent	Average	Slight	None	Low	None	Good	Good

TABLE XXXIX. General properties of selected cushioning materials. - Continued

Material	Compression set	Damping shock absorption[1]	Density	Dusting	General corrosive effect	Moisture absorption	Moisture content	Fungus resistance [4]	Low-temperature function
Polyethylene, sheet	Slight	Excellent	Varies	None	None	Low	None	Good	Good
Polystyrene, molded	Varies	Good	Low	Slight	None	Slight	Low	Good	Good
Strands	Slight	Excellent	Low	Slight	None	Slight	Low	Good	Good
Resilient sheet	Slight	Excellent	Low	Slight	None	Slight	Low	Good	Good
Polyurethane, rigid	Much	Varies	Varies	High	None	Low	Low	Good	Good
Polyurethane, flexible	Slight	Excellent	Varies	Slight	None	High	High	Good	Poor
Polypropylene, sheet	Slight	Excellent	Low	Slight	None	Slight	Low	Good	Good
Cellulose wadding:									
Creped	Much	Excellent	Average	Much	None	Varies	Low	Poor	Good
Homogeneous	Varies	Excellent	Varies	Varies	None	Varies	Low	Poor	Good
Cotton	Much	Excellent	Low	Much	None	Much	Varies	Poor	Good
Plant fibers, rubber bonded	Slight	Fair	Average	Slight	Slight	Slight	Low	Poor	Fair
Fiberglass	Slight	Fair	Average	Slight	Slight	Slight	Low	Good	Good

Ratings shown are general. Properties differing from those given here can vary greatly according to type of material, amounts used, and conditions of use. Consult producers regarding specific requirements.

[1]Capacity of cushion to absorb and not transmit shock.
[2]Values for flutes in column or flat.
[3]Shock absorption declines as material crushes under repeated shock.
[4]Many treatments are used to avoid problem of poor fungus resistance.
[5]Good when treated.
[6]Highly flammable.

TABLE XL. Specifications for cushioning materials.

Specification No.	Title
C-F-202	Felt Sheet (Hair) and Felt Roll (Hair)
PPP-C-795	Cushioning Material, Cellular, Plastic Film (For Packaging Applications)
PPP-C-843	Cushioning Material, Cellulosic
PPP-C-850	Cushioning Material, Polystyrene, Expanded, Resilient (For Packaging Uses)
PPP-C-1120	Cushioning Material, Uncompressed Bound Fiber for Packaging
PPP-C-1683	Cushioning Material, Expanded Polystyrene Goose Fill Bulk (For Packing Application)
PPP-C-1752	Cushioning Material, Packaging, Unicellular, Polyethylene Foam, Flexible
PPP-C-1797	Cushioning Material, Resilient, Low Density, Unicellular, Polypropylene Foam
PPP-E-911	Excelsior, Wood, Fabricated Pads and Bulk Form
PPP-F-320	Fiberboard, Corrugated and Solid, Sheet Stock (Container Grade) and Cut Shapes
PPP-P-291	Paperboard, Wrapping and Cushioning
MIL-B-3106	Board, Composition, Water-Resistant, Solid (For Filler or Cushioning Pads)
MIL-R-6130	Rubber, Cellular, Chemically Blown
MIL-H-9884	Honeycomb Material, Cushioning Paper
MIL-C-17435	Cushioning Material, Fibrous Glass
MIL-P-19644	Plastic Molding Material (Polystyrene Foam Expanded Bead Type)
MIL-R-20092	Rubber Sheets and Molded Shapes, Cellular, Synthetic, Open Cell (Foamed Latex)
MIL-P-21929	Plastic Material, Cellular, Polyurethane Foam-In-Place, Rigid (2 and 4 pound per cubic foot)
MIL-P-26514	Polyurethane Foam, Rigid or Flexible, for Packaging
MIL-C-26861	Cushioning Material, Resilient Type, General
MIL-F-83670	Foam-In-Place Packaging, Procedures for

5.6.2.4.4 Cellulose wadding, cotton, and wood-fiber felt. Cellulose wadding, cotton, and wood-fiber felt may be used for lightweight, delicate objects, and these materials are available in thicknesses of 0.25 to 1.00 inch. They are readily moldable and fairly resilient. In combination with an overwrap of corrugated paper, they form effective cushions to protect relatively heavier items from shock. Any items that may be damaged by lint or small fibers should first be wrapped to exclude lint. These materials, even when treated, are water absorbent and retain water in their pores; therefore, they must not be placed directly against metal surfaces. They should not be used on the outside of a waterproof or watervaporproof barrier as they lose much of their cushioning properties when wet.

5.6.2.4.5 Excelsior. Excelsior is one of the oldest cushioning materials used. It is a good cushioning material when properly used. Also, it is relatively economical and available. When improperly used, wood particles and dust may enter machined parts or assemblies; or highly finished surfaces may be scratched by it. Humid conditions have less effect on its cushioning qualities than on many other materials, but dampness together with exuded wood acids may corrode metal contacting it. It should have a moisture content of about 12 to 18 percent to be most efficient as a cushioning material, because when very dry it frequently disintegrates into fine particles. For these reasons, excelsior is best used when it is made up into sealed pads covered with waterproof paper, or as a cushioning layer between the walls of an outer and inner container. When excelsior is used, the required density or weight of the excelsior is determined by the pressure imposed by the item on each square inch of load bearing area. Excelsior is highly flammable and under certain conditions spontaneous combustion is possible.

5.6.2.4.6 Hair or fiber and rubber. Rubber-coated and impregnated fibrous products are lightweight, resilient, and have low compression-set characteristics as compared to other nonrubber-base cushioning materials. They are very widely used in military packaging. Animal hair or vegetable fiber bonded with rubber is usually provided by the manufacturer in sheet form, but it may be furnished molded into the required shape and thickness for a specific article. Intricate shapes should be molded since the material cannot, as a rule, be efficiently fabricated to fit the item at the packing line. The molded forms are often used with reusable containers which may be used several times.

5.6.2.4.7 Foamed sponge rubber. Foamed sponge rubber is particularly adaptable to the cushioning of items that might otherwise be damaged by dust from other cushions. Generally, it is highly resilient and its cushioning properties are not materially affected by moisture. It is a relatively expensive product, but it may be reused. Sponge rubber may be produced in molded forms for intricately shaped articles. Also, it is furnished in flat sheets of various densities and thicknesses.

5.6.2.4.8 Unicellular sponge rubber. This cushioning material is a special type of sponge rubber, chemically blown under pressure to produce a uniform non-interconnecting cell structure. It has high resilience, since each cell acts as an individual air cushion. It is best as a bumper pad where it occasionally receives impact loads. It also has an important value as an insulating material or a flotation material since it is extremely buoyant.

5.6.2.4.9 Shredded paper. Shredded paper--such as newsprint, waxed paper, or cellophane--is economical and easy to obtain. It is adversely affected by water, and may absorb and retain moisture through wicking action unless protected. It will not prevent an item from ultimately settling against the face of the container, and should be used only for light, bulky items. It is available in wrapped pad forms that may have moisture barriers. Shredded paper is highly flammable and under certain conditions, spontaneous combustion is possible.

5.6.2.4.10 Mineral wool. Mineral or rock wool is fireproof and water resistant. It is dusty, hard to handle, and may produce skin irritation. Mineral wool should never be placed directly in contact with surfaces which can be damaged by abrasion.

5.6.2.4.11 Foamed (cellular) plastics. Foamed plastic cushioning materials are lightweight and have excellent shock damping properties which make them well suited for military packaging. Additional properties which make them desirable as cushioning materials are described in table XXXIX. Many types of foams are available with a wide range of properties to fit most packaging needs. Foamed plastics may be obtained in flexible, rigid, or semirigid forms and with densities varying from 0.1 to 60 lb/cu. ft. Some are available in open or closed cell foams. Open cell foams are more resilient but are subject to moisture absorption. Closed cell foams may be flexible or rigid and are generally free from any appreciable moisture absorption. The nine general types of plastics used for foam-making are: (1) cellulose acetate, (2) epoxies, (3) phenol-formaldehyde, (4) polyethylene, (5) polystyrene, (6) silicones, (7) urea-formaldehyde, (8) urethanes, and (9) vinyls. Of the listed foams, those most frequently used in packaging are polyurethane, polyethylene, and polystyrene. Foams come in many different forms. They may be obtained premolded to any desired shape; in a slab; sheet, or block form; and in some cases they may be foamed-in-place. However, it must be kept in mind that foam-in-place produces heat which may be excessive for the packaging of certain items. Sheet, block, and slab stock are easily cut and shaped into almost any desirable configuration needed for cushioning or blocking. Adhesives are available for bonding these foams to containers or barriers. See 5.10.6 for applicable adhesives. Foam-in-place plastics, primarily polyurethanes, are the result of mixing the plastic ingredients under the action of catalysts and the introduction or generation of a blowing agent during the mixing. This mixture is poured into the mold or cavity to be filled and, upon expansion, fills all voids or cavities of the mold. As the material foams, it adheres strongly to all surfaces and eliminates any need for adhesives. By use of the foam-in-place method, an item to be packed may be placed in its shipping container and the foam chemicals poured or pumped into the container. When the foaming has been completed, the item is completely encased in cushioning which exactly conforms to the shape of the item and the shipping container. This provides an excellent combination of cushioning coupled with blocking and bracing. Mixing can be as simple as hand batching the ingredients in a pail and pouring them into the cavity to be filled. For other applications, spraying with a gun may be used, or frothing may be employed. In frothing, the blowing agent is introduced into the chemicals under pressure before they are mixed. In this way, expansion is started before the chemical reaction takes place. This produces a foam of very low density. Equipment required for these processes includes chemical metering devices, mixing devices, in some cases an aerating system for the blowing agent, and an applicator device such as a spray gun, nozzle, or pump. Foam-in-place plastics are showing increased usage in areas where costs are justified based on labor and materials savings. The requirement for special equipment suggests an application where a moderate production run of like items will warrant the setup and maintenance time necessary. There are presently situations where extensive labor time is being expended on certain items for forming complex blocking, bracing, and cushioning systems. In cases like these, foam-in-place may provide an answer by greatly reducing total packaging costs. MIL-F-45216, MIL-F-83670, and Air Force Technical Order 00-85-37 provide detailed procedures for foam-in-place application.

5.6.2.4.12 Unicellular polypropylene foam. This material is a low density, resilient unicellular (closed cell) foam sheeting for use as a protective cushioned wrap. The foam can be laminated to a wide range of products including paper, paperboard, plastics, textiles, and may be used for the protection of surfaces from abrasion. Polypropylene foam is non-dusting, non-linting, and unaffected by most exposures to grease, water, and most acids, bases, and solvents. Typical packaging application(s) is/are surface protection for optical lenses, equipment with critical surfaces, electrical and electronic equipment, glassware, ceramics, and magnetic tape rolls.

5.7 Container materials. This section provides information on the various materials that may be used in the fabrication of containers for military items. The data presented include general information on container types as well as tables of properties and characteristics of common container materials. In addition, specifications covering the various types of materials are given. (This information supplements the general data given in 5.8.)

5.7.1 Selection of container materials. As discussed in 5.3, container materials must be in accord with the method of preservation prescribed. The selection of container materials will usually be governed by the following general criteria:

a. Compatibility and suitability of the materials to provide the degree of protection required for the item and to insure the proper functioning of the package or pack.

b. Economy and efficiency of the materials with regard to--

(1) Simplicity and economy of application of material in procurement and field operations.

(2) Ease and economy of removal of materials under field conditions.

(3) Comparative procurement cost of materials.

(4) Availability of the materials.

c. Reduction of weight and cube.

d. Standardization of materials and reduction of types, grades, and classes prescribed and used in the packaging of like or similar items.

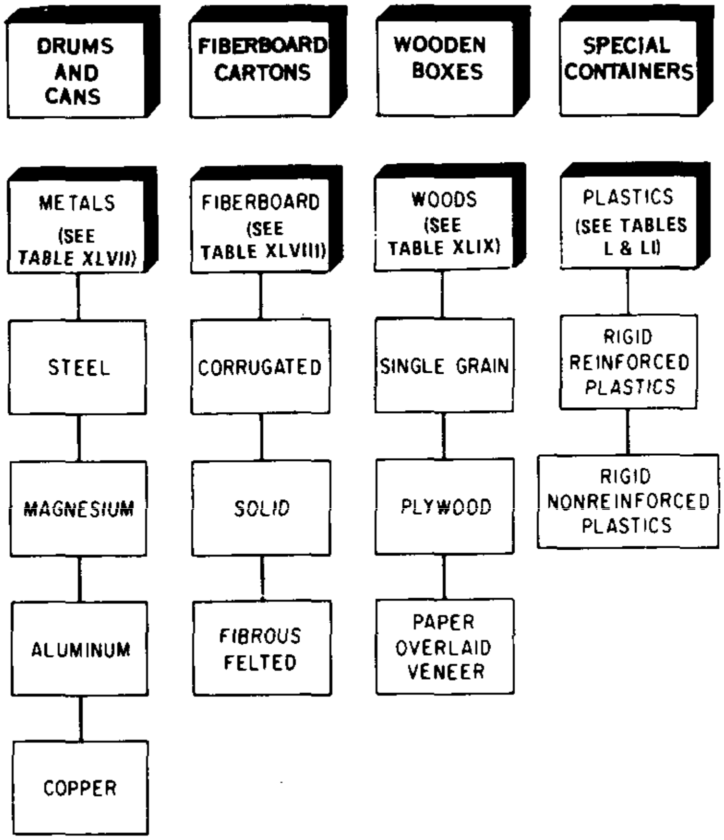


FIGURE 24. Types of containers and container materials.

5.7.2 Types of container materials. A wide variety of materials is fabricated for use as containers. Figure 24 categorizes the various types of containers and container materials. This chapter provides data on the following materials commonly used as military containers:

a. Metals.

b. Fiberboard and paperboard.

c. Wood, plywood, and paper overlaid veneer.

d. Plastics and reinforced plastics.

The information given includes general physical properties, available forms of the materials, and ease or difficulty in working with the item. References to other documents are also provided to aid the packaging engineer in locating pertinent data on these and other materials.

5.7.2.1 Metals. Metal containers are particularly suitable for the preservation and packing of delicate items, especially those such as instruments, generators, gyros, starters, and magnetos which require a high degree of protection. Because metal containers are structurally rigid, they are especially useful as reusable containers and for long-term storage of equipment. Also, they may be palletized for convenience in handling. When properly sealed, metal containers provide a simple and highly effective watervapor barrier and thereby provide a degree of protection for the item equal to that afforded by other types of Method II protection. The containers may be drums, cans, or pails. The metals most commonly used for containers are steel, aluminum, and magnesium. Containers made from these metals, or from their alloys, are adaptable for most container applications except those in which transparency is a requirement. An important consideration in the use of metal as a container material is cost. Metals, although less expensive than reinforced plastics, are still fairly expensive and should be used only when a more economical container material will not satisfy the requirements of a particular application. Also, consideration must be given to the ease or difficulty of fabricating the metal into usable containers.

5.7.2.1.1 Steel. The high carbon steel alloys are strong but difficult to weld. Medium- and low-carbon steels, however, are weldable and are available in many forms including flat sheet, coiled sheet, plate, rods, and rolled structural shapes. The low-alloy, high-strength steels possess greater strength and hardness, although they are more difficult to work with. Specific physical properties of steel relevant to containerization usage are given in table XLVII. Specifications covering steels which are commonly used for container fabrication are:

a. QQ-S-741, Steel, Carbon, Structural, Shape, Plate and Bar.

b. QQ-S-698, Steel Sheets and Strips, Low Carbon.

5.7.2.1.2 Aluminum. Aluminum alloys are available in either a clad or bare form. The clad material has a surface coating of an aluminum alloy that is corrosion resistant and provides electrolytic protection against corrosion of the core alloy. The working of aluminum requires less energy than does the working of low carbon steel. Forms of pure aluminum that are available for fabrication include sheet, plate, wire, bar, rod, and tubing. Aluminum alloys are produced in the form of castings, extruded shapes, bar, rod, and wire. Welding decreases the strength of heat-treated material; but in many cases the weldments may be heat treated to restore strength. Various properties of aluminum alloys are listed in table XLI. More detailed physical properties of aluminum alloys relevant to their use in containers are given in table XLVII. Specifications covering aluminum alloys commonly used for container fabrication are:

a. QQ-A-200, Aluminum Alloy Bar, Rod, Shapes and Tube, Extruded, General Specification For.

b. QQ-A-225, Aluminum Alloy Bar, Rod, Wire or Special Shapes, Rolled, Drawn, or Cold Finished, General Specification For.

c. QQ-A-250, Aluminum Alloy Plate and Sheet, General Specification For.

TABLE XLI. Mechanical properties of aluminum alloys.

Property	Cast	Wrought
Tensile Strength, minimum psi	42,000	80,000
Yield Strength, minimum psi	22,000	72,000
Endurance Limit, minimum psi	13,500	24,000
Elongation, %	6	Varies markedly
Modulus of Elasticity, psi	9.9×10^6 to 11.4×10^6 (generally taken as 10.3×10^6)	

5.7.2.1.3 Magnesium. Magnesium alloys are lighter in weight than aluminum, and have similar working characteristics. Magnesium, however, is prone to crack more easily than aluminum during bending operations. The alloys of magnesium are produced in various commercial forms including castings, sheet, plate, extruded shapes, and forgings. Magnesium structures are readily assembled by welding or riveting. Physical and mechanical properties of magnesium alloys are given in tables XLII and XLIII. The properties of magnesium alloys revelant to their use in containers are compared with those of other metals in table XLVII. Specifications covering magnesium alloys commonly used for container fabrication are:

a. MIL-M-26696, Magnesium Alloy, Bar, Rod, and Special Shaped Sections, Extruded, PZk60B.

b. QQ-M-31, Magnesium Alloy, Bars, Rods, and Special Shaped Sections, Extruded.

c. QQ-M-44, Magnesium Alloy Plate and Sheet, AZ31.

5.7.2.2 Fiberboard and paperboard. Fiberboard, because of its low cost, ease of fabrication, light weight, and ability to resist transportation hazards, is one of the most widely used container materials. These materials are available in solid or corrugated, domestic or weather-resistant board (fig 25). Corrugated fiberboard is also available in several forms of sheet stock including single- and double-faced board, double-wall board, and triple-wall board. The four principal factors affecting the carrying capacity of corrugated and solid fiberboard boxes are resistance to compression, strength at the score lines, resistance to puncture, and the ability to resist the weakening effect of moisture. Since fiberboard boxes are, in general, a light type of container, every effort should be made to use them only for items falling within stated weight and dimension limitations. Although fiberboard boxes are normally used to accommodate only loads that lend support to the container, wide use of special die-cut inserts, scored pads, partitions, and cushioning will convert many nonsupporting loads to supporting loads and permit the use of fiberboard. V-board and W-board should be used whenever possible because of their high strength and weather resistance.

5.7.2.2.1 Advantages of fiberboard cartons. Fiberboard cartons offer a number of advantages, namely:

a. Made of materials of exactly specified strength and water resistance.

b. Made in various styles to suit various shapes and sizes of items.

c. Shipped and stored flat, resulting in space savings.

d. Easy to assemble and handle.

e. High strength and light weight.

TABLE XLII. Physical properties of magnesium alloys.

Property	Range: Casting Alloys	Range: Wrought Alloys	Notes
Specific Gravity	1.74 to 1.86	1.76 to 1.83	About one-fourth that of steel
Weight, lb/in^3	0.0628 to 0.0670	0.0633 to 0.0661	Approximately 112 lb/ft^3
Electrical Conductivity (International Annealed Copper Standard) %	10.0 to 30.3	11.9 to 34.5	Values depend upon composition and temper of the alloys. Heat treatment of casting alloys generally tends to lower conductivity as compared with the as-cast condition. The lowest values appear in the -T4 temper for a given composition. The high value for wrought alloys appears in alloy M1A and the low value in AZ80A (both specified in QQ-M-31 and QQ-M-40).
Thermal Conductivity col/(sec)(cm^2)(°C/cm)	0.10 to 0.29	0.12 to 0.33	Appreciably lower than the values for corresponding aluminum-alloy materials.
Thermal Expansion means coefficient per degree F. between the range of 20° to 100° C.	26.1 x 10^{-6}	26.1 x 10^{-6}	In applications where magnesium alloys are rigidly connected to other material and the assembly is subject to appreciable variation in temperature, this relatively high coefficient must be given consideration.

TABLE XLIII. Mechanical property ranges of magnesium alloys.

Property	Cast	Wrought
Tensile Strength, psi	12,000 to 35,000	28,000 to 48,000
Yield Strength, psi	10,000 to 22,000	14,000 to 38,000
Fatigue Strength, psi	9,000 to 14,000	11,000 to 22,000
Elongation, %	2 to 7	2 to 12
Modulus of Elasticity, psi	Generally taken as 6.5×10^6	

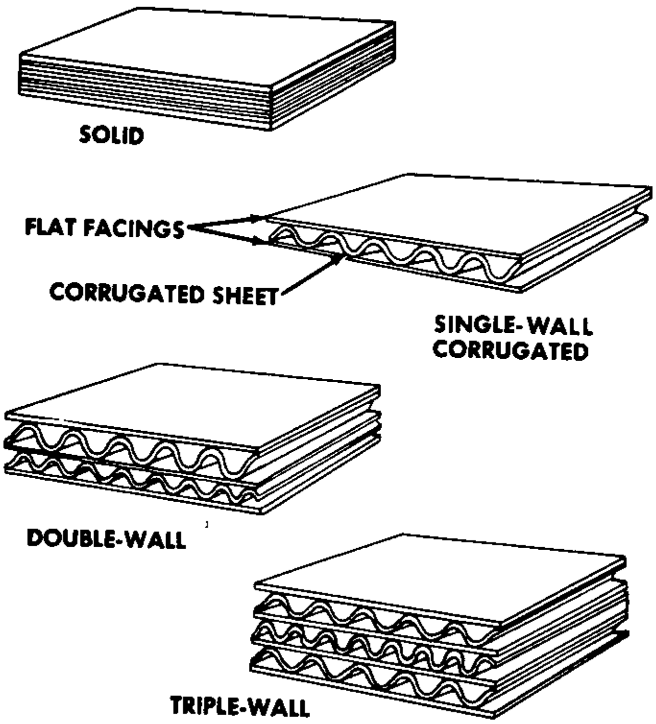


FIGURE 25. Types and varieties of fiberboard.

f. When packed, they occupy less space than most other containers having the same interior dimensions.

5.7.2.2.2 Fiberboard container specifications. Minimum requirements for fiberboard containers are listed in table XLIV. The properties of fiberboard relevant to containerization usage are given in table XLVIII. Some of the more commonly used fiberboard container specifications are:

a. PPP-B-591, Box, Shipping, Fiberboard, Wood-cleated.

b. PPP-B-636, Box, Shipping, Fiberboard.

c. PPP-B-640, Box, Fiberboard, Corrugated, Triple-wall.

d. PPP-B-1163, Box, Corrugated Fiberboard, High Compression Strength, Weather-resistant, Wax-resin Impregnated.

e. PPP-B-1364, Box, Corrugated Fiberboard, High Strength, Weather-resistant, Double-wall.

f. PPP-B-1672, Boxes, Shipping, Resuable With Cushioning.

g. MIL-B-38721, Boxes, Consolidation, Fiberboard.

h. MIL-B-43666, Boxes, Shipping, Consolidation.

5.7.2.2.3 Use of fiberboard boxes and drums. Fiberboard boxes and drums may be used as exterior containers (see 5.8). Fiberboard drums are intended primarily for packaging powdered, granular, or flaked materials, or for hot-poured materials that solidify on cooling to atmospheric temperatures.

5.7.2.2.4 Use of paperboard containers. Paperboard containers should be prescribed only for use as unit containers to provide protection to the contents or for convenience in handling; they are not to be used as external containers. Usually they are intended for items weighing not more than 10 pounds. Because they lack waterproof qualities, they must be protected by suitable means whenever conditions require. Paperboard containers may be in the form of folding setup, or metal-stayed boxes. Folding boxes of various styles, types, and classes are made of bending grade paperboard having a thickness between 0.012 and 0.045 inch. They are received flat or collapsed ready for mechanical or hand setup and use. Setup boxes are made of nonbending grade paperboard having a thickness between 0.026 and 0.048 inch. They are normally received already set up or flat ready for mechanical or hand setup and use. Paperboard boxes may

TABLE XLIV. Requirements for fiberboard boxes.

(1) Maximum Weight	(2) Maximum Dimensions	(3) Minimum Board Weight	(4) Minimum Bursting Test	
	Single-wall Corrugated Boxes			
20	40	52	125	
40	65	75	175	
65	75	84	200	
90	90	138	275	
120	100	180	350	
	Double-wall Corrugated Boxes			
65	75	92	200	
90	90	110	275	
120	100	126	350	
140	110	222	500	
160	120	270	600	
	Triple-wall Corrugated Boxes			
275	120	264	(5)	
	Solid Fiberboard Boxes			
20	40	114	125	
40	65	149	175	
65	75	190	200	
90	90	237	275	
120	100	283	350	
140	110	330	500	
160	120	360	600	
	Weather-resistant Fiberboard (6)		Dry	Wet
20	30	20	175	50
40	50	40	275	100
70	80	40	400	150
90	90	60	550	500
100	100	70	750	500

Notes:
(1) Maximum weight of box and contents, lb.
(2) Maximum inside dimensions, length plus width plus depth, in.
(3) Minimum added total weight of the facings (flat sheets) including inner sheets but not the corrugated walls and not the adhesives, in the corrugated boxes, and, in the solid fiberboard boxes, the total weight of the component plies making up the board but not including the adhesives, in $lb/1000\ ft^2$.
(4) Minimum bursting test of the combined board in accordance with the prescribed method, in lb/in^2.
(5) Puncture test to be used instead of bursting; minimum is to be 1100 units.
(6) Type 2 load.

also be made of one or more paperboard flats assembled with metal stays. Commonly used paperboard container specifications are:

a. PPP-B-566, Box, Folding, Paperboard.

b. PPP-B-676, Box, Setup.

c. PPP-B-665, Box, Paperboard, Metal Edged and Components.

5.7.2.3 Wood, plywood, and paper overlaid veneer. Wooden boxes and crates make satisfactory containers for equipment that can be damaged easily.

a. The advantages of wooden boxes and crates include the following five points:

(1) Maximum protection for contents against damage from puncture, distortion, or breakage.

(2) Ability to support loads resulting from stacking during transit and storage.

(3) Ability to contain difficult loads without undue distortion.

(4) Adaptability to complex wood blocking.

(5) Easy workability and simple construction.

b. Military specifications for general purpose crates are listed in table XLV. Specifications covering wooden and paper-overlaid veneer boxes commonly used are:

(1) PPP-B-576, Box, Wood, Cleated, Veneer, Paper Overlaid.

(2) PPP-B-585, Box, Wood, Wirebound.

(3) PPP-B-601, Box, Wood, Cleated-plywood.

(4) PPP-B-621, Box, Wood, Nailed and Lock Corner.

(5) MIL-P-9302, Panels, Full Cleated, Partially Cleated, and Uncleated; Plywood, Veneer, Paper-overlaid, and Solid Fiberboard For Box, Modular Systems.

(6) MIL-B-43666, Boxes, Shipping, Consolidation.

Properties of wood, plywood, and paper-overlaid veneer relevant to their use in container fabrication are categorized in table XLIX.

TABLE XLV. Specifications for general purpose crates.

Specification	Maximums			
	Net Load, lb	Length, ft	Width, ft	Height, ft
MIL-C-104(1)				
Sill Base	20,000	30	9	10
Skid Base	30,000	30	9	10
MIL-C-3774(1)				
Nailed	12,000	16	8	8
Bolted	16,000	40	8	16
MIL-C-52950(2)				
Style A-I	250	4	3	3
A-II	1,000	12	4	2
A-IV	1,000	6	4	4
A-V	2,500	12	6	6
B-I	200	4	3	3
B-III(3)				
B-V (4)	4,000	32	6	10

Notes:
(1) All dimensions overall, exterior.
(2) All dimensions, interior.
(3) No load or size restrictions except as limited by handling methods. Crates are designed for long self-supporting items such as structural sections.
(4) Crates shall be further classified as being nondemountable or demountable. Style 8 may be open or covered.

5.7.2.4 Plastics. In general, most plastics exhibit the highly desirable characteristics of light weight and high strength-to-weight ratio. Other advantages of plastics are a high resistance to corrosion, fungus, and insects. The main disadvantage of plastic containers are strength limitations at temperature extremes. At low temperatures, plastics become brittle. At high temperatures, they become soft. Temperature limitations can best be overcome by the selection of the proper plastic for the temperature conditions expected to be encountered by the container. A factor not found in other container materials and to be considered in the use of plastics is the susceptibility to electrostatic charge buildup. The problems associated with electrostatic charge are explained in 5.6.1.5. The problems as explained relate to plastic film, but are also applicable to sheet plastic as used in containers. The advantages and disadvantages of different types of plastics from a structural point of view are shown in table XLVI. Properties of plastics relevant to their use in container fabrication are provided in table L. Specifications covering some of the more commonly used plastics are:

a. General.

MIL-M-14, Molding Plastics and Molded Plastic Parts, Thermosetting.
MIL-P-14591, Plastic Film, Nonrigid, Transparent.
L-P-505, Plastic Sheet, Corrugated, Translucent, Glazing.

b. Acrylonitrile Butadiene Styrene (ABS).

MIL-B-19904, Plastic Sheet, Acrylonitrile Butadiene Styrene Copolymer, Rigid.

c. Cellulose acetate.

MIL-P-21094, Plastic Sheet, Cellulose Acetate Optical Quality.

d. Cellulose acetate butyrate.

MIL-C-5537, Cellulose Acetate Butyrate.

e. Halogenated hydrocarbons.

MIL-P-19468, Plastic Rod, Polytetrafluoroethylene, Molded and Extruded.
MIL-P-22241, Plastic Sheet and Film, Polytetraflouroethylene (tfe Fluorocarbon Resin).
MIL-P-46036, Plastic Sheets, Rods, Tubes and Disks, Chlorotrifluoroethylene Polymer.

TABLE XLVI. Advantages and disadvantages of plastics.

Plastic	Advantages	Disadvantages
Thermoplastics		
Acrylic	Formability; good impact strength; high index of refraction; good aging and weathering resistance; high transparency; shatter-resistance, rigidity.	Tendency to cold flow; softening point of 170° to 220° F.; low scratch resistance.
Cellulose acetate	Ease of fabrication; moderate impact strength and toughness; good optical properties; good electrical properties; good resistance to gasoline and oil.	Loss of strength at 140° to 180° F.; decomposition by strong acids and alkalis; high water absorption; low temperature brittleness; poor outdoor aging.
Cellulose acetate butyrate	Excellent molding properties; high impact strength and toughness; good dimensional stability and resilience; low moisture absorption	Low flexural strength; low softening point (100° to 180° F.;) suitable only for relatively low loads; poor thermal dimensional stability.
Cellulose nitrate	Ease of fabrication; relatively high impact strength and toughness; good dimensional stability and resilience; low moisture absorption.	Extreme flammability; very rapid degradation when exposed to sunlight; poor electrical insulating properties; harder with age; low heat distortion point.
Ethyl cellulose	Toughness at low and normal temperatures; high tensile and impact strengths; comparatively stable in high humidities.	Softening point of 110° to 200° F.; poor resistance to attack by organic solvents; poor outdoor weathering resistance.
Polystyrene	Very low specific gravity; excellent moldability; dimensional stability; properties maintained over range of -40 to +180° F.;	Extreme brittleness; softening point of 190° F.; tendency to craze; attacked by aromatic solvents; poor weathering resistance.

TABLE XLVI. Advantages and disadvantages of plastics. - Continued

Plastic	Advantages	Disadvantages
Thermoplastics (Cont)		
Polystyrene (Cont)	relatively high tensile, compressive, flexural strengths; high modulus of elasticity; exceptional electrical properties which remain constant over wide range of frequencies, temperatures and humidities, and after long immersion in water; fungi-inert; negligible water absorption; low cost.	
Modified polystyrene (1)	10° to 30° F. improvement in heat distortion temperature over polystyrene; greater resistance to chemical and solvent attack; higher impact strength; complete water resistance.	Degrades excessively when stored at high temperatures or subjected to outdoor exposure.
Polyamide (nylon)	High resistance to distortion under load at temperatures up to 300° F.; high tensile strength, excellent impact strength at normal temperatures; (2) does not become brittle at temperatures as low as -70° F.; excellent resistance to gasoline and oil; low coefficient of friction on metals.	Absorption of water: large coefficient of expansion; high molding temperatures; relatively high cost; sensitive to ultraviolet light; weathering resistance poor.

Notes: (1) Developed especially to overcome disadvantages of polystyrene.
(2) Tensile strength decreases with rising temperatures, elongation, and impact strength increases, as with all thermoplastics.

TABLE XLVI. Advantages and disadvantages of plastics. - Continued

Plastic	Advantages	Disadvantages
Thermoplastics (Cont)		
Polyethylene	Inert to many solvents and corrosive chemicals; flexible and tough over wide temperature range, remains so at temperatures as low -100° F.; unusually low moisture absorption and permeability; high electrical resistivity; low dielectric constant and power factor; dimensionally stable at normal temperatures; will not support fungal growth; ease of molding; low density; low cost.	Low tensile, compressive, flexural strength, very high elongation at normal temperatures; subject to spontaneous cracking when stored in contact with alcohols, toluene, and silicone grease, etc.; softens at temperatures above 200° F.; poor abrasion and cut resistance; may be deteriorated by ultraviolet light unless properly compounded; cannot be bonded unless given special surface treatment.
Polytetrafluoroethylene	Extreme chemical inertness; high heat resistance; nonadhesive; tough; low dielectric loss over wide temperature range; low coefficient of friction.	Not easily cemented; cannot be molded by usual methods; generates toxic fumes at high temperatures; high cost.
Polytrifluorochloroethylene	Extreme chemical resistance; good electrical properties; high heat resistance; zero water absorption; good resistance to cold flow; stability over wide temperature range; good weathering qualities.	Limited elasticity; high cost; difficulty of cementing.
Vinyl chloride	Good tensile strength; good acid, solvent, caustic resistance; low water absorption; fair electrical properties.	Low softening point; adverse effect of sunlight; requires plasticizers.

TABLE XLVI. Advantages and disadvantages of plastics. - Continued

Plastic	Advantages	Disadvantages
	Thermoplastics (Cont)	
Rigid polyvinyl chloride	Good weathering resistance; good resistance to most acids, alcohols, organic solvents; does not support combustion; high flexural strength; excellent toughness and ductility (even at -65° F.); high impact strength.	Difficult to mold; subject to flow under load at 140° to 180° F.
Vinylidene Chloride	Exceptional chemical resistance; good aging resistance; good electrical properties; low moisture absorption; high strength.	Poor thermal stability; low thermal conductivity; adverse effect of sunlight.
Rigid vinylidene chloride	Good tensile, compressive, flexural strengths; low elongation; fair impact resistance; dimensionally stable at moderate loadings and temperatures; performs satisfactorily at moderately high temperatures.	Strength and physical stability reduced with rising temperatures; not recommended at over 170° F., or for uses involving resistance to high speed impact, shock resistance, or flexibility at subfreezing temperatures.
	Thermosetting Plastics	
Phenol-formaldehyde	Used by U.S. Army for ordnance purposes in greater variety of end items and greater total tonnage than any other plastic; better permanence characteristics than most plastics; may be used at temperatures from 250° to 475° F.; good aging resistance; good electrical insulating properties; not readily	Difficult to mold when filled for greatest impact strength, or when in sections less than 3/32-inch thick; can be expanded or contracted by unusually wet or dry atmosphere; poor tracking and arc resistance.

TABLE XLVI. Advantages and disadvantages of plastics. - Continued

Plastic	Advantages	Disadvantages
Thermosetting Plastics (Cont)		
Phenol-formaldehyde (Cont)	flammable, does not support combustion; inserts can be firmly embedded; strong, light; low water absorption; low thermal conductivity; good chemical resistance; economical in production of complex shapes; free from cold flow; relatively insensitive to temperature; low coefficient of thermal expansion; no change in dimensions under a load for a long time; does not soften up to the degradation temperature or become brittle down to -65° F.; inexpensive.	
Melamine-formaldehyde	Good arc, track, organic solvent, and heat resistance (210° to 250° F.); high impact strength with some fillers; rigid; hard surface withstands continuous handling and wear with negligible effect; flame resistant; low temperature resistant.	High power factor; high cost; dimensionally unstable with varying humidities.
Urea-formaldehyde	High degree of translucency and light finish; hard surface finish; outstanding electrical properties when used within temperature range of -70° to +170° F.; complete resistance to organic solvents; dimensionally stable under moderate loading and exposure conditions.	Low impact strength; slight warping with age; poor water resistance.
Allyl	Good clarity; freedom from optical creep; good resistance to chemicals,	Low impact strength; high shrinkage; care required in machining and

TABLE XLVI. Advantages and disadvantages of plastics. - Continued

Plastic	Advantages	Disadvantages
Thermosetting Plastics (Cont)		
Allyl (Cont)	abrasion, crazing, and deformation under heat; rigid and dimensionally stable at moderate temperatures and loadings.	handling; physical properties reduced at elevated temperatures.
Alkyd	Excellent electrical properties; heat distortion temperatures of 350° to 400° F., 300° to 350° F. for continuous service; reinforced compounds have high impact strength dimensional stability, and yield strength; good flow properties.	Poor resistance to strong acids; require fast-closing molds; high specific gravity.
Epoxy resin	Excellent chemical resistance; excellent adhesion to metals, glass, ceramics; good mechanical and electrical properties; retains electrical properties under severe temperature and humidity; castings can be cycled from -60° to +400° F. without cracking.	Relatively high cost; relatively poor heat resistance (compared to polyesters and phenolics).
Silicones	High heat resistance; do not support combustion; low water absorption; good electrical properties over a wide frequency range; electrically nontracking.	Require a special molding and curing technique; relatively expensive.

TABLE XLVI. Advantages and disadvantages of plastics. - Continued

Plastic	Advantages	Disadvantages
Thermosetting Plastics (Cont)		
Polyester resins	Very high strength in the form of glass reinforced laminates; excellent electrical properties; can be molded in very large sections under low pressure in inexpensive molds; good heat resistance; good resistance to chemicals, gasoline and oil; excellent low temperature properties; good weathering resistance.	Excessive (4 to 8%) shrinkage on molding; only fair adhesion.

f. Nylon (polyamide).

MIL-N-18352, Nylon Plastic, Flexible, Molded or Extruded.
MIL-M-20693, Molding Plastic, Polyamide (Nylon) Rigid.
MIL-P-22096, Plastic, Polyamide (Nylon), Flexible Molding and Extrusion Material.

g. Phenolics.

MIL-R-3745, Resin, Phenol-formaldehyde, Laminating.
MIL-R-9299, Resin, Phenolic, Laminating.
TT-R-271, Resin, Phenol-formaldehyde (Para-phenyl and Para-butyl).

h. Polyester (alkyd).

MIL-R-7575, Resin, Polyester, Low Pressure Laminating.
MIL-R-21607, Resin, Polyester, Low Pressure Laminating, Fire Retardant.
MIL-R-25042, Resin, Polyester, High Temperature Resistant, Low Pressure Laminating.

i. Polyethylene.

MIL-P-21922, Plastic Rods and Tubes.

MIL-P-55010, Plastic Sheet, Polyethylene, Terephthalate.
L-P-378, Plastic Sheet and Strip, Thin Gauge, Polyolefin.

j. Polyvinyl alcohol.

MIL-P-265, Polyvinyl Alcohol, Granular.

k. Polyvinyl chloride.

MIL-P-20307, Polyvinyl Chloride.

l. Silicone.

MIL-R-25506, Resin, Silicone, Low Pressure Laminating.

m. Vinyl chloride and copolymers.

MIL-P-6264, Plastic Sheet, Vinyl Copolymer, Thin.
MIL-P-18080, Plastic Sheets, Vinyl, Flexible, Transparent, Optical Quality.
L-P-375, Plastic Film, Flexible, Vinyl Chloride.

5.7.2.5 Reinforced plastics. Reinforced plastics are used for sheathing or for structural members of containers. They are a combination of a plastic and a reinforcing material embedded in or saturated with the plastic. The properties of reinforced plastics depend upon the material combined, the relative amounts of the material used, and the manner in which the combination is formed. The properties of some common reinforced plastics are shown in table LI.

5.7.3 Container materials selection charts. The physical properties and characteristics of the various container materials are presented in tables XLVII through LI. The information given in these tables will aid in the selection of a material capable of meeting the physical requirements of a particular application. It should be noted that factors other than physical characteristics are important in selecting a container material and the data listed in tables XLVII through LI must be evaluated with these factors in mind. Important physical characteristics of container material include specific gravity; tensile strength; compressive strength; ratios of tensile and comprehensive strength to specify gravity; modulus of elasticity; resistance to impact, abrasion, and puncture; and reported hazards to stability. The identification of material given in the first column of tables XLVII through LI is the commercial identification of the material. In some instances, the ultimate tensile strength is not shown, but yield strength is given and indicated by the prefix Y. Yield strength is defined as "the lowest tensile force at which elongation continues without an increase in force divided by the minimum cross-sectional area of the specimen before a load is applied." Ratios of tensile and compressive strength are useful in comparing the weights required for a particular strength. The modulus of elasticity determines the ability of a material to resist deflection under loads. Impact resistance is measured by a variety of test methods and, even within one group of similar materials, more than one method is used. The test method is given by a footnote for the material or group of materials, and the energy required to produce failure of the material is given in the table. Comparisons of impact resistance determined by different methods are not valid, even though energy units are the same. Abrasion resistance is not used in design and is rarely the cause of container failure. The information is useful, however, in the selection of parts subject to wear, such as rubbing strips and skids. Puncture resistance is measured by a variety of tests, depending on the form of the material. Hardness is a measure of the resistance of the material to the penetration of a point or other indenter. The hardness of different material may be compared if the same indenter is used, but when different indenters are used the data must be converted to a common scale. Listed in tables XLVIII through LI, under the column, "Reported Hazards to Stability," are code letters for the hazards of environment that cause a 10 percent reduction in any one of the characteristics. The definitions of the code letters are:

a. Temperature extremes, -65° or +160° F. (-54° or 71° C.).

b. Submersion in water for 24 hours.

c. Submersion in oil for 24 hours.

d. Organic solvents.

e. Acids.

f. Salts and salt solutions.

g. Bacteria and fungi.

h. High humidity.

i. Low humidity.

j. Sunlight.

k. Chemical bases.

TABLE XLVII. Container material selection chart - metals.

Material	Specific gravity (Sp gr)	Tensile strength F_t, psi	Ratio $\left(\frac{10^{-3} F_t}{Sp\ gr}\right)$, psi	Compressive strength F_c, (1) psi	Ratio $\left(\frac{10^{-3} F_c(1)}{Sp\ gr}\right)$, psi	Modulus of elasticity E, 10^{-6} psi	Resistance to Impact	Resistance to Abrasion	Resistance to Puncture
Steels, Wrought(2)									
High carbon C1095, hot rolled	7.85	142,000	18.1	Y 84,000	Y 10.7	30.0	3	--	293
C1095, annealed	7.85	100,000	12.7	Y 53,000	Y 6.75	30.0	5		197
C1055, C1060, hot rolled	7.85	110,000	14.0	Y 51,500	Y 6.56	30.0	15		240
C1055, C1060, annealed	7.85	100,000	12.7			30.0	20		190
Medium C1040, C1045, hot rolled	7.85	95,000		Y 42,000	Y 5.35	30.0	--		205
C1040, C1045, annealed	7.85	100,000	12.7			30.0	--		210
C1030, C1035, hot rolled	7.85	80,000		Y 37,500	Y 4.77	30.0	--		170
Low carbon C1018, hot rolled	7.85	69,000	8.79	Y 32,000	Y 4.08	30.0			143
C1015, C1010, hot rolled	7.85	51,000	6.50	Y 26,000	Y 3.31	30.0			101
C1020, C1025, hot rolled	7.85	65,000	8.28	Y 30,000	Y 3.82	30.0			143
Low alloy, high strength (hardened and tempered)									
Alloy No. 4023	7.8	120,000	15.4	Y 85,000	Y 10.9	30.0	--		255
Alloy No. 4063	7.8	269,000	34.5	Y 231,000	Y 29.6	30.0			534
Alloy No. 4130	7.8	200,000	25.6	Y 170,000	Y 21.8	30.0	25		375
Alloy No. 4150	7.8	230,000	29.5	Y 215,000	Y 27.5	30.0	12		444
Alloy No. 6150	7.8	187,000	24.0	Y 179,000	Y 22.8	30.0	13		444
Steels, Wrought(2)									
Steels, stainless									
Austenitic No. 201, annealed	7.85	115,000	14.6	Y 55,000	Y 7.00	28.6			B90
Austenitic No. 301, annealed	7.9	110,000	13.9	Y 40,000	Y 5.06	28.0	165		B85
Austenitic No. 304, annealed	7.9	85,000	10.8	Y 35,000	Y 4.43	28.0	110		B80
Austenitic No. 201 and 301, full hard	7.9	185,000	23.4	Y 140,000	Y 17.7	28.0			

TABLE XLVII. Container material selection chart - metals. - Continued

Material	Specific gravity (Sp gr)	Tensile strength F_t, psi	Ratio $\left(\frac{10^{-3} F_t}{Sp\ gr}\right)$, psi	Compressive strength F_c, (1) psi	Ratio $\left(\frac{10^{-3} F_c (1)}{Sp\ gr}\right)$ psi	Modulus of elasticity E, 10^{-6} psi	Resistance to Impact	Resistance to Abrasion	Resistance to Puncture
Aluminum Alloys, Wrought(3)									
7178-T6	2.8	88,000	31.4	Y 78,000	Y 27.9	10.4			
Alclad 7178-T6	2.8	81,000	28.9	Y 71,000	Y 25.4	10.4			
7075-T6	2.8	83,000	29.6	Y 73,000	Y 26.1	10.4			B90
Alclad 7075-T6	2.8	76,000	27.1	Y 67,000	Y 23.9	10.4			B100
Alclad 2024-T86	2.8	70,000	25.0	Y 66,000	Y 23.6	10.6			
Magnesium Alloys, Wrought(4)									
AZ31B-H24	1.78	39,000	21.9	Y 29,000	Y 16.3	6.5	32		B83
ZE10A-H24	1.78	36,000	20.2	Y 25,000	Y 14.0	6.5			
ZK60 A and B - T5	1.83	50,000	28.1	Y 40,000	Y 22.5	6.5			B88

Notes:
(1) The prefix "Y" before an entry identifies it as yield strength.
(2) Steels: the resistance to impact is given in foot-pounds as determined by the notched Izod test, and the resistance to puncture is the hardness number as determined by either the Brinell test (no prefix is given) or the Rockwell test (scale prefix letter is given).
(3) Aluminum alloys: the resistance to puncture was the hardness number as determined by the Rockwell test.
(4) Magnesium alloys: the resistance to impact is given in foot-pounds as determined by the Charpy test, and the resistance to puncture is the hardness number determined by the Rockwell test.

TABLE XLVIII. Container material selection chart - fiberboards.

Material	Specific gravity (Sp gr)	Tensile strength F_t, psi	Ratio $\left(\frac{10^{-3} F_t}{Sp\ gr}\right)$, psi	Compressive strength F_c, psi	Ratio $\left(\frac{10^{-3} F_c}{Sp\ gr}\right)$, psi	Modulus of elasticity E, 10^{-6} psi	Resistance to: Impact	Resistance to: Abrasion	Resistance to: Puncture	Reported hazards to stability (3)
Corrugated Fiberboard(1)										
(Double-faced, 125-lb Mullen)										
A-flute	0.096			120	1.25				140	
B-flute	0.156			210	1.34				126	
C-flute	0.119			160	1.34				133	
(Double-faced, 350-lb Mullen)										
A-flute	0.194			310	1.60				375	
B-flute	0.271			490	1.80				375	
C-flute	0.234			380	1.62				356	
(Double-wall 200-lb Mullen)										
A- and B-flutes	0.113			200	1.77				250	
A- and C-flutes	0.100			180	1.80				262	abdegh
B- and B-flutes	0.151			280	1.85				225	
B- and C-flutes	0.130			230	1.77				237	
C- and C-flutes	0.113			200	1.77				250	
(Double-wall, 600-lb Mullen)										
A- and B-flutes	0.198			290	1.46				700	
A- and C-flutes	0.179			260	1.45				735	
B- and B-flutes	0.256			380	1.48				630	
B- and C-flutes	0.224			330	1.47				665	
C- and C-flutes	0.198			290	1.46				700	
(Triple-wall board)										
A-C-A-flutes	0.135			230	1.70				1100	

TABLE XLVIII. Container material selection chart - fiberboards. - Continued

Material	Specific gravity (Sp gr)	Tensile strength F_t, psi	Ratio $\left(\frac{10^{-3} F_t}{Sp\ gr}\right)$, psi	Compressive strength F_c, psi	Ratio $\left(\frac{10^{-3} F_c}{Sp\ gr}\right)$, psi	Modulus of elasticity E, 10^{-6} psi	Resistance to: Impact	Resistance to: Abrasion	Resistance to: Puncture	Reported hazards to stability (3)
Solid Fiberboards(1)										
Domestic (low values)	0.54			910	1.44					abdegh
(high values)	0.65			1,250	2.07					
VUS	0.72			1,170	1.62					
V2s	0.74			1,200	1.62					
V3a	0.67			1,080	1.61					
W5s	--			1,350	--					
Fibrous Felted Boards(2)										
Superhard board	1.36	7800	5.74	26,500	18.4					abdegh
Superhard board	1.44	7800	5.42	26,500	19.5					
Tempered hardboard	0.96	4000	4.17	4,200	4.37					
Tempered hardboard	1.28	7800	6.10	6,000	4.69					
Untempered hardboard	0.8	3000	3.75	1,800	2.25					
Untempered hardboard	1.28	6000	4.69	6,000	4.69					
Medium density board	0.42	800	1.91	500	1.18					
Medium density board	0.8	2000	2.50	3,400	4.25					
Structural insulating board	0.16	200	1.25	--	--					
Structural insulating board	0.42	500	1.19	--	--					

Notes:

(1) Corrugated and solid fiberboard: the resistance to puncture is given in inch-pounds as determined by ASTM Test Method designation, and the compressive strength is determined by the short column test method.
(2) Fibrous felted properties from various sources and test methods are not identified.
(3) Refer to paragraph 5.7.3 for the code letter definitions.

TABLE XLIX. Container material selection chart - wood, plywood, and paper overlaid veneer.

Material	Specific gravity (Sp gr)	Tensile strength F_t M of R, psi	Ratio $\left(\frac{10^{-3} F_t}{Sp\ gr}\right)$, psi	Compressive strength F_c, psi	Ratio $\left(\frac{10^{-3} F_c}{Sp\ gr}\right)$, psi	Modulus of elasticity E, 10^{-6} psi	Resistance to Impact	Resistance to Abrasion	Resistance to Puncture	Reported hazards to stability (3)
Wood, Clear and Straight Grain(1)										
(Group I container woods)										
Aspen (popple)	0.35	5100	14.6	2140	6.1	0.95	22		300	adegi
Basswood	0.32	5000	15.6	2220	6.9	1.14	16		250	adeg
Buckeye	0.33	4800	14.5	2050	6.2	1.08	18		290	adegi
Cedar, northern white	0.29	4200	14.5	1990	6.9	0.70	15		230	adegi
Cedar, Alaska	0.42	6400	15.2	3050	7.3	1.25	27		440	adeg
Chestnut	0.40	5600	14.0	2470	6.2	1.02	24		420	adegi
Cottonwood	0.37	5300	14.3	2280	6.2	1.11	21		340	adeg
Cypress (bald cypress)	0.42	6600	15.7	3580	8.5	1.30	25	0.056	390	adeg
True firs, balsam	0.34	4900	14.4	2400	7.1	1.06	16		290	adeg
True firs, grand	0.37	6100	16.5	3020	8.2	1.43	22		360	adeg
Magnolia	0.46	6800	14.8	2700	5.9	1.22	54		740	adeg
Pines, sugar	0.35	5100	14.6	2530	7.2	1.03	17	0.148	310	adeg
Pines, Virginia	0.45	7300	16.0	3420	7.6	1.30	21		540	adeg
Redwood	0.38	7500	19.7	4200	11.0	1.30	21	0.154	410	adeg
Spruces, Engelmann	0.32	4500	14.1	2190	6.8	1.06	16	0.040	260	adeg
Spruces, red	0.38	5800	15.3	2650	7.0	1.31	18		350	adeg
Willow, black	0.34	3800	11.2	1520	4.5	0.62	36		430	adegi
Yellow poplar	0.40	6000	15.0	2660	6.7	1.34	26	0.060	440	adeg
(Group II container woods)										
Douglas fir	0.40	6400	16.0	3000	7.5	1.30	20	0.038	450	adeg
Hemlock	0.38	6100	16.0	2990	7.9	1.34	22		430	adeg
Southern yellow pine, loblolly	0.47	7300	15.5	3490	7.4	1.54	30		450	adeg

TABLE XLIX. Container material selection chart - wood, plywood, and paper overlaid veneer. - Continued

Material	Specific gravity (Sp gr)	Tensile strength F_t M of R, psi	Ratio $\left(\frac{10^{-3} F_t}{Sp\ gr}\right)$, psi	Compressive strength F_c, psi	Ratio $\left(\frac{10^{-3} F_c}{Sp\ gr}\right)$, psi	Modulus of elasticity E, 10^{-6} psi	Resistance to Impact	Resistance to Abrasion	Resistance to Puncture	Reported hazards to stability (3)
Wood, Clear and Straight Grain(1) (Cont)										
Southern yellow pines, longleaf	0.54	8700	16.1	4300	8.0	1.76	35	0.027	590	adeg
Tamarack	0.49	7200	14.7	3480	7.1	1.36	28		380	adegi
Western larch	0.51	8200	16.1	3990	7.8	1.68	29		510	adeg
(Group III container woods)										
Ash, black	0.45	6000	13.3	2300	5.1	1.14	33		520	adeg
Ash, green	*0.53*	*9500*	*17.9*	*4200*	*7.9*	*1.54*	35		*870*	adeg
Soft elm	0.46	7200	15.6	2900	6.3	1.22	38		620	adeg
Soft maple	0.44	5800	13.2	2490	5.7	1.03	29		590	adegi
Sweetgum	0.46	7100	15.4	3040	6.6	1.32	36		600	adeg
Sycamore	0.46	6500	14.1	2920	6.3	1.17	26		610	adeg
Tupelo	0.46	7000	15.2	3040	6.6	1.13	30		640	adegi
(Group IV container woods)										
Beech	0.56	8600	15.4	3550	6.3	1.52	43	0.027	850	adeg
Birch (except paper birch)	0.55	8300	15.1	3380	6.1	1.65	48	0.023	810	adeg
Hackberry	0.49	6500	13.3	2650	5.4	1.05	48		700	adegi
Hard maple	0.52	7900	15.2	3270	6.3	1.46	48	0.012	840	adegi
Hickory, shellback	0.62	10,500	16.9	3920	6.3	1.47	74			adegi
Hickory, pignut	0.66	11,700	17.7	4810	7.3	1.82	89	0.009		adegi
Oak, southern red	0.52	6900	13.3	3030	5.8	1.25	29		860	adegi
Oak, swamp white	*0.64*	*9900*	*15.5*	*4360*	*6.8*	*1.75*	50	*0.018*	*1160*	adeg
Pecan	0.60	9800	16.3	3990	6.6	1.51	53		1310	adegi
Rock elm	0.57	9500	16.7	3780	6.6	1.31	54		940	adeg
White elm	0.55	9600	17.5	3990	7.3	1.61	38	0.018	960	adeg

TABLE XLIX. Container material selection chart - wood, plywood, and paper overlaid veneer. - Continued

Material	Specific gravity (Sp gr)	Tensile strength F_t M of R, psi	Ratio $\left(\frac{10^{-3} F_t}{Sp\ gr}\right)$, psi	Compressive strength F_c, psi	Ratio $\left(\frac{10^{-3} F_c}{Sp\ gr}\right)$ psi	Modulus of elasticity E, 10^{-6} psi	Resistance to: Impact	Resistance to: Abrasion	Resistance to: Puncture	Reported hazards to stability (3)
Plywood(2)										
(Container grade NN-P-530) Three-ply, group A, 3/16 in.	0.416	6620	15.9						250	abdegh
		1280	3.1							
	0.403	5820	14.4						175	abdegh
Paper-overlaid Veneer(2)										
1/8 in. sweetgum (undried) with 0.016 in. kraft overlay	0.532	8070	15.2						328	abdeghi
		1900	3.6							
1/8 in. red oak (undried) with 0.016 in. kraft overlay	0.622	8170	13.1						240	abdeghi
		1420	2.3							
1/8 in. Douglas fir (dry-distended) with 0.016 in. kraft overlay	0.467	7410	15.9						208	abdegh
		520	1.1							
1/12 in. birch (dried) with 0.027 in. asphalt-impregnated kraft overlay	0.770	8760	11.4						280	abdegh
		2380	3.1							

TABLE XLIX. Container material selection chart - wood, plywood, and paper overlaid veneer. - Continued

Material	Specific gravity (Sp gr)	Tensile strength F_t M of R, psi	Ratio $\left(\frac{10^{-3} F_t}{Sp\ gr}\right)$, psi	Compressive strength F_c, psi	Ratio $\left(\frac{10^{-3} F_c}{Sp\ gr}\right)$, psi	Modulus of elasticity E, 10^{-6} psi	Resistance to: Impact	Resistance to: Abrasion	Resistance to: Puncture	Reported hazards to stability (3)
Paper-overlaid Veneer(2) - (Cont)										
1/12 in. basswood (dried) with 0.027 in. asphalt-impregnated kraft overlay	0.617	5050 2090	8.2 3.4						155	abdegh
1/16 in. birch (dried) with two sheets 0.030 in. in sulfate cylinder kraft each face	0.666	3000 3420	4.5 5.1						371	abdegh

Notes:

(1) Wood: the strengths, elasticity impact resistance, and puncture resistance were determined by ASTM Test Method D-143; impact resistance was expressed as the maximum height in inches from which a 50-pound weight was dropped to cause complete rupture in bending of a 2- x 2-in. specimen on a 28-in. span; the puncture resistance, or hardness, was the force required to embed a 0.44-in. diameter steel ball to a depth of 0.22 in.; and resistance to abrasion was expressed in inches removed per 1000 revolutions as measured on the U.S. Navy wear-test machine.

(2) Plywood and paper-overlaid veneer: the resistance to puncture was given in inch-pounds as determined by ASTM Test Method D-781, and tensile strength was measured by ASTM Test Methods D-3499, D-3500, D-3501, D-3502, and D-3503.

(3) Refer to paragraph 5.7.3 for the code letter definitions.

(4) M of R = modulus of rupture.

TABLE L. Container material selection chart - plastics.

Material	Specific gravity (Sp gr)	Tensile strength F_t, psi	Ratio $\left(\frac{10^{-3} F_t}{Sp\ gr}\right)$, psi	Compressive strength F_c, psi	Ratio $\left(\frac{10^{-3} F_c}{Sp\ gr}\right)$, psi	Modulus of elasticity E, 10^{-6} psi	Resistance to: Impact	Resistance to: Abrasion	Resistance to: Puncture	Reported hazards to stability (3)
Plastics(1)										
Acetal	1.42	10,000	7.04	18,000	12.67	0.41	1.4	20.	R120	,aejk
Acrylic	1.18	Y14,000	Y11.86	17,000	14.40	0.40	0.3		M88	
	1.19	9,000	7.56	15,000	12.60	0.35	0.4		M102	
	1.19	8,000	6.72	12,000	10.08	0.35	0.4		M84	
Acrylonitrile butadiene	1.07	7,000	6.54			0.34	4.5		R107	
styrene (ABS)	1.02	4,000	3.92			0.21	6.5		R83	
	1.07	4,000	3.74	5,500	5.14	0.20	5.0		D76S	
	1.00	2,000	2.00				6.5		D60S	
Cellulose acetate	1.32	12,000	9.10							abdehik
	1.26	7,000	5.56							
	1.34	6,000	4.48	7,200	5.37		0.4		R112	
	1.33	5,000	3.76	5,000	3.76		0.8		R101	
	1.34	2,000	1.49	2,100	1.566		2.0		R52	
Cellulose acetate butyrate	1.25	6,000	4.80	6,500	5.20		0.6		R114	
	1.18	2,000	1.70	1,100	0.932		3.2		R59	
Cellulose acetate propionate	1.24	5,000	4.03			0.14	0.8		R100	
	1.19	1,000	0.84			0.05	9.0		R20	
Diallyl phthalate	1.60	7,000	4.38	25,000	15.6		0.5			
(allyl resin)	1.40	4,000	2.86	25,000	17.8		1.7			
	1.65	4,000	2.42	20,000	12.1		0.2		M99	
	1.31	4,500	3.43	20,000	15.3	0.60	0.55			
Epoxy resin	1.15	9,500	8.26	40,000	34.8	0.3	0.20		M110	
	1.12	7,000	6.25	30,000	26.79	0.3	0.43		M90	
	1.00	100	0.10	3,000	3.00	0.2	7.00			
Ethyl cellulose	1.16	6,000	5.18			0.15	1.8		R110	
	1.16	4,000	3.45			0.10	3.5		R80	
	1.16	3,000	2.58				4.0		R70	
Halogenated hydrocarbons	2.10	4,000	1.90	12,000	5.72	0.01			R112	
	2.30	1,000	0.43			0.03	2.5		J75	

TABLE L. Container material selection chart - plastics. - Continued

Material	Specific gravity (Sp gr)	Tensile strength F_t, psi	Ratio $\left(\frac{10^{-3} F_t}{Sp\ gr}\right)$, psi	Compressive strength F_c, psi	Ratio $\left(\frac{10^{-3} F_c}{Sp\ gr}\right)$, psi	Modulus of elasticity E, 10^{-6} psi	Resistance to Impact	Resistance to Abrasion	Resistance to Puncture	Reported hazards to stability (3)
Plastics(1) - (Cont)										
Melamine formaldehyde	1.53	8,000	5.23	30,000	19.60	1.6	0.5		M119	
	1.53	7,000	4.57	40,000	26.13	1.3	0.2		M118	
	1.46	5,000	3.42	9,000	6.16		0.3			
	2.00	6,000	3.00				4.0			
Nylon (polyamide)	1.14	8,000	7.02	13,000	11.4	0.40	1.0	5.	R118	adefhk
	1.09	6,000	5.50	7,200	6.60		1.0		R111	
Phenolic	1.41	7,000	4.96	30,000	21.3	1.4	0.48			adeg
	1.36	6,000	4.41	25,000	18.37	1.2	0.28			
	1.74	6,000	3.45	15,000	8.62		2.0		M110	
	1.75	5,500	3.14	25,000	14.28	2.6	0.30			
	1.35	3,000	2.22	15,000	11.11	0.40	0.30		M50	
	2.00	4,000	2.00	15,000	7.50	3.0	0.30		M100	
Polycarbonate	1.2	10,500	8.8	11,000	9.16	0.32	16.			
	1.2	9,000	7.5				12.			
Polyester (alkyd)	2.08	6.000	2.88	24,000	11.53	2.2	8.0		70Bhn	
	1.90	4,000	2.10	21,000	11.05	1.8	0.3		58Bhn	
	2.28	3,000	2.28	16,000	7.02	2.2	0.3		60Bhn	
Polyethylene	0.96	4,800	5.0			0.15	3.0		R41	ade
	0.96	4,000	4.17			0.08			R30	
	0.91	1,100	1.21							
Polypropylene	0.9	5,000	5.56			0.14	0.8			ade
	0.9	4,500	5.0			0.20	0.9			
Polystyrene	1.06	7,700	7.2	13,000	12.26	0.44	0.5			
	1.06	5,500	5.2	14,130	13.32	0.44	0.42		M70	
	1.05	3,740	3.53	9,000	8.57	0.35	2.2			
	1.10	3,000	2.73	3,500	3.18	0.25	1.5		M15	

TABLE L. Container material selection chart - plastics. - Continued

Material	Specific gravity (Sp gr)	Tensile strength F_t, psi	Ratio $\left(\frac{10^{-3} F_t}{Sp\ gr}\right)$, psi	Compressive strength F_c, psi	Ratio $\left(\frac{10^{-3} F_c}{Sp\ gr}\right)$, psi	Modulus of elasticity E, 10^{-6} psi	Resistance to: Impact	Resistance to: Abrasion	Resistance to: Puncture	Reported hazards to stability (3)
Plastics(1) - (Cont)										
Polyvinyl chloride	1.44	8,950	6.22	9,600	6.66	0.41	3.0		D80S	abcdef
	1.30	5,600	4.31	6,500	5.00		0.4		D76S	
Silicone	2.0	5,000	2.50	13,000	6.50		3.0			
	2.0	4,000	1.50	12,000	6.00		0.3			
	2.0	3,000	1.50	16,000	8.00		0.2		M85	
Urea formaldehyde	1.55	6,000	3.87	30,000	19.35	1.3	0.2		E94	
	1.50	5,500	3.67	30,000	20.00	1.3	0.26		E94	
Vinyl chloride acetate	1.35	7,000	5.18				0.2			
	1.40	5,000	3.57				0.3			
	1.40	4,000	2.86				0.3			
Vinylidene chloride	1.75	3,000	1.71			0.05	0.5		M50	

Notes:

(1) Plastics: resistance to impact is in foot-pounds per inch determined by the Izod test of 1/2-in. notched bar specimens resistance to puncture is the Rockwell hardness number except when either the suffix "Bhn" is used to indicate a Brinell hardness number or the suffix "S" is used to indicate a Shore hardness; and abrasion resistance is the percentage of light diffused as measured by ASTM Test Method D-1044. Tensile strength and elasticity were determined by ASTM Test Method D-638 and compressive strength by ASTM Test Method D-695. Prefix letters in "puncture column" indicate Rockwell test scale.

(2) See paragragh 5.7.3 for the code letter definitions.

TABLE LI. Container material selection chart - reinforced plastics.

Material	Specific gravity (Sp gr)	Tensile strength F_t, psi	Ratio $\left(\frac{10^{-3} F_t}{Sp\ gr}\right)$, psi	Compressive strength F_c, psi	Ratio $\left(\frac{10^{-3} F_c}{Sp\ gr}\right)$, psi	Modulus of elasticity E, 10^{-6} psi	Resistance to Impact	Resistance to Abrasion	Resistance to Puncture	Reported hazards to stability (3)
Reinforced Plastics(1)--Average Results of Tests of Specimens in Wet Condition										
Epoxy and glass 143	1.91			68,700	36.0	5.39			70	
				30,900	16.2	2.13				
Epoxy and glass 120	1.81			56,500	31.2	3.35			71	
				50,700	28.0	3.11				
Epoxy and glass 181	1.82			45,060	24.8	3.59				
				43,770	24.1	3.38				
Epoxy and glass 112	1.74			51,200	29.4	3.23			70	
				49,700	28.6	3.03				
Phenolic and cotton fabric	1.36	9530	7.0	15,650	11.5	0.78			46	
		9940	7.4	14,700	10.8	0.77				
Phenolic and glass fabric 181	1.82	43,850	24.1	31,650	17.4	3.20			59	
		42,530	23.4	28,510	15.7	3.06				
Polyester and glass 143	1.85	73,200	39.6	32,990	17.8	4.87			69	
		9120	4.9	14,130	7.5	0.98				
Polyester and glass 120	1.73	41,600	24.1	24,540	14.2	2.60			71	
		38,470	22.2	20,440	11.8	2.39				
Polyester and glass 181	1.80	39,370	21.9	24,240	13.5	2.53			73	
		38,790	21.5	22,340	12.4	2.69				
Polyester and glass 112	1.70	31,900	18.8	28,360	16.7	2.47			69	
		30,190	17.8	21,860	12.9	2.34				
Polyester and glass 116	1.82	36,850	20.3	16,660	9.2	2.82			68	
		33,180	18.2	13,960	7.7	2.56				
Polyester and glass 182	1.83	45,200	24.7	21,870	12.0	2.92			67	
		41,510	22.7	19,670	10.8	2.76				
Polyester and glass mat 503	1.69	22,920	13.6	11,340	6.7	1.54			62	
		23,340	13.8	12,250	7.2	1.61				
Silicone and glass 181	1.81			19,970	11.0	2.560			59	
				16,840	9.3	2.590				

Note:
(1) Reinforced plastics: puncture resistance was the Barcol hardness number. Tensile strength was measured by ASTM Test Method D-638, and the compressive strength and stiffness were measured by ASTM Test Method D-695.

5.8 Exterior protection and containers. Packed items are shipped to destinations which may not have been known at the time of packaging. Some of these items will be issued to organizations or delivered to depots within the continental limits of the United States, and the remaining items may be shipped to oversea areas. The oversea areas represent the climatic spectra--the tropical jungles, the arctic regions, and the various islands of the seas. These areas have climatic conditions which include extremes in temperature and humidity. All of these possibilities must be taken into consideration when the container is initially designed. The container must insure adequate protection from the time of packing, to the delivery, and after arrival to the using agency where there is a possibility of being further subjected to adverse field conditions.

5.8.1 Container functions. A shipping container is any exterior bag or sack, box, can or drum, crate, etc., which is required to inclose one or more items during storage or shipment. The primary design consideration of an exterior container is the protection of the contents while providing for the ease of handling. The extent of protection provided by a container is dependent upon the contents, the type of container, the materials used in its construction, its assembly features, its final destination, and the anticipated hazards.

5.8.2 Exterior containers. The term "container" may be correctly applied to a wide variety of objects ranging from tiny paper envelopes to steel drums, huge wooden crates, container express (CONEX), and military-owned demountable containers (MILVANs). Containers selected should be durable and consistent with logistic flow and environmental conditions. The minimum number of different containers necessary to house the complete item should be used, provided it is consistent with logistic flow and safety regulations. The same basic design should be used for containers holding similar items with similar requirements. When possible, uniformity in basic configurations, construction, and arrangement of auxiliary features should be designed into containers. Although adequate protection of the item is the controlling factor in selecting containers, all the factors illustrated in figure 26 may become critical for particular items.

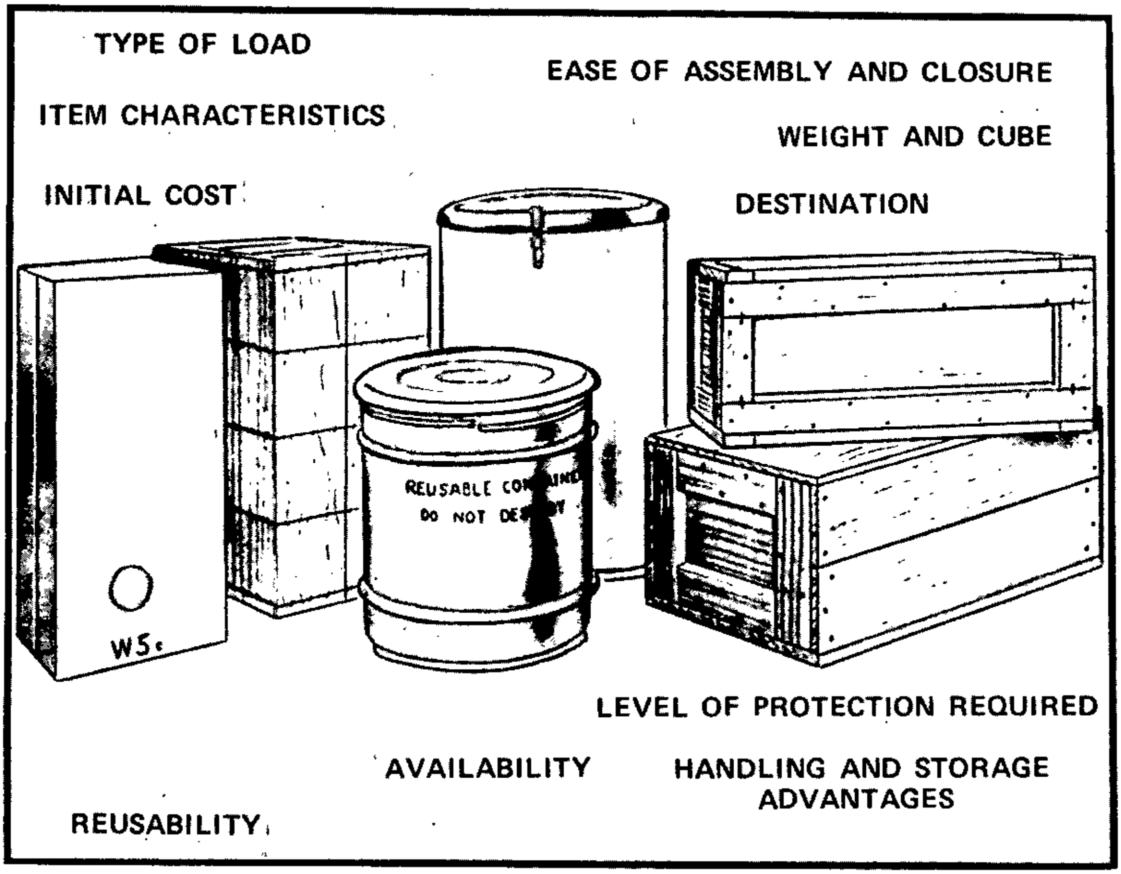


FIGURE 26. Container selection factors.

5.8.2.1 Item characteristics. In selecting containers, the packaging engineer will need answers to the following questions concerning the item:

a. Is it extremely fragile?

b. Is it made of hazardous material?

c. Is there a need for its use in minimum reaction time?

d. Is it repairable or recoverable?

e. Does it have a high dollar value?

f. Is a high reliability required?

g. What is its tactical essentiality?

h. What is the logistic pattern?

i. What is the cost of an alternative?

The physical characteristics of size, fragility level, weight, and weight distribution of an item determine, to a large extent, the container size, type, and cost. The item weight may influence the size of the container structural members, type and capacity of shock and vibration systems, and in turn, transportation costs, and the manual and mechanical handling requirements. The item weight distribution will affect the overall size of the container, the design and location of strength members such as reinforcing ribs, and the design of the shock and vibration isolation systems.

5.8.2.2 Type of load. The type of load or the ability of an item to add strength to, or cause damage to, the faces of the container is important in determining container selection. Internal and external forces developed during transit vary greatly for different loads. If a container is not subjected to appreciable loads, it can be thin and light, but structural strength is required to resist loads imposed during handling, stacking, and shipping operations. Besides the force of the item on the container during shipment, pressures of shipping bands drawn tightly over the load and the additional dynamic loads caused by transportational vibration and shock must be considered. After taking into account all these loads, containers must then be selected which will not be dented or crushed, i.e., result in damage to the packed item.

5.8.2.3 Initial cost of container. Initial costs include those that accrue in preparing for the first shipment, such as the cost of materials and the cost of labor. To keep costs to a minimum, standard parts, materials, and processes should be used to the maximum extent possible. Container design should require mechanical finishes and tolerances no more stringent than necessary to insure reliable operations throughout testing, storage, and operating life of the equipment. Containers chosen should be efficient and economical to fabricate, efficient to assemble, and made with minimum requirements for strategic materials, manpower, and plant facilities.

5.8.2.4 Ease of assembly and closure. The advantage of quick opening is closely related to the cost of the container. Reaction time is a prime consideration for some items. In those cases, containers should have closures and fasteners that result in minimum packing and upacking items commensurate with security of packed items. Large containers, especially, should provide ready access to the mounting supports, and permit installation and removal of contents by means of a sequence of easy operations, using authorized lifting devices and tools.

5.8.2.5 Availability of materials. Containers should be made by fabricating processes appropriate to the number of pieces required in a normal procurement request. Fabricating processes, if possible, should be readily available from several commercial sources that use mass production techniques. Selection should be confined, in most cases, to containers that are stocked at major supply points. Current regulations should be referred to for guidance in the conservation of strategic and critical materials associated with the design and production of military items.

5.8.2.6 Ease in handling and storage. All military containers must withstand handling and storage without impairment of the item by the effects of extreme conditions. For ease in storage, containers should be stable, strong, and capable of stacking and nesting on authorized pallets. All containers should have a minimum of protrusions such as closures, humidity indicators, handles, and valves. Also, any container that is too large, heavy, or awkward to be carried by one person and would, therefore, normally be pushed, dragged, or handled by mechanical equipment should be provided with skids that allow ample clearance from ground level to permit removal by forklift.

5.8.2.7 Degree of protection required. The degree of protection required from the container will depend on the ultimate destination of the shipping container, the nature of the item or contents, and known hazards. Depending on the protection required for an item, containers may use free-breathing design, pressurization, or desiccants. Consideration should also be given to the use of water- and fungus-resistant materials, protective coatings on metal containers and on large wooden containers, and the use of suitable preservative treatments on wooden members. Although protection is aimed at the item, not the container, in many cases, container deterioration may result in an attendant decrease in item protection.

5.8.2.8 Reusability. The following four factors concerning the item will determine whether or not a reusable container will be selected:

a. Military characteristics (this would be the overriding factor).

b. Logistic characteristics.

c. Maintenance.

d. Repairability and recoverability.

Reusable containers are used to prevent unserviceability or damage to large bulky, fragile, or expensive items that must be returned by the using or field maintenance organization or activity to a supply source or repair or rebuilding facility. Reusable containers are especially useful for items of a critical nature which may have to be returned from the field where packing facilities are limited and inadequate to supply required protection. Reusable containers are also useful for items to be shipped for testing or modification, and which will require subsequent repacking for shipment or storage. Such containers should be selected only if they are economically and logistically practicable. Features that contribute to excessive production costs, weight, and cube should be eliminated.

5.8.3 Standard containers. The most common types of containers in use today are bags and sacks, fiberboard and paperboard boxes, wooden boxes, pails and drums, and crates. Each has its uses and limitations and some are designed to handle specific items. These basic containers, as mentioned, are briefly described.

5.8.3.1 Bags and sacks. A bag is a preformed container made of flexible material (fig 27) generally closed on all sides except one which forms an opening that may or may not be sealed after filling. A sack generally refers to heavier duty or shipping bags (fig 28). Both bags and sacks may be employed to handle the same weights and kinds of commodities. Bags and sacks possess the advantage of having low tare weight ratio, being flexible, providing ease in filling and handling, requiring a minimum of storage space, and being constructed of low cost materials.

5.8.3.2 Fiberboard and paperboard containers. A fiberboard container is made of one or more pieces of corrugated or solid fiberboard. The pieces are creased, slotted, joined, and folded according to standard styles (fig 29 and 30). A fiberboard box weighs considerably less than a wooden box of the same capacity. This difference in weight is a factor when large shipments are involved because any saving of weight is reflected in lower shipping costs and easier handling. The chief requirements for a shipping container are light weight, low cost, ability to protect the contents against loss or damage, and the ability to withstand rough handling. If a fiberboard box meets these requirements, it should be used. Paperboard containers are usually reserved for interior packaging. Depending on the item, a paperboard box may be used in packing when using parcel post.

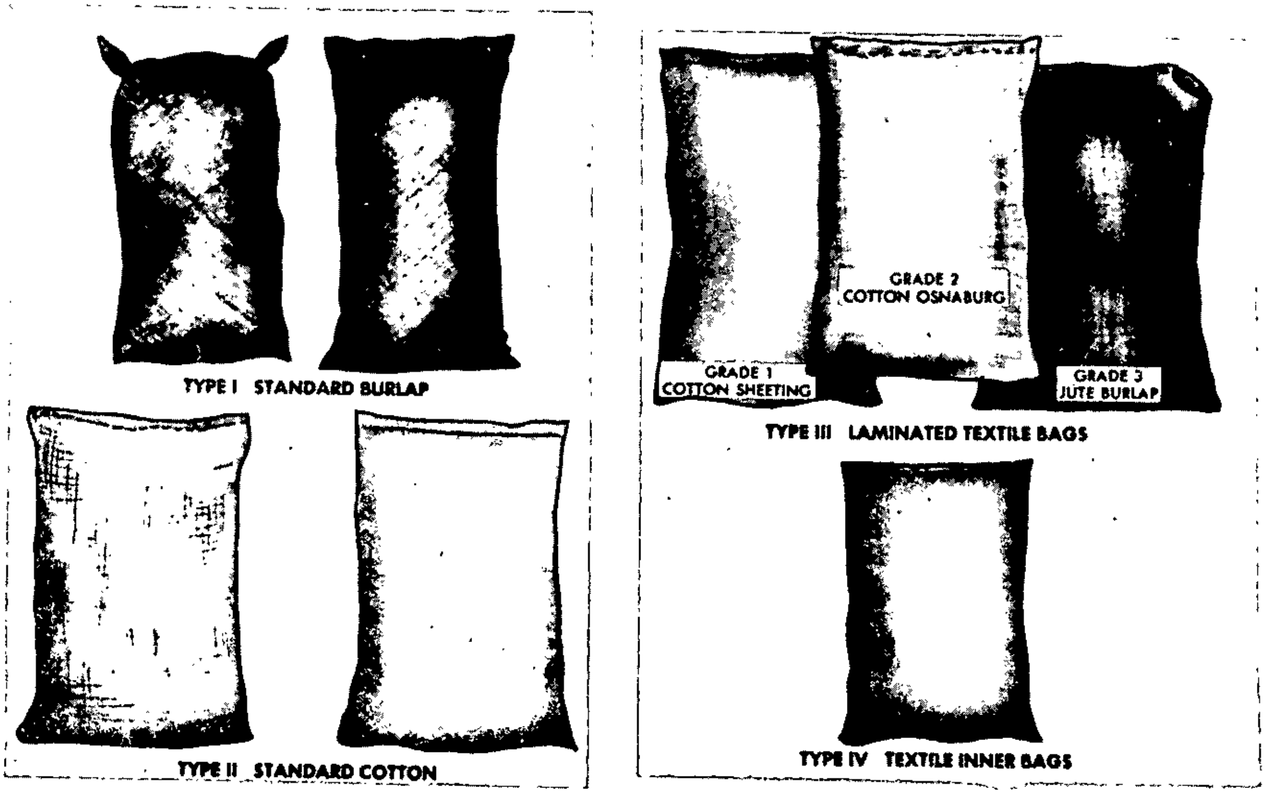


FIGURE 27. Types of textile shipping bags.

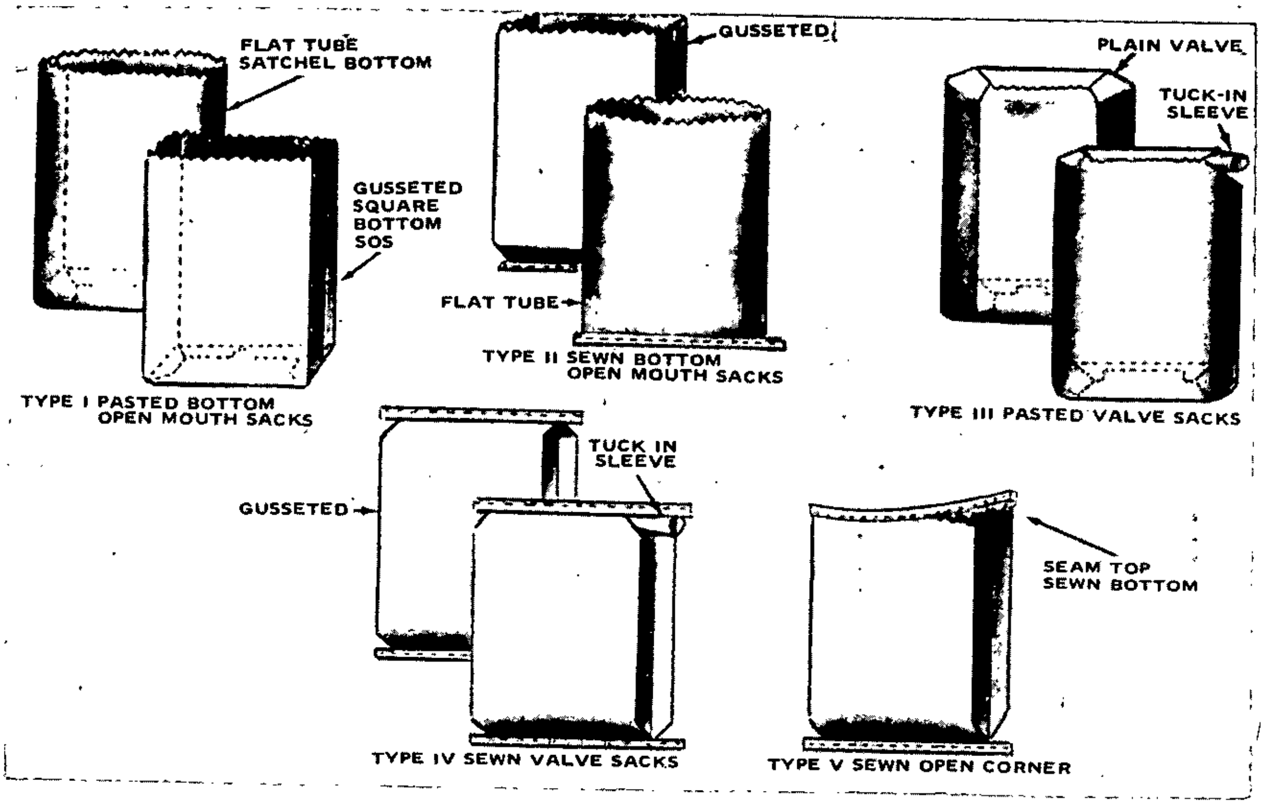


FIGURE 28. Types of paper shipping sacks.

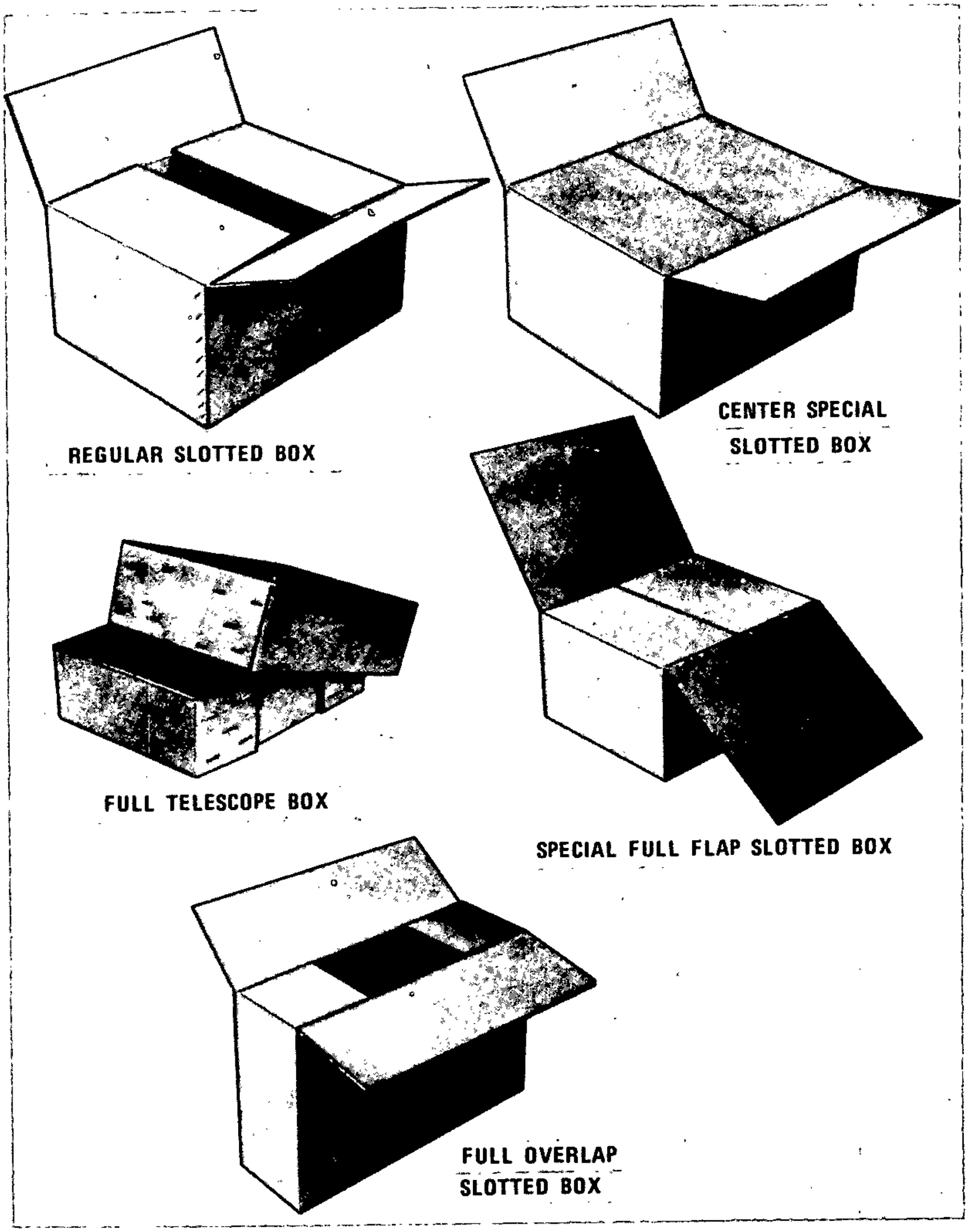


FIGURE 29. Styles of fiberboard boxes.

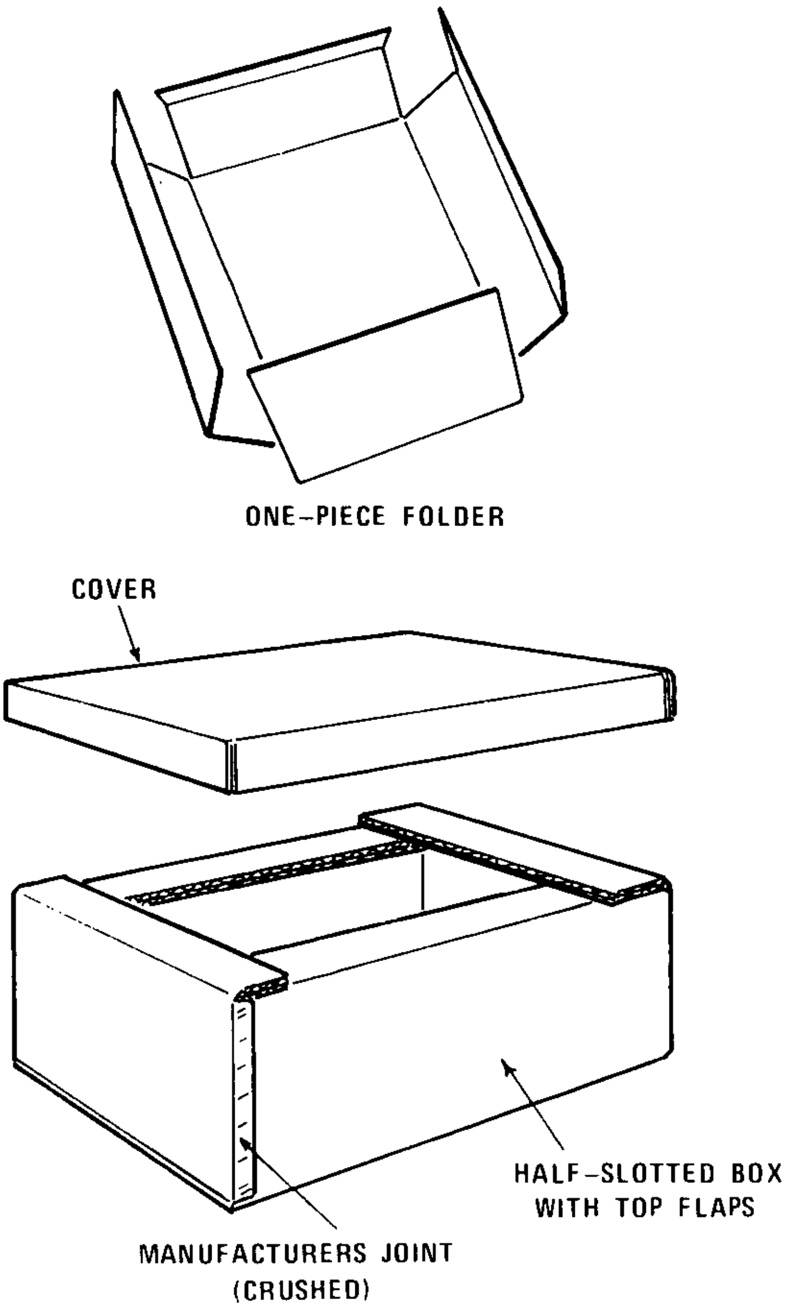


FIGURE 30. Styles of fiberboard boxes.

5.8.3.3 Wooden boxes. Wooden boxes are available in various sizes, types, and styles. Space does not permit discussion of the many wooden boxes available. Figures 31 and 32 illustrate a few boxes of several styles. Wood is particularly valuable as a container material due to its high strength/weight ratio, which compares favorably with mild steel. The strength of a wooden container depends largely upon the type of wood used in its construction.

5.8.3.4 Pails and drums. Pails are cylindrical containers usually made of metal, with or without a handle. They are usually constructed of 29-gauge or heavier metal with capacities ranging from one to twelve gallons. In some cases they may be made from fiberboard. The heads may be fixed and employ spouts of various designs or have full removable heads (fig 33). Drums are cylindrical containers made of metal, fiber, or molded plastic, or a combination of metal and fiber, wood, or plywood (fig 34 and 35). They may be provided with rolling hoops which may be pressed or expanded from the body of the drum, or may be I-bars welded to the body. The heads may be fixed or removable (fig 34 and 36). Pails and drums are classified as interior and exterior, reusable and nonreusable, and metal or nonmetal containers.

5.8.3.5 Crates. A crate is a rigid container constructed of structural members made of wood or metal, which are fastened together to protect the contents. Crates are grouped into several categories. Crates may be nondemountable, single-trip crates of nailed construction or bolted, reusable, demounted crates. Some crates are designed for general use while others are constructed to comply with a specification or DOT regulation for a particular item. Crates also may be open or sheathed (fig 37 and 38). Commonly used crate specifications are:

a. MIL-C-104, Crate, Wood, Lumber and Plywood Sheathed, Nailed and Bolted.

b. MIL-C-3774, Crate, Wood, Open, 12,000- and 16,000-Pound Capacity.

c. MIL-C-9897, Crate, Slotted Angle, Steel or Aluminum (Maximum Loads of 3,000 Lbs.).

d. MIL-C-52950, Crate, Wood, Open and Closed.

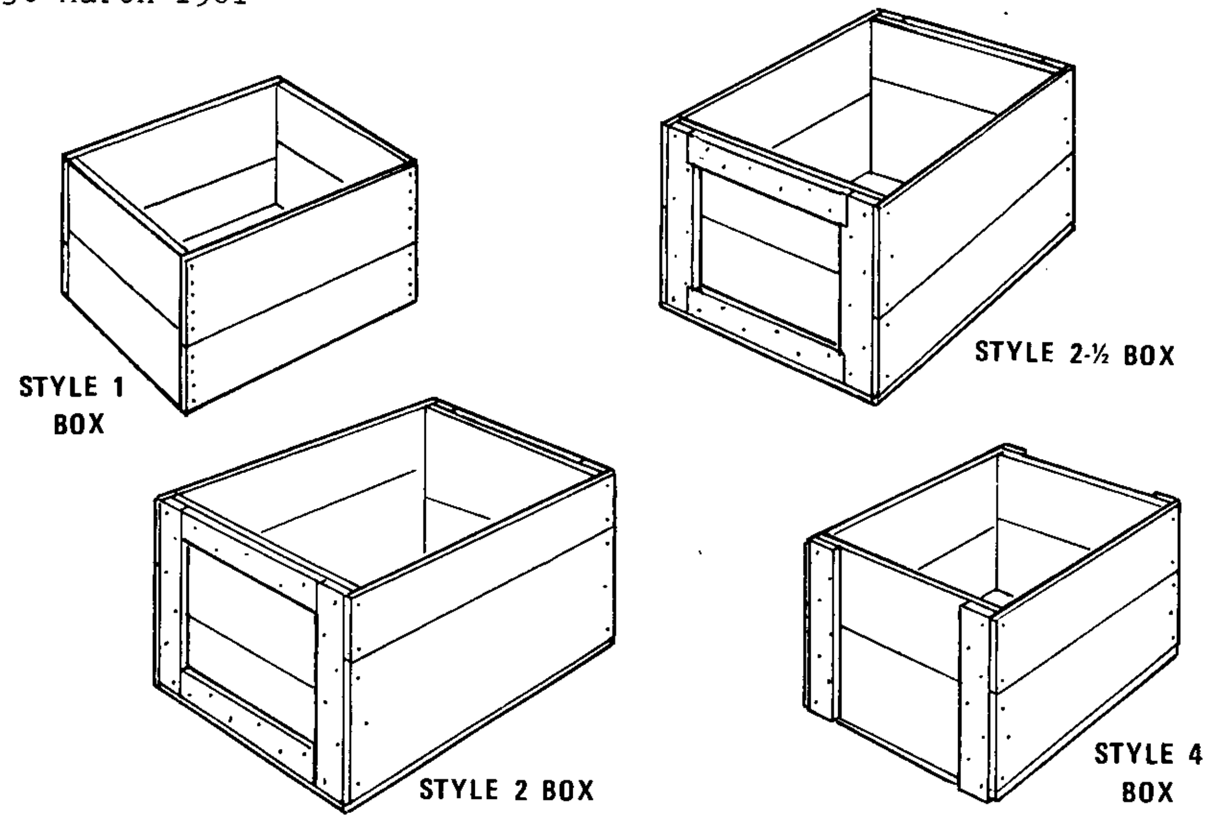


FIGURE 31. Styles of nailed wooden boxes.

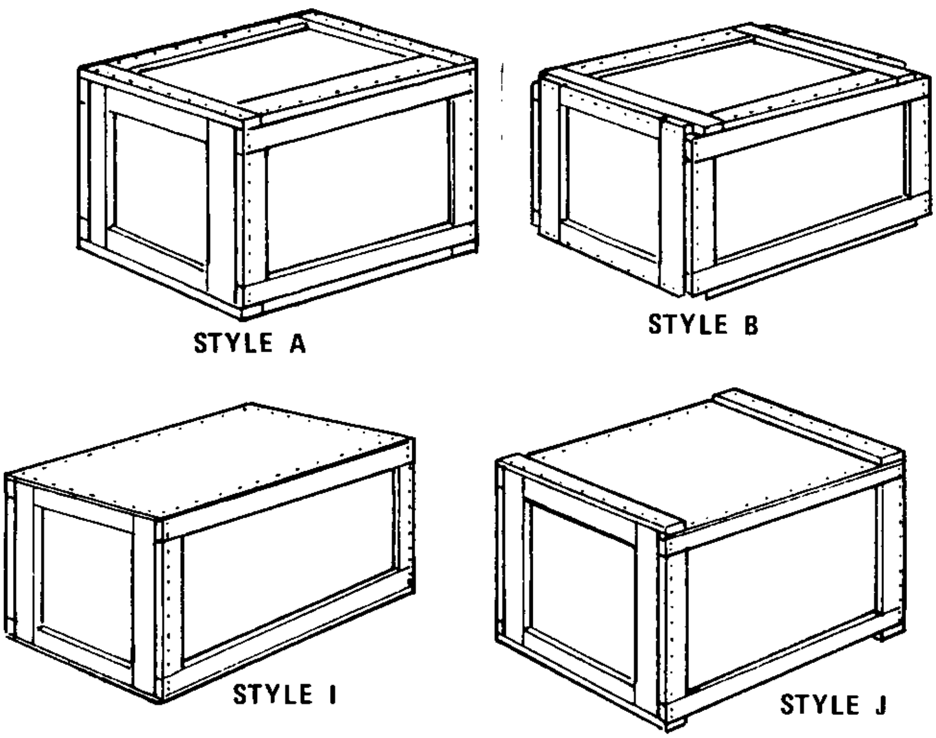


FIGURE 32. Styles of cleated plywood boxes.

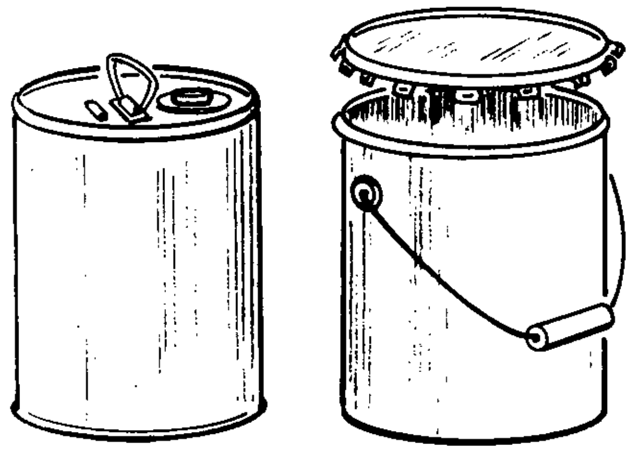


FIGURE 33. Tight head and lug covered pails.

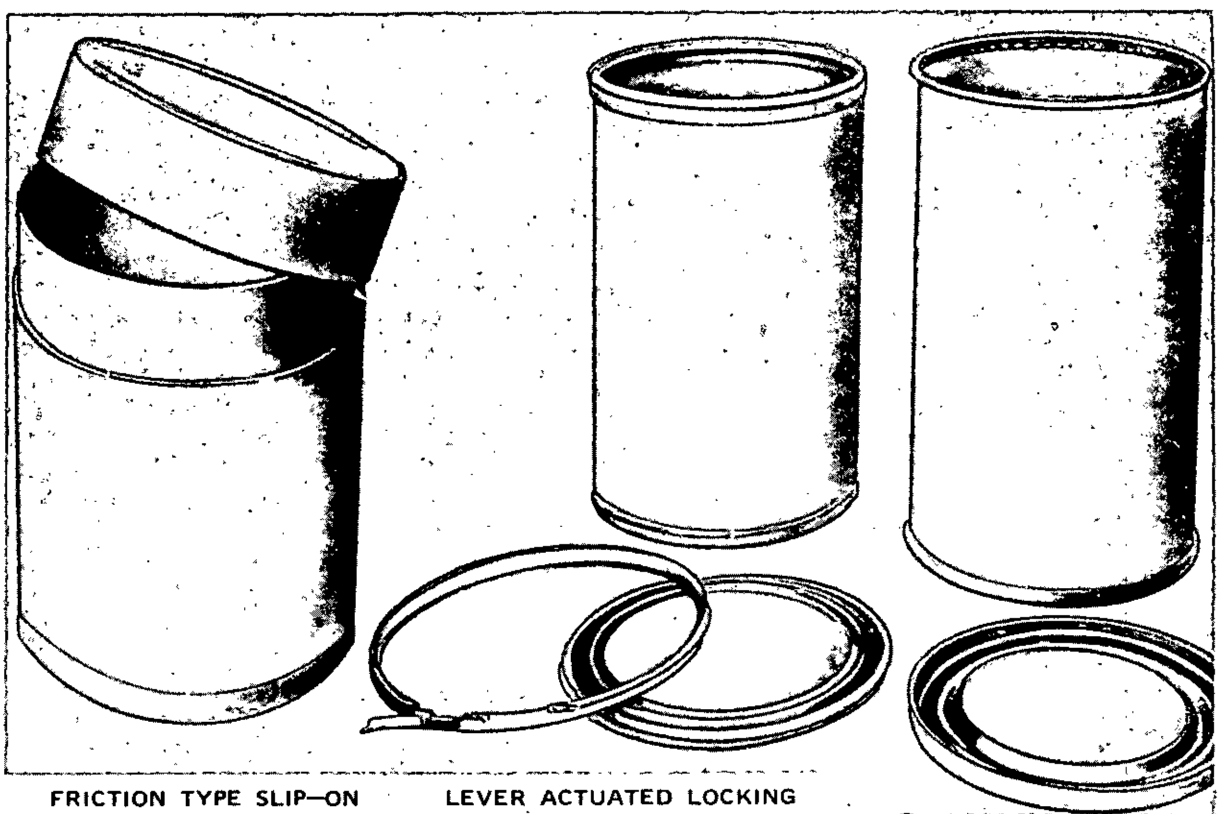


FIGURE 34. Types of fiber drums and closures.

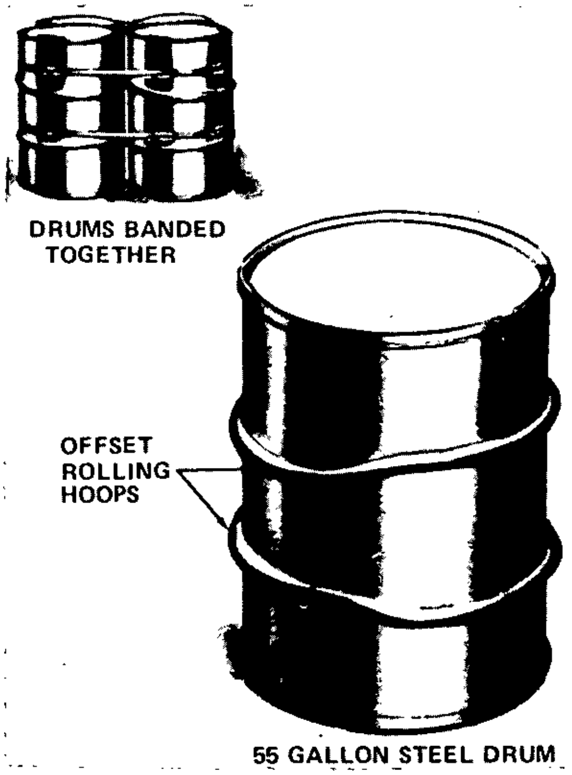


FIGURE 35. Drum with offset rolling hoops.

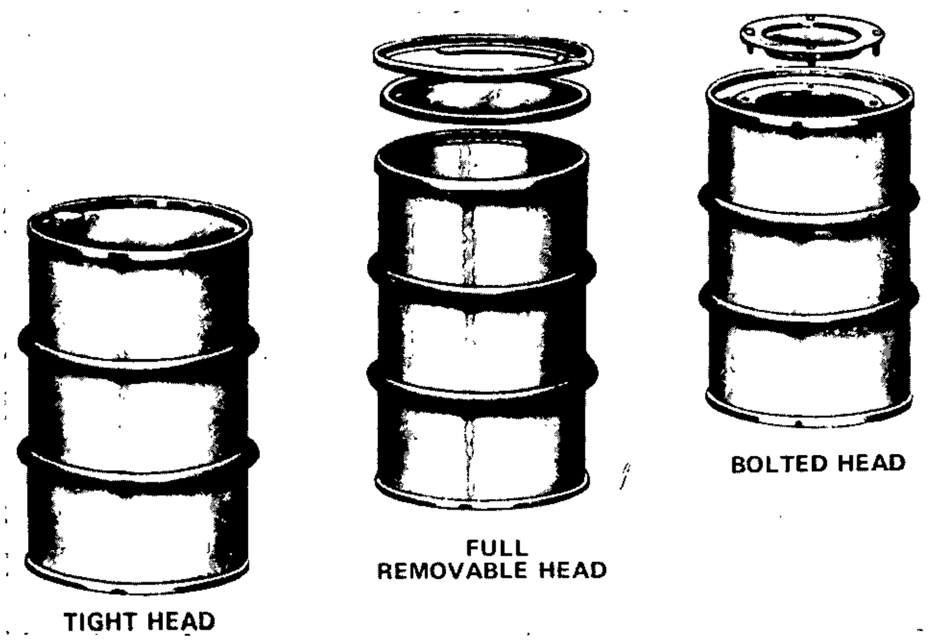


FIGURE 36. Types of drum closures.

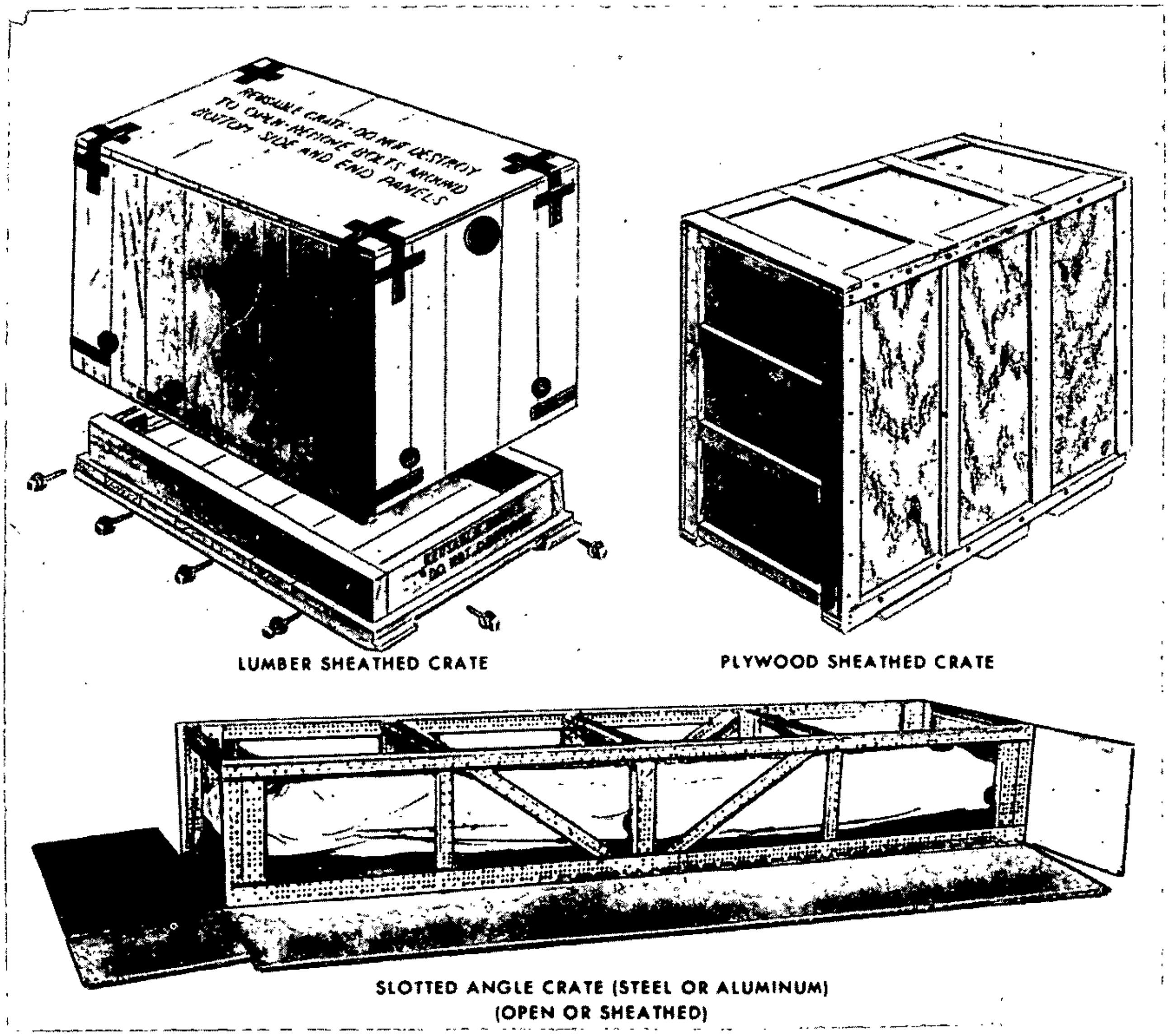


FIGURE 37. Special use crates.

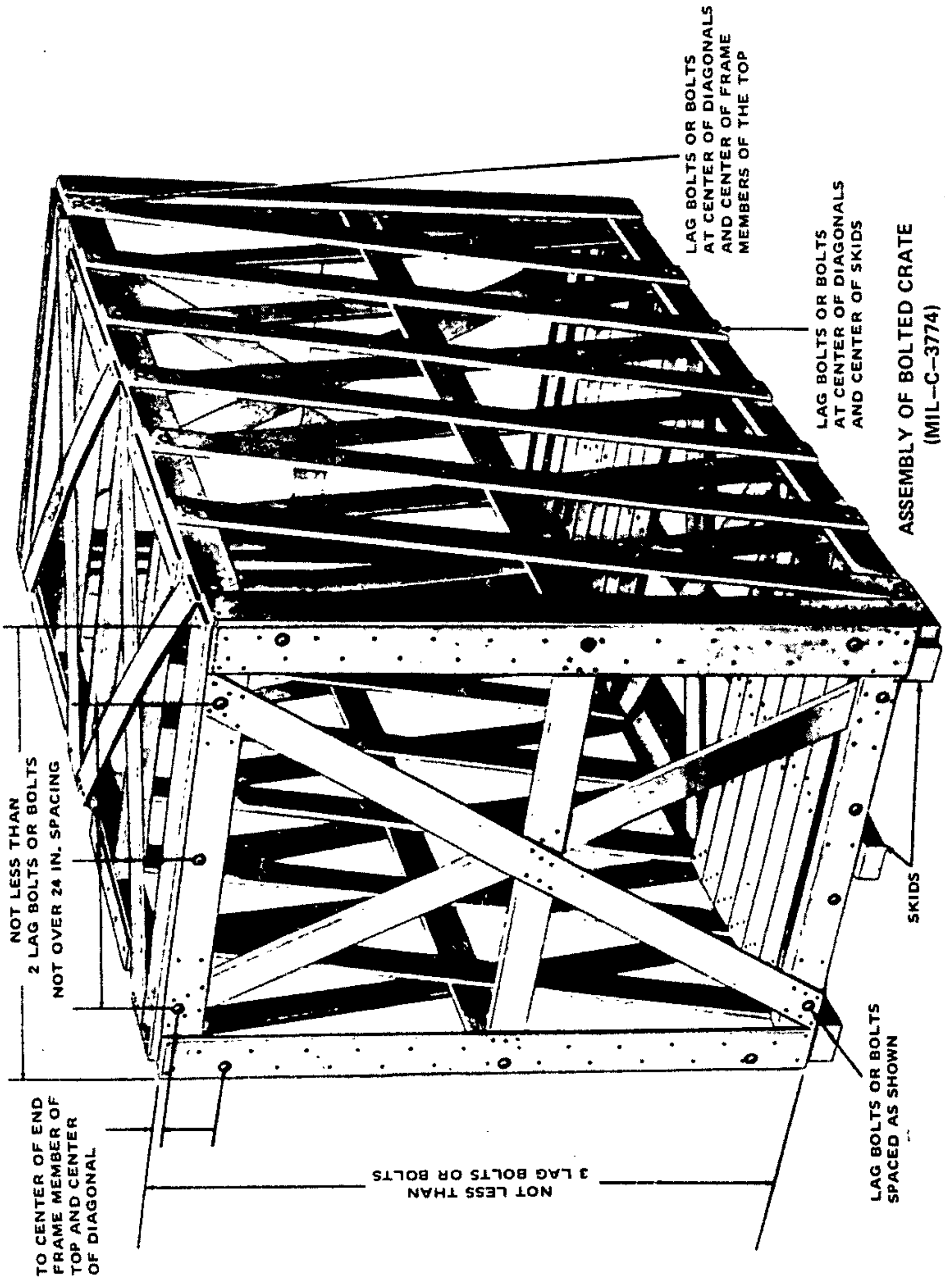


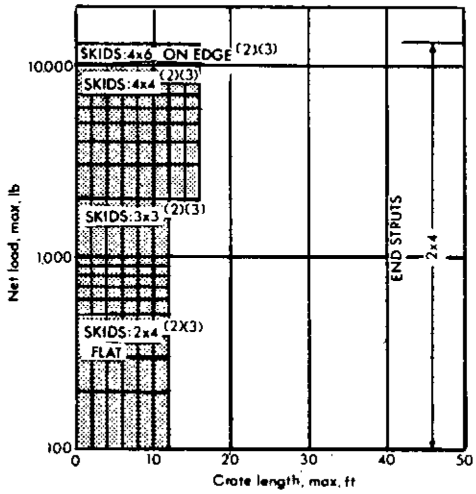
FIGURE 38. Assembly of open bolted crate.

Table LII summarizes the lumber size requirements of these specifications. Nails, bolts, screws, and other fasteners used in the fabrication of crates are detailed in 5.9.

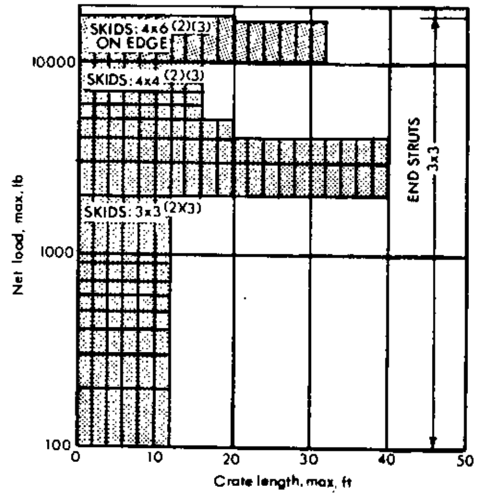
5.8.3.6 Closure tools and equipment. Tools used in the closure of containers vary, in some instances, as widely as the types of containers involved. In most cases, regular hand tools such as hammers, wrenches, screwdrivers, drive bars, etc., are used. In other instances, special closure equipment has been designed to insure effective closures. Special closure tools in use are mentioned throughout this paragraph. Information on closures is contained in 5.9 in greater detail. Steel shipping pails use a lug cover for closure purposes. Lug covers may be secured by a tool specifically designed to accomplish closure on this type of container cover (fig 39 and 40). Hands, pliers, screwdrivers, hammers, or other improvised means are not satisfactory and should not be used. Reusable steel shipping drums are divided into two groups. One type has a bolted ring-type cover with a gasket beneath the locking ring and is secured by means of a bolt and nut (fig 41). Only common hand tools are required to effect a satisfactory closure. The second type uses the twist lock-type cover and closure is accomplished by screwing the threaded cover into engaged threads on the body of the container (fig 41). Wirebound wooden boxes require special tools designed specifically for this type of closure (fig 42). For closure of style 1, there are three choices of special tools available: a hand twister, a crank twister, or a power twister (fig 43). The closure of style 2 and style 3 wirebound wooden boxes requires the use of a Sallee closer (fig 44). The use of common hand tools, such as screwdrivers, pliers, etc., to effect a closure of wirebound wooden boxes, is not recommended because an adequate closure cannot be made and their use may be a safety hazard.

5.8.4 Reusable metal containers. Some military supply items cannot be packed using available exterior containers. The items may be too large, too heavy, highly susceptible to physical damage, or of a nature that requires special environmental protection. Typical examples of items requiring special containers are missile sections, electronic units, engines, and transmissions. These items require the design and construction of containers to suit their individual needs. The containers may require special dimensions, mounting brackets, shock mounts, desiccant holders, humidity indicators, breather valves, pressurizing and depressurizing valves, and inspection ports or panels. Figure 45 illustrates some of the special features of containers. Certain features of containers require attention regardless of the characteristics of their contents. The location of the center of gravity of a container is important in handling and stacking. Improperly located centers of gravity

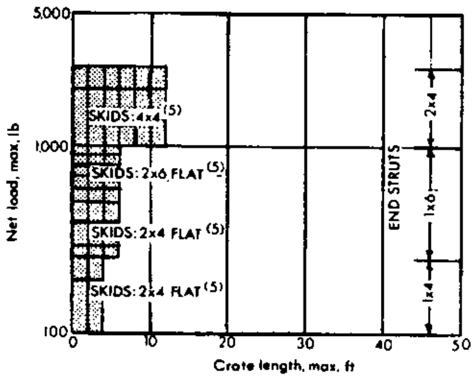
TABLE LII. Lumber selection chart for crate skids and end struts.



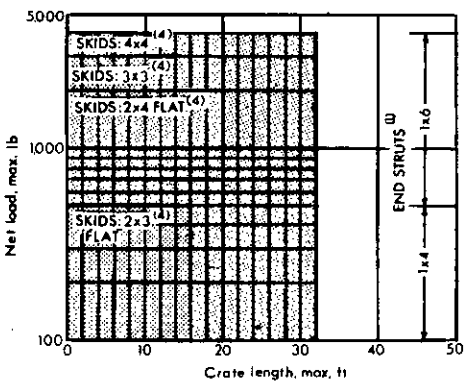
(A) MIL-C-3774, TYPE I



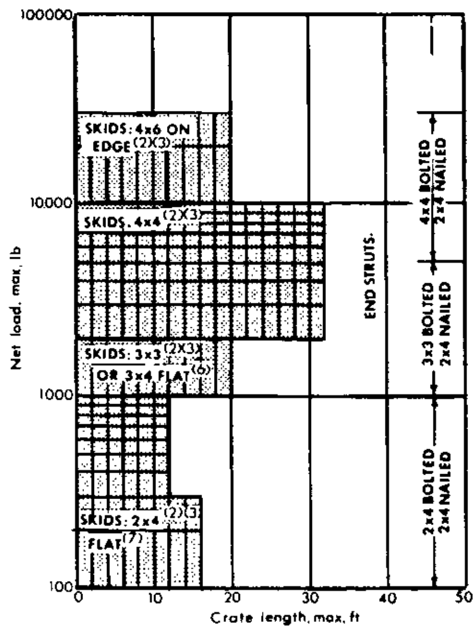
(B) MIL-C-3774, TYPE II



(C) MIL-C-52950, STYLE A



(D) MIL-C-52950, STYLE B



(E) MIL-C-104, TYPES I&II

Notes:

(1) For crates over five feet high, use 2x4 end struts.

(2) When maximum crate length or weight are exceeded, use next larger size lumber for skids. For example, in chart A, a 200 lb crate, 15 ft long would require 3x3 skids.

(3) Maximum distance between skids shall be 48 inches center to center. With concentrated loads, intermediate skids may be used.

(4) For crates up to 42 inches wide, use two skids. Over 42 inches, use three skids.

(5) For loads up to 1000 lb, use two skids. Over 1,000 lb, use two skids for crates under three feet wide, and three skids for crates over three feet wide.

(6) For crates with 2 inch end struts or lower frame members.

(7) For nailed crates only.

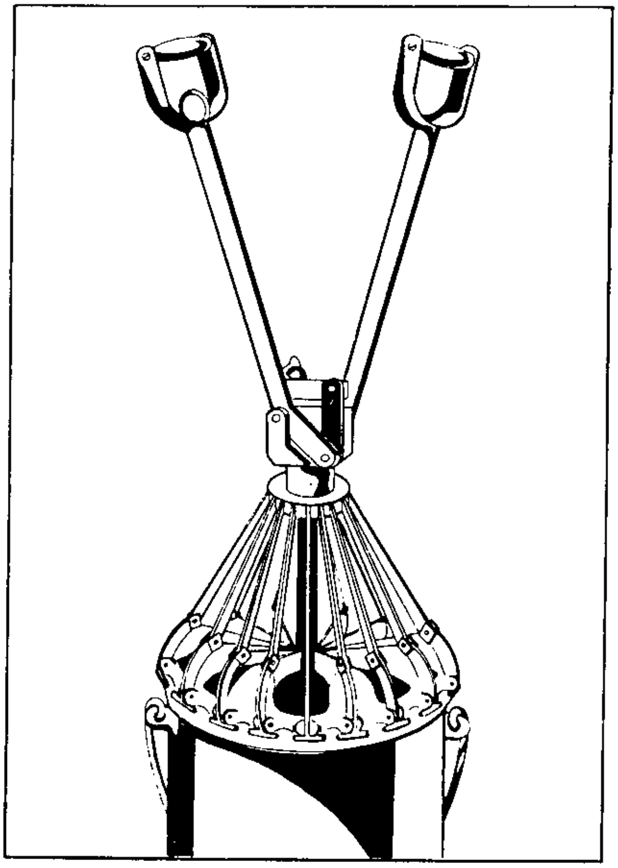


FIGURE 39. Lug cover closing machine.

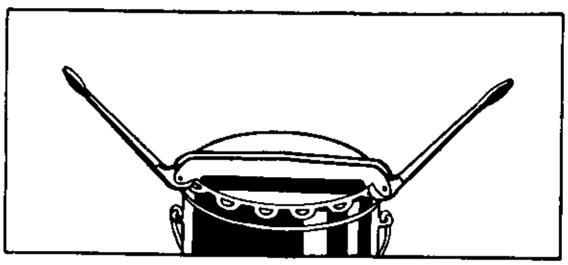


FIGURE 40. Hand closing tool for lug covers.

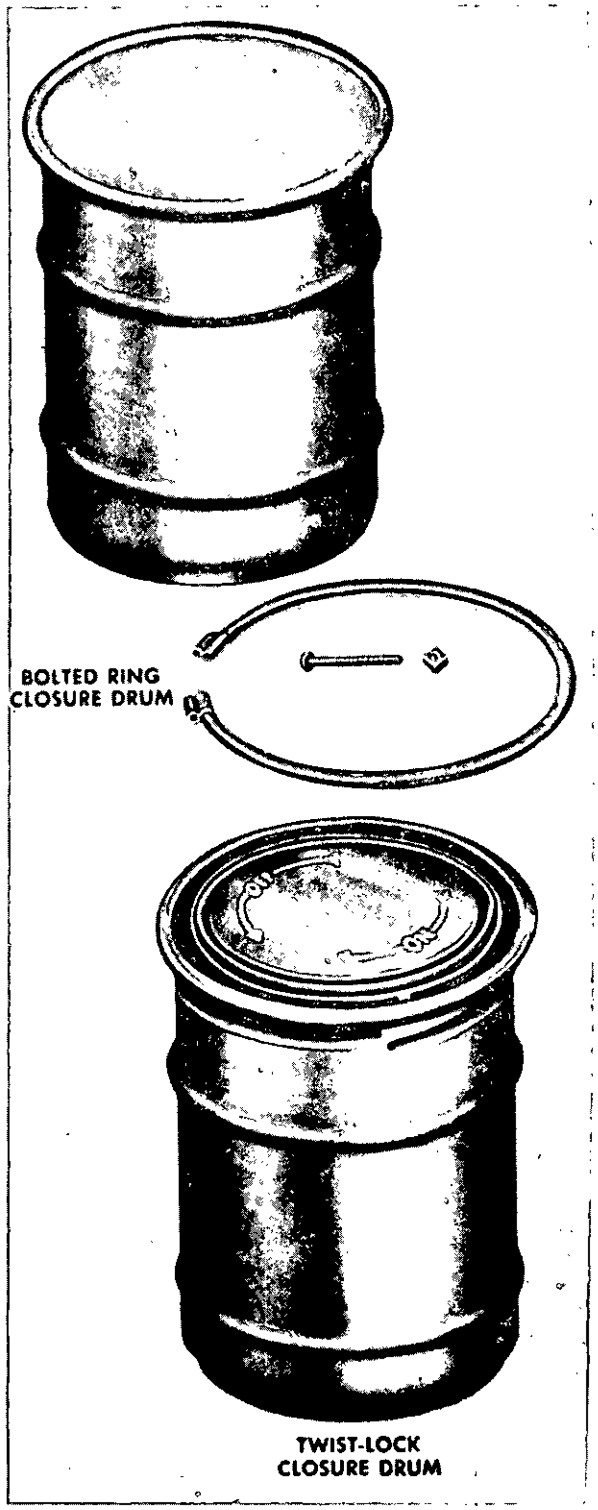


FIGURE 41. Bolted ring and twist-lock closures.

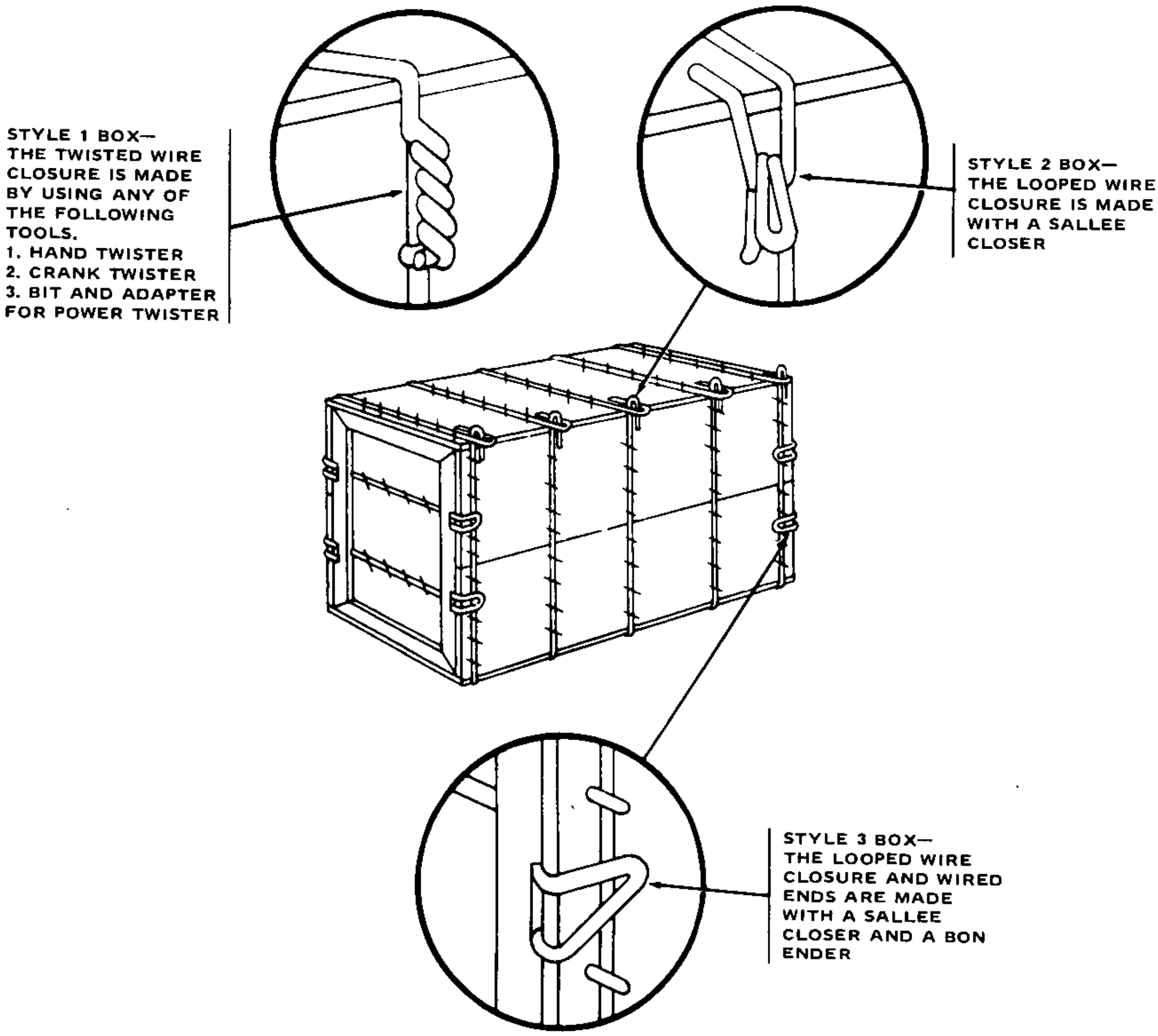


FIGURE 42. Styles of wirebound wood boxes.

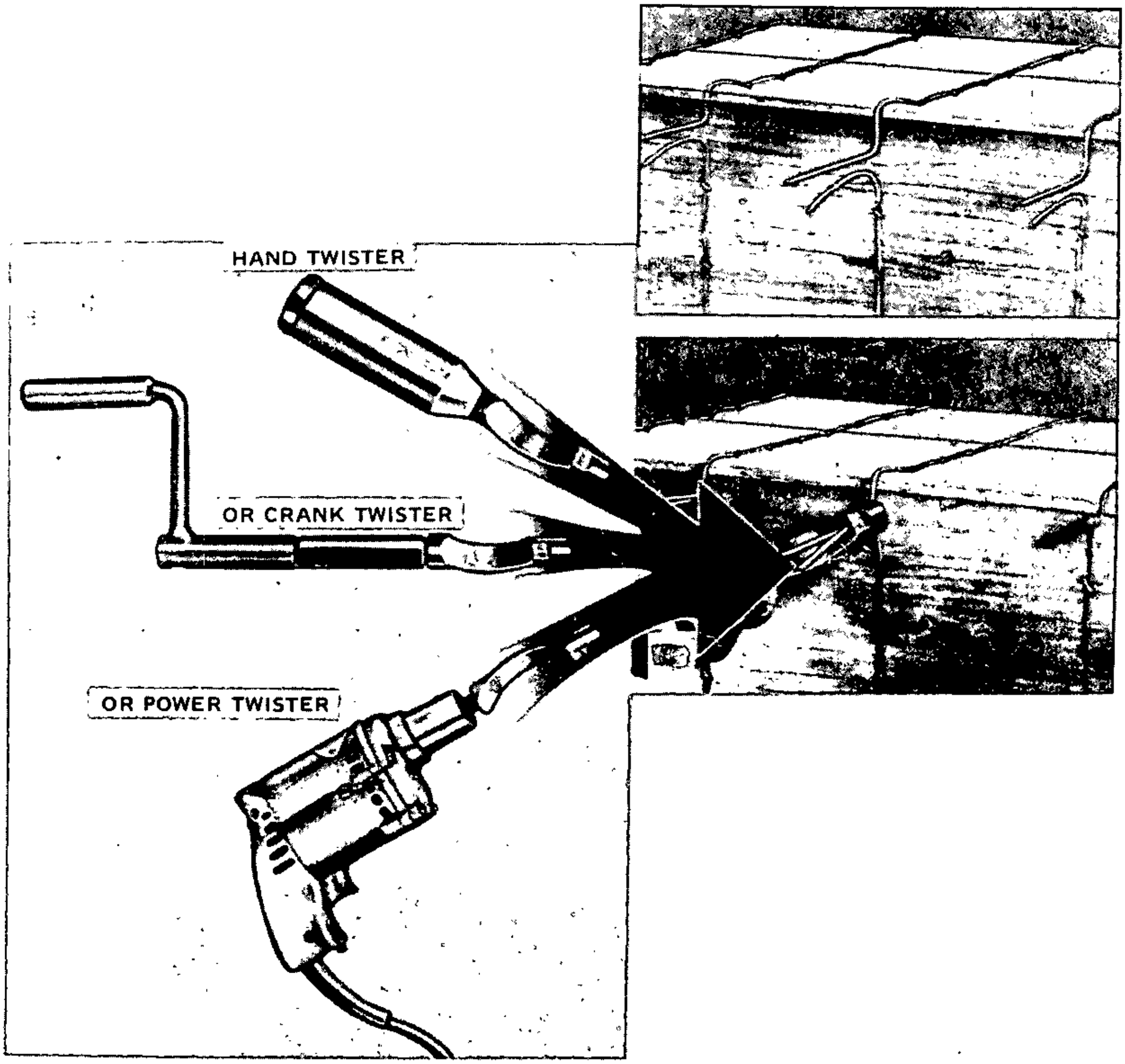


FIGURE 43. Closing of style 1 wirebound wooden boxes.

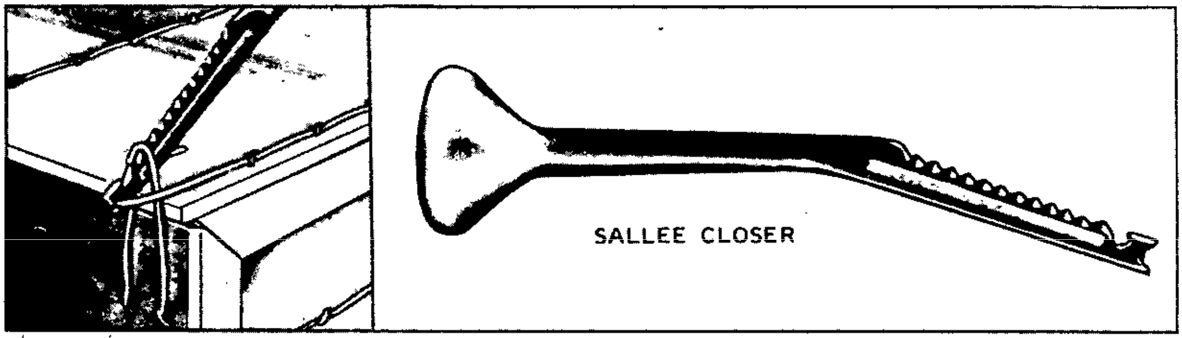


FIGURE 44. Closing of style 2 and style 3 wirebound wooden boxes.

make handling difficult. If the center of gravity is too high, stacking may be unstable. A broad profile may cause problems where wind forces could tip over a container. Figure 46 shows undesirable and preferred end profiles for stacking. Figure 47 shows positioning and alignment features for stacking. Figure 48 shows design considerations for container weight and cube reduction. Strength considerations require analysis of stacking requirements, lifting and handling problems, internal air pressure, weight of contents, and protection from drops. A spherical shape provides the greatest strength, while a cubical shape provides the best stacking and use of storage space. A round shape provides the best protection of contents if containers roll over. Flat sides can cause considerable forces during falls, tearing mountings loose and damaging contents.

5.8.4.1 Types. There are three types of reusable metal containers in use: pressurized, free breather, and valve-controlled breather. Pressurized containers are completely sealed, desiccated, and pressurized to a value above that of the atmosphere. Free breather containers have an opening from the container interior to the atmosphere. They do not restrict air intake, but rely on a desiccant charge to dry out inhaled air. Controlled breather containers have valves which are closed at normal pressures. When the container interior pressure is too high or too low, the valves open to relieve the pressure. In this way the amount of breathing is reduced and desiccant life increased. Pressurized containers offer the greatest protection but are heavy and bulky since they must be made strong enough to withstand the pressure changes caused by temperature variations and altitude changes in airlift operations. The life of desiccant in pressurized containers is indefinite as long as the containers remain pressurized. Free breather containers can be made lighter

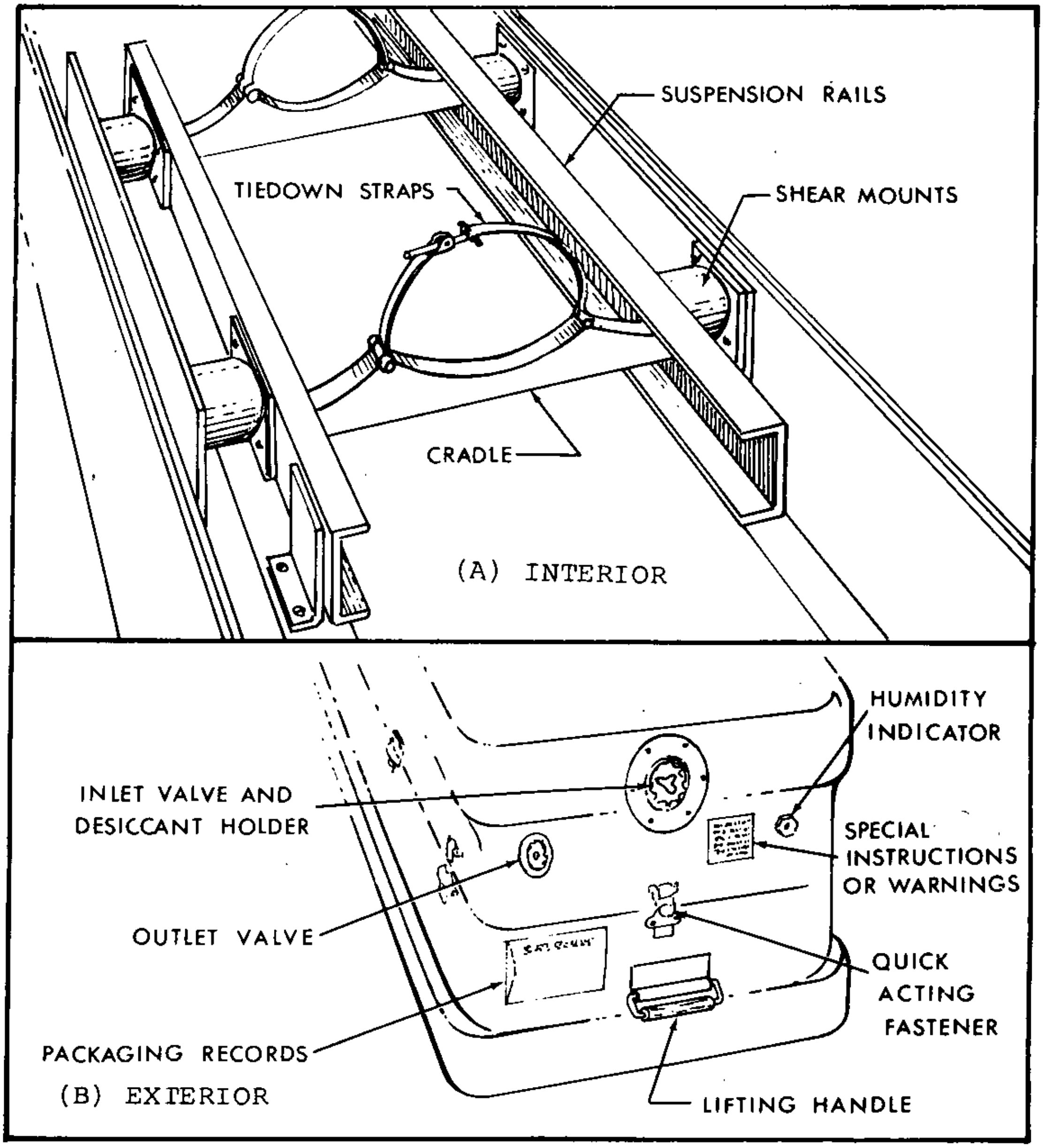
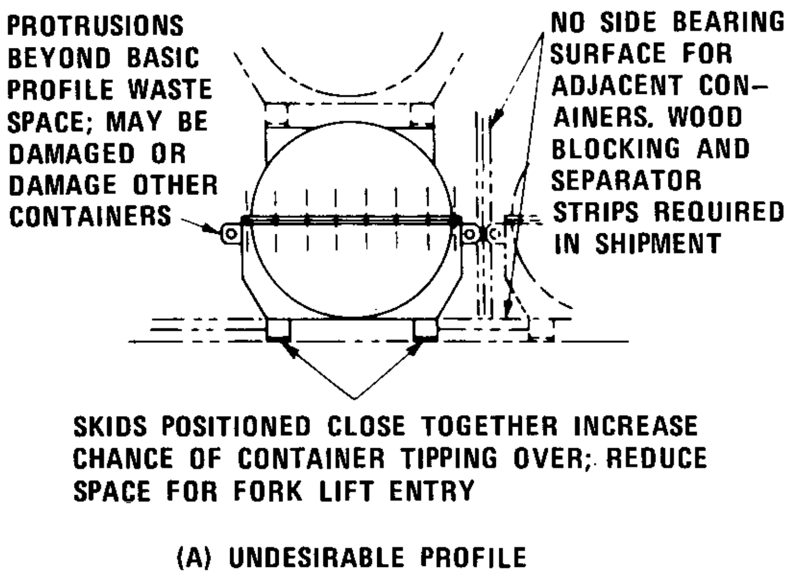


FIGURE 45. Features of reusable containers.



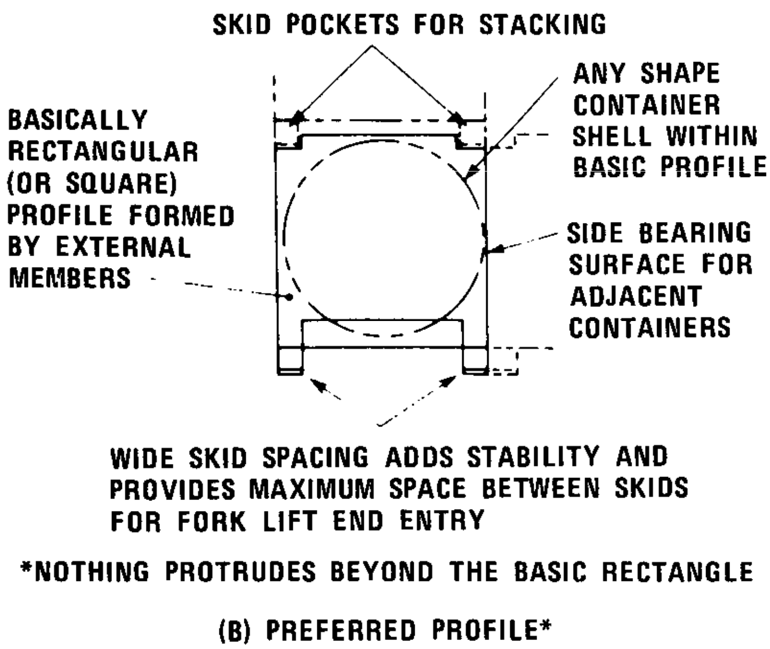
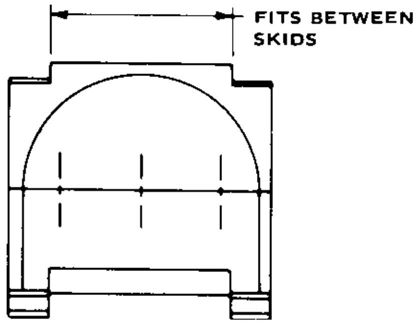
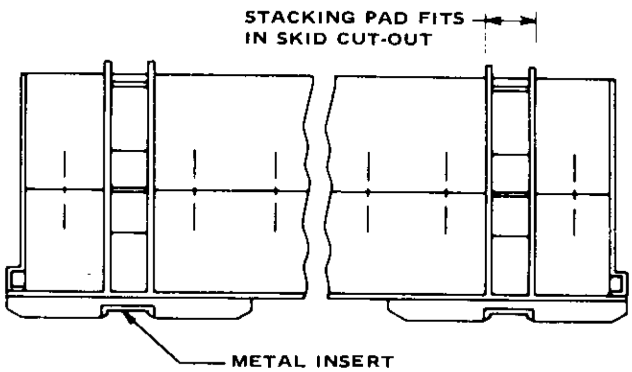


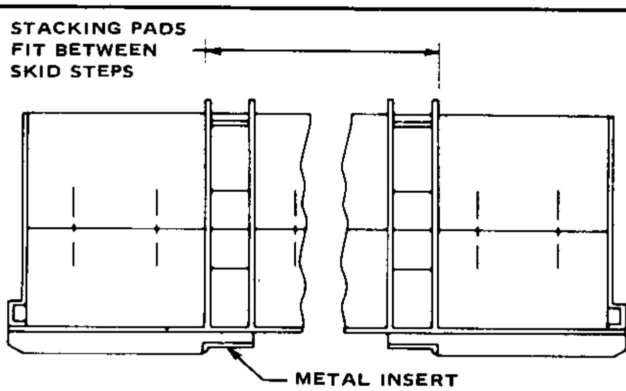
FIGURE 46. Undesirable and preferred end profiles for stacking containers.



(A) END VIEW OF BOTH TYPES (B) AND (C)



(B) CUT-OUT SKIDS



(C) STEPPED SKIDS

FIGURE 47. Positioning and alignment features for stacking containers.

DESIGN OF REUSABLE CONTAINERS
FOR WEIGHT AND CUBE REDUCTION

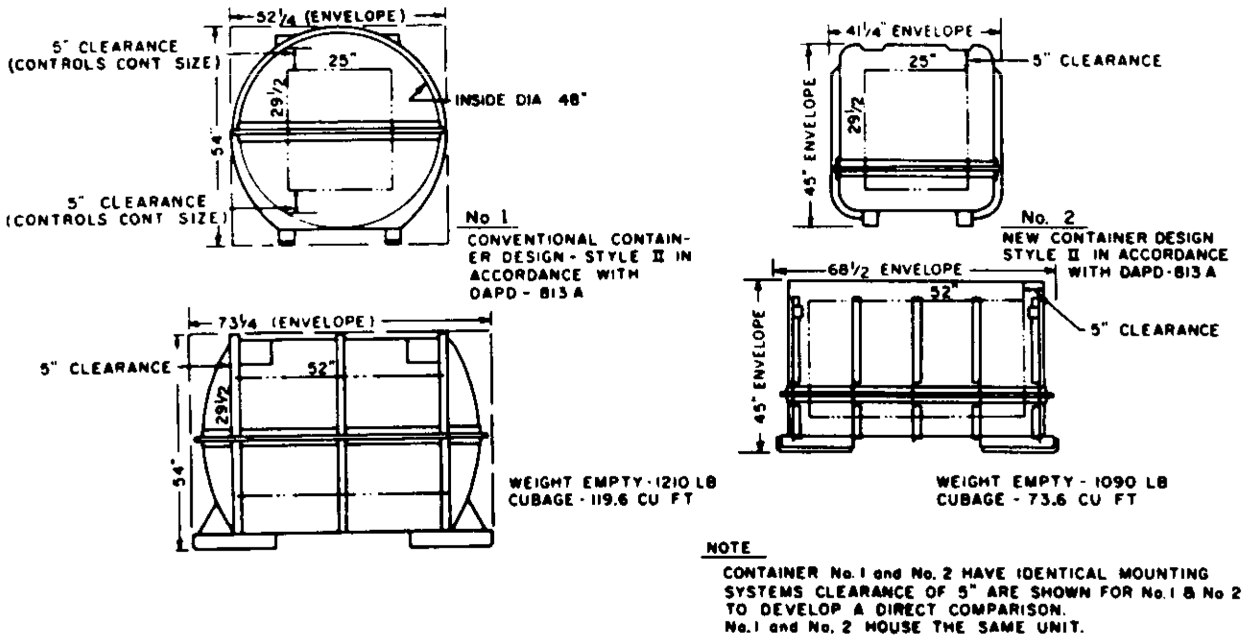


FIGURE 48. Reusable exterior containers.

and smaller than pressurized containers. The strength required is limited to that necessary to withstand handling and stacking forces. The continual breathing, however, allows a considerable amount of atmospheric moisture to enter the container and this soon saturates the desiccant. The life span of the desiccant in a free breather container is approximately 6 months to 1 year depending on atmospheric humidity conditions and breather hole size. Controlled breather containers are a compromise between pressurized and free breather containers. By selecting breather valves with a proper operating pressure, breathing can be reduced, and the life of the desiccant extended for a considerable period of time. The valves also allow the container to be less heavily constructed than a pressurized container since only moderate pressures can build up inside. No definite life span can be given for controlled breather containers because the life varies with the valve settings and the atmospheric conditions, but the life can be several years.

5.8.4.2 Temperature and pressure considerations. Atmospheric temperature variations affect a metal container in several ways:

a. They change the container internal temperature.

b. They change the container internal pressure.

c. They change container internal relative humidity.

The container internal temperatures are affected by direct contact with the atmosphere resulting in heat conduction and also by solar radiation directly on the surface of the container. At night, containers assume the temperature of the ambient atmosphere. During a bright day, the internal temperature reaches a value determined by solar radiation. On cloudy days, the temperature tends to closely approximate ambient temperature. Temperature changes cause container internal pressures to change due to expansion and contraction of the contained air. The effect can be quite severe over a 1-year period since container interior temperatures can be as low as -15° or -20° F. (-26° or -29° C.) and as high as 165° F. (74° C.) with solar radiation. The variations in pressure due to altitude changes, as found in airlift operations, are quite severe. Pressure changes from altitude are shown in figure 49. These are the pressure changes that must be compensated for in container strength or by breather valves. The effect of temperature on container relative humidity is shown in the psychrometric chart of figure 64. Briefly, the effect is that the relative humidity decreases as temperature rises and increases as temperature drops. The only practical method of compensation for this is proper humidity control through the use of desiccants.

5.8.4.3 Breather valves. A breather valve must perform two functions: (1) prevent the entry of moisture into the container, and (2) prevent the buildup of excessively high pressures or vacuums which may damage the container. To accomplish this, the valve must have a low leakage rate, a high cracking (operating) reliability, and a high flow rate after cracking. Excessive valve leakage permits a container to breathe before the designed cracking pressure is reached and can reduce container life. Leakage to some extent is unavoidable since no valve seal is perfect. However, leakage must be kept to the lowest value possible. When a valve nears its cracking pressure, it begins to unseat and will leak before it actually cracks. The same situation occurs when a valve reseats; some leakage will occur before total reseating. Careful consideration should be given to this factor when selecting a valve. Leakage is also a function

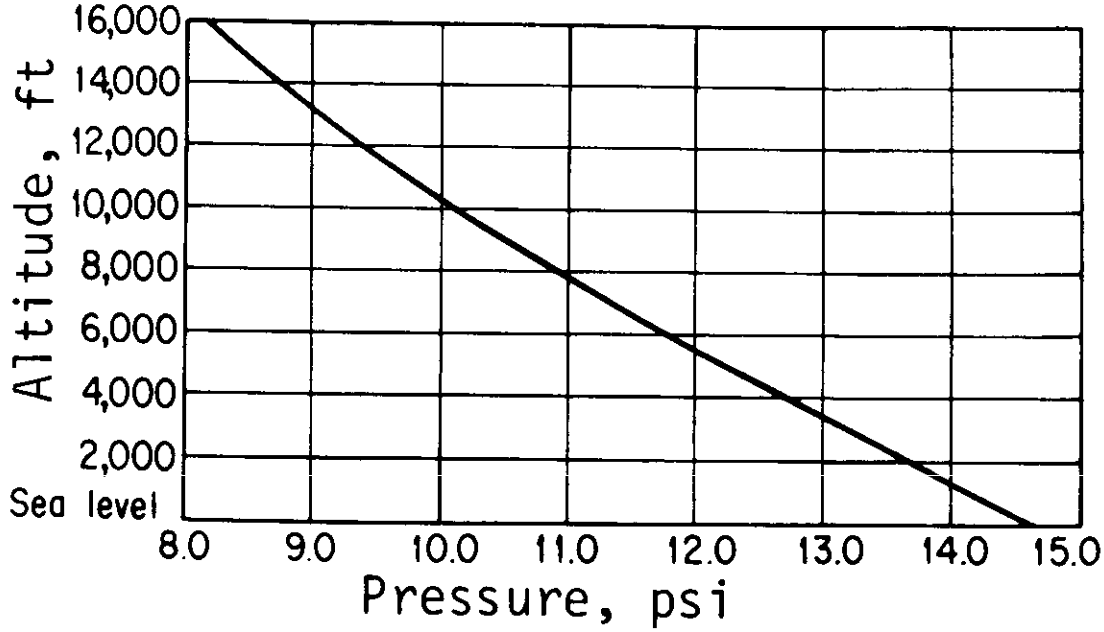


FIGURE 49. Atmospheric pressure as a function of altitude.

of valve age and environment which can deteriorate the valve seat and spring. Therefore, careful consideration should be given to materials used in construction. Foreign particles entering the valve can cause malfunction if a screen or protective cover is not provided. Breather valves are available in almost any cracking pressure range desired. Pressures for containers may vary anywhere from one-half to ten psi. The correct pressure to select is dependent on a number of variables. The higher the cracking pressure the less often a valve will breathe, but the heavier and stronger the container must be made to withstand the pressure. A choice must be made according to container design strength, desiccant load, and desired life of the container. High accuracy in cracking pressure is not necessary; positive cracking action is critical, however, since failure to crack can damage the container. MIL-V-27166 specifies three types of breather valves: (1) vacuum relief, (2) pressure relief, and, (3) combined vacuum and pressure relief. The selection of the type depends on the container design configuration. Flow rates of container valves are dependent on the maximum pressure differential expected to be built up in the container, and in the case of airlift, the rate of pressure change caused by aircraft ascent and descent. The minimum acceptable flow rate (ft^3/min) from MIL-V-27166 is calculated as follows:

$$0.12\ (V_c - V_m),\ ft^3/min$$

where

V_c = volume of container, ft^3

V_m = minimum volume of material in container, ft^3

Since the volume of the container contents may vary, or the container may be air-shipped empty, it may be desirable to calculate flow rate with an empty container for a safety factor. Valves should be located on a container in a place where water drops, dew, snow, or ice cannot collect on the valve inlet causing possible malfunction. If water collects on the inlet during a breathing-in period, a considerble amount of water can be inhaled.

5.8.5 Other exterior protection devices. The ideal material storage situation would be, theoretically, a controlled humidity building where one can be reasonably certain that the stored material will be subjected only to a climate conducive to long-term storage. In military operations, this panacea does not exist, and proper and more costly preservation and packing methods must be adopted as is discussed in previous chapters of this handbook. In the event of quick deployment of men and materiel, the circumstances of leaving supplies exposed to the elements is a reality which man has been dealing with for centuries. Many items are large and bulky and the practice of controlled humidity storage cannot be applied because the cost and material requirements would be prohibitive. Several methods of exterior protection are available for such items. There are various types of sprayable, strippable films in use. They are used under specific circumstances on long-term storage, namely:

a. MIL-C-3254 is a nonadhering, multilayer, strippable film often called cocoon, which provides watervaporproof protection equivalent to that afforded by MIL-B-131 barrier material.

b. MIL-C-16555 is a strippable coating intended to protect metal and fabric surfaces from deterioration and physical damage on items in outdoor storage and during shipment. It is capable of being sprayed and stripped from painted surfaces in addition to metal and fabric surfaces.

c. MIL-C-6799 covers the requirements for water emulsion, protective, strippable, sprayable, single- or multi-coatings for application over metallic, painted, and plastic surfaces. They are classified in three types and four classes. Figures 50 and 51 depict the coats of strippable compounds required for protection of large items. More complete information on the type and class of film required for application can be found in referenced specification (see 2).

5.8.5.1 Pallets. A pallet is a portable platform upon which materiel is placed to facilitate handling and transportation. This platform is generally a two-deck structure which permits mechanical handling and tiering of unit loads of supplies and equipment. Pallet types are classified as expendable or permanent, and also as general purpose or special purpose, namely:

a. Expendable pallets are usually made of wood, fiberboard or plastic, and are used for one shipment and then discarded.

b. Permanent pallets are labeled as general purpose or special purpose.

c. General purpose pallets are of a standard size and made of hardwood. Three general purpose pallets are the four-way entry post constructed and the two-way and four-way (partial) four stringer pallets (fig 52).

d. Special purpose pallets, which are made of metal, are suitable for certain heavy duty usage. They are more rugged and can withstand the abuse better than wooden pallets.

5.8.5.2 Unit load requirements for pallets. MIL-STD-147 gives the palletized unit load requirements on 40- by 48-inch pallets for Department of Defense materiel using the two pallets mentioned. The standard establishes loading patterns for various types of commodities, listing the pattern for stacking containers and methods of unitizing to be used and the limitations imposed.

5.8.6 Testing of exterior protection. The methods of protection and preservation of military supplies and equipment against the effects of nature and the forces of handling are of primary concern to the packaging engineer. Without adequate preparation against these effects, it becomes rather doubtful whether any item of equipment will be capable of serving its purpose once it comes into the possession of the user. Therefore, adequate and frequent test procedures must be established to properly test and evaluate all methods of preservation and packing. Exterior containers of new design and materials must be tested and evaluated for their ability to extend protection to the contents which they were designed to hold. Test requirements and procedures for evaluation of preservation and packing are outlined in 5.15.

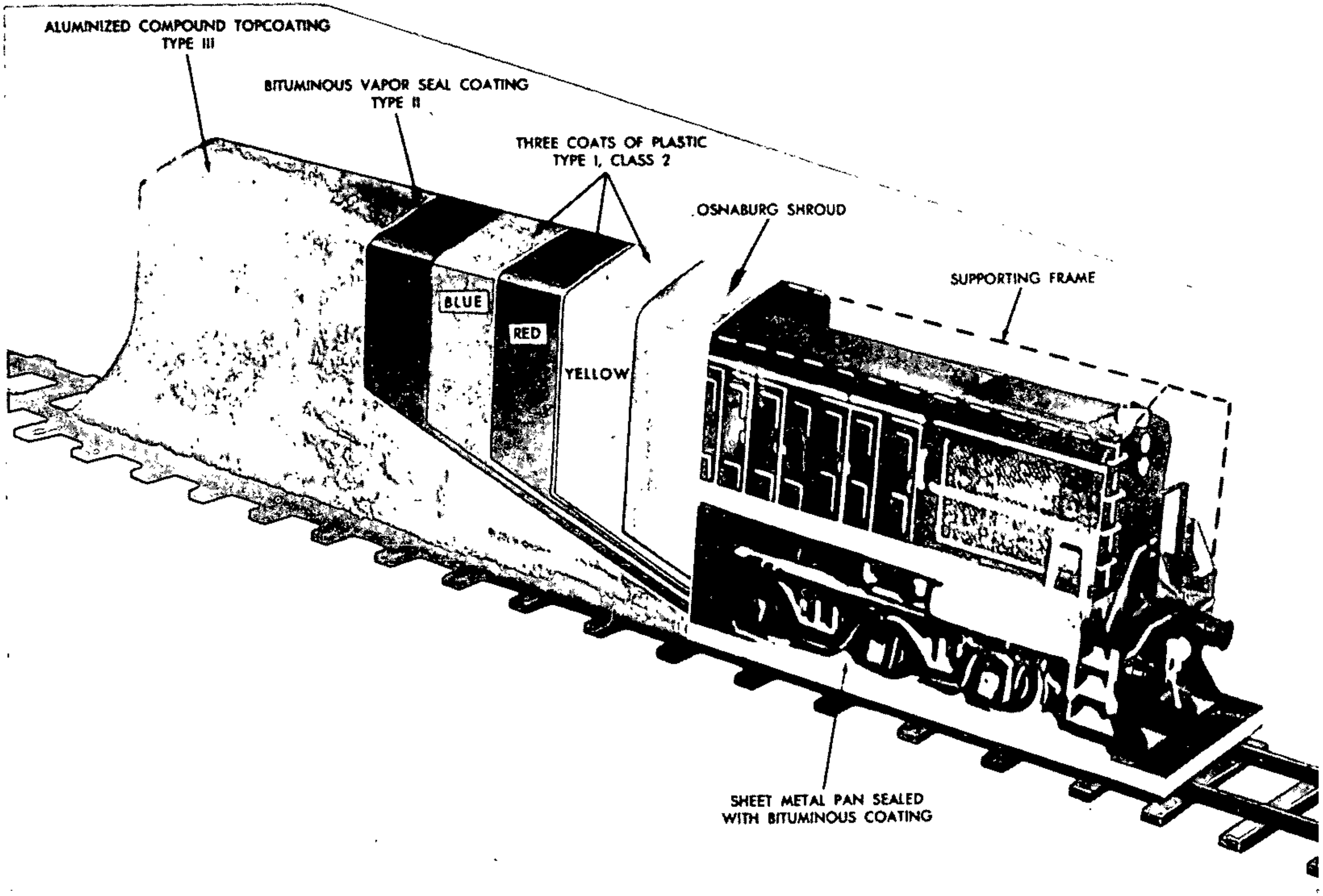


FIGURE 50. Application of strippable films to locomotive.

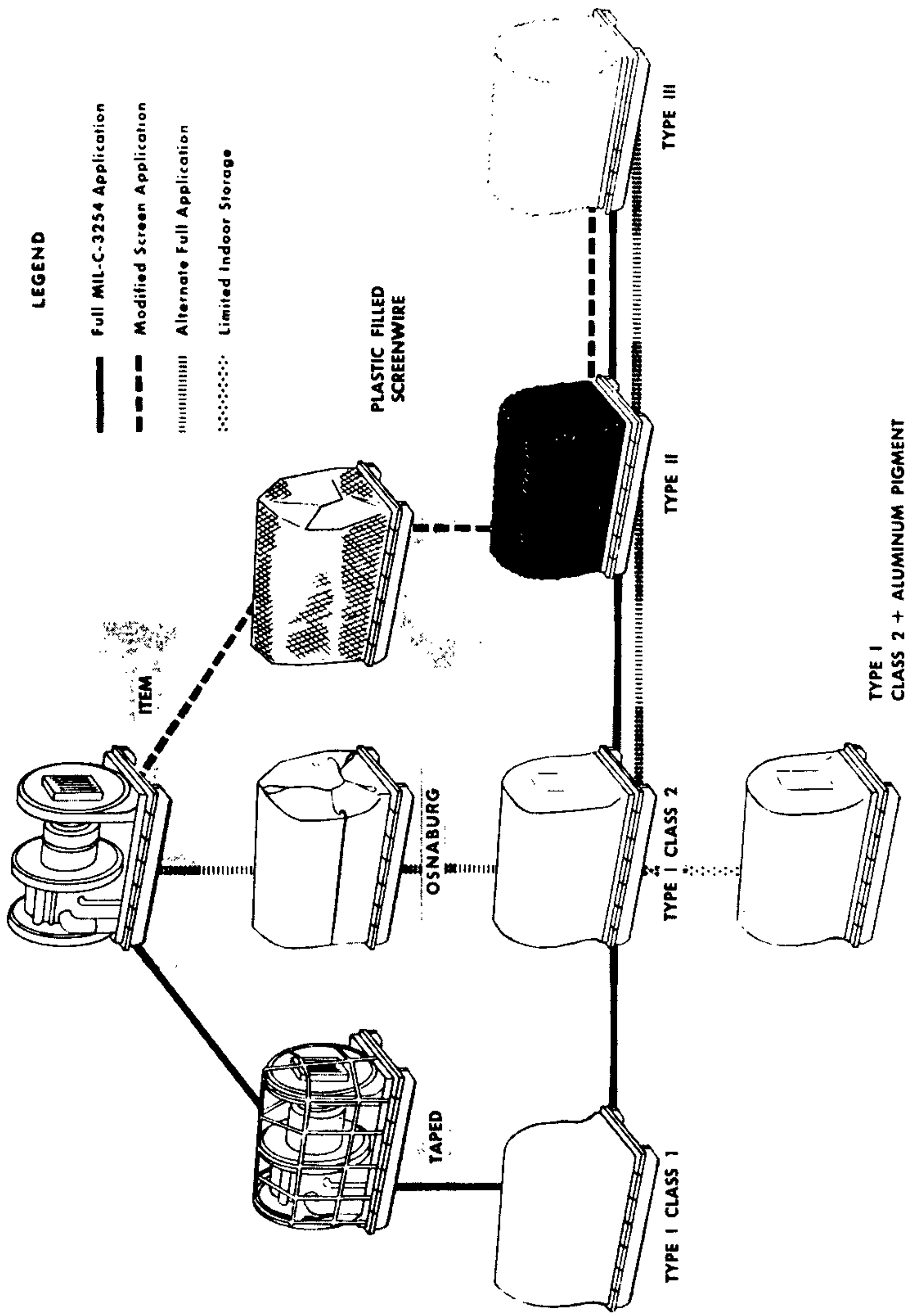


FIGURE 51. Sprayable, strippable film application.

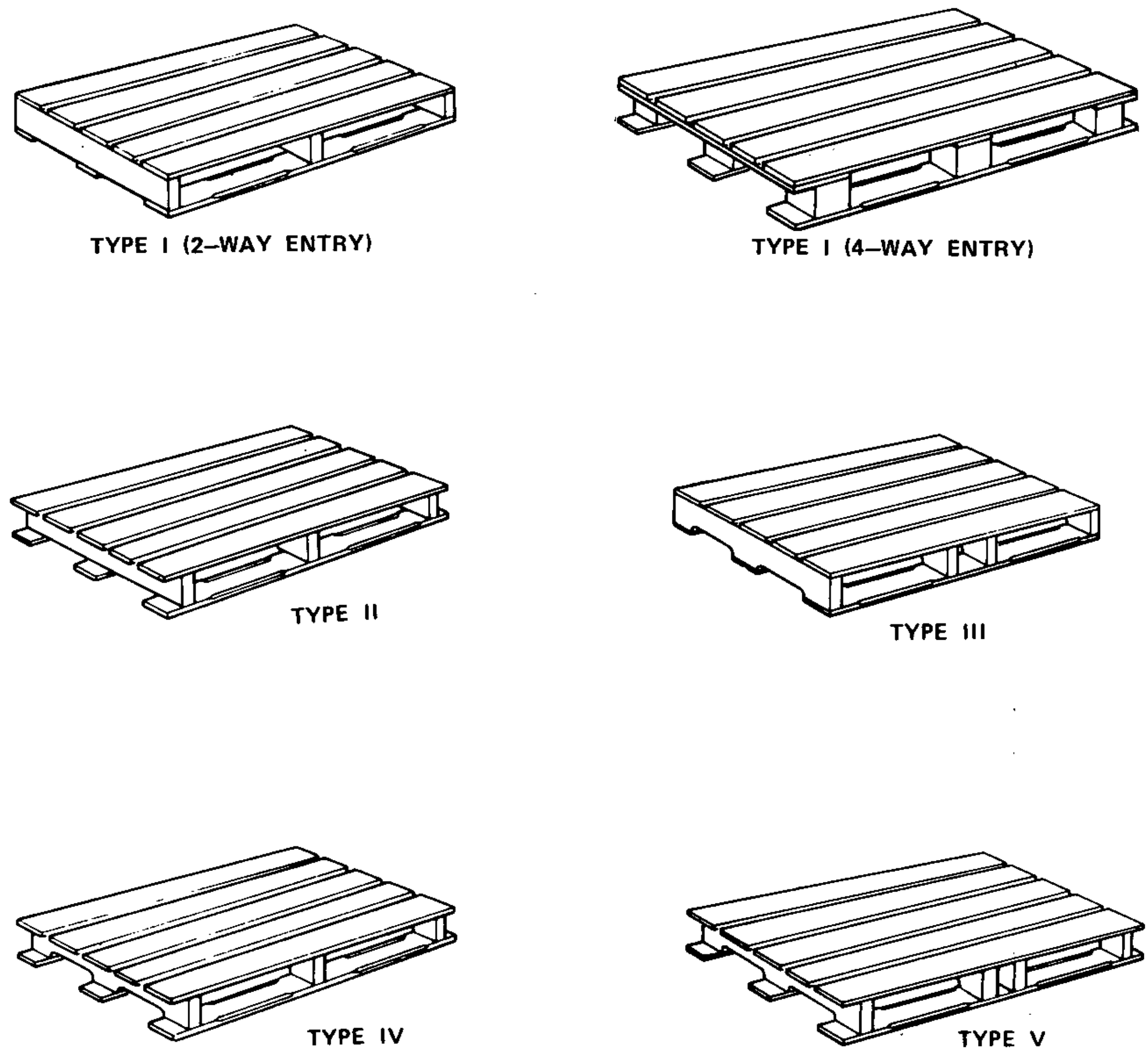


FIGURE 52. Types of pallets.

5.9 Fasteners and closures.

5.9.1 Uses and types. Typical fasteners include links, hooks, clinches, rivets, clamps, ties, bolts, screws, nails, and tacks. Typical closures include latches, straps, and binders. Fasteners and closures are used in the following ways in packaging: to fabricate containers, to secure items within containers, to close containers, and to secure shipping containers to skids and pallets. Although the packaging engineer is rarely concerned directly with these operations, his/her design of packages is affected by the adequacy of these operations. A knowledge of the properties of the common methods of fastening and closure is relevant to package design and to selection of containers. Each military container specification has a section or appendix devoted to closure. It is important that the instructions contained in these publications be observed. This section covers the following types of closure devices:

a. Nails.

b. Screw.

c. Corrugated fasteners.

d. Bolts.

e. Strapping.

f. Staples and stitching.

g. Twine.

Tapes and adhesives which are also used extensively for fastening are mentioned only briefly in this chapter since they are covered in more detail in 5.10.

5.9.2 Fasteners. The fabrication of a satisfactory wooden container depends on two primary factors:

a. Selection of the proper sizes of lumber.

b. Selection and proper use of the various methods of fastening the selected lumber together to form the container.

Boxes are assembled with nails, screws, and corrugated fasteners.

Screws and nails may be used alternately, although nails are preferred for most applications. Screws, however, are sometimes particulaly desirable when the contents of the box require check, test, relubrication, or other inspection during storage. In such cases, screws should be substituted for nails for the top of the box.

5.9.2.1 Nailing. Nails are the most common fastenings for boxes as well as for blocks and braces. Common types of nails available and information on these different types are given in tables LIII through LXVII.

5.9.2.1.1 Box construction defects. Tests of packing boxes indicate that the most common defect in box construction is inadequate nailing. Attempts to strengthen boxes by the use of thicker lumber without regard for nailing often waste material without achieving the desired results.

5.9.2.1.2 Nailing techniques. The following general characteristics of nails should be especially noted in box construction:

a. Cement-coated or chemically etched nails have a holding power considerably greater than smooth nails. About 25 percent more nails of the same size are needed when smooth nails are used in place of cement-coated or chemically etched nails.

b. The sizes of nails for fastening sides, top, and bottom to ends and cleats are determined by the types of wood used as well as by the size of the members (tables LIII and LIV).

c. The nails commonly used in box fabrication are coolers, corkers, sinkers, standard box, or common (tables LV to LIX). The box and cooler nails have thin heads and shanks, whereas the other nails are thick-shanked. Also in use are mechanically deformed nails, as shown in table LX, designed for added holding power.

d. A slender nail is likely to hold better than a thick nail under the repeated shocks and constant weaving action to which boxes are subjected in shipment because the slender nail bends near the surface of the pieces joined without loosening the friction grip of the nail shank.

TABLE LIII. Nail size for assembly of sides, top, and bottom to ends or cleats (wooden boxes).

Species of wood	Thickness of ends or cleats to which sides, tops, and bottoms are nailed, in.											
	Exceeding	---	7/16	1/2	9/16	5/8	11/16	13/16	7/8	1	1-1/8	1-1/4
	Not exceeding	7/16	1/2	9/16	5/8	11/16	13/16	7/8	1	1-1/8	1-1/4	---
Group I		4	5	5	6	7	8	8	9	9	10	12
Group II		4	4	5	5	6	7	7	8	9	9	12
Group III		3	4	4	5	5	6	7	7	8	9	10
Group IV		3	3	4	4	4	5	6	7	8	8	9

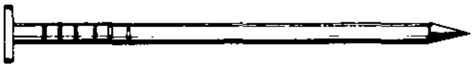
NOTE. Nail sizes are in pennyweights.

TABLE LIV. Domestic types, sizes, and spacing for fastening together adjacent cleated panels.

Cleats, thickness, in.	Nails, Spacing, maximum in.	Size of nails for wood groups(1)		
		I and II Penny	III Penny	IV Penny
5/8	5	6	6	5
3/4	4	7	7	6
7/8	3	8	7	7

(1) If the nail protrudes through the last edge cleat or if it splits the cleat, then the next smaller size penny nail shall be used.

TABLE LV. Cement-coated standard nails (coolers).



Flat head, diamond point

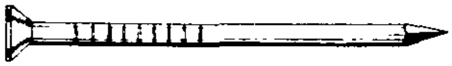
Size	Length, in.	Diameter, in.	Head, in.	No./lb
2d	1	0.062	.172	1,100
3d	1-1/8	.067	.188	839
4d	1-3/8	.080	.219	493
5d	1-5/8	.086	.234	366
6d	1-7/8	.092	.250	278
7d	2-1/8	.099	.266	212
8d	2-3/8	.113	.281	144
9d	2-5/8	.113	.281	131
10d	2-7/8	.120	.297	105

TABLE LVI. Cement-coated countersunk railroad nails (corkers).

Flat countersunk head, diamond point

Size	Length, in.	Diameter, in.	Head, in.	No./lb
2d	1	.062	.156	1,217
3d	1-1/4	.072	.188	720
4d	1-1/2	.086	.219	419
5d	1-5/8	.086	.219	387
6d	1-7/8	.099	.250	253
7d	2-1/8	.099	.250	223
8d	2-3/8	.120	.281	135
9d	2-5/8	.120	.281	122
10d	2-7/8	.135	.312	89
12d	3-1/8	.135	.312	81
16d	3-3/8	.148	.344	62
20d	3-7/8	.177	.375	38
30d	4-3/8	.192	.406	29
40d	4-7/8	.207	.438	22
50d	5-3/8	.226	.469	17
60d	5-7/8	.244	.500	13

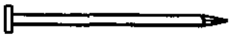
TABLE LVII. Cement-coated countersunk head nails (sinkers).



Flat countersunk head, diamond point

Size	Length, in.	Diameter, in.	Head, in.	No./lb
3d	1-1/8	.067	.172	923
4d	1-3/8	.080	.203	527
5d	1-5/8	.086	.219	387
6d	1-7/8	.092	.234	293
7d	2-1/8	.099	.250	223
8d	2-3/8	.113	.266	153
10d	2-7/8	.120	.281	111
12d	3-1/8	.135	.312	81
16d	3-1/4	.148	.344	64
20d	3-3/4	.177	.375	40
30d	4-1/4	.192	.406	30
40d	4-3/4	.207	.438	23
60d	5-3/4	.244	.500	14

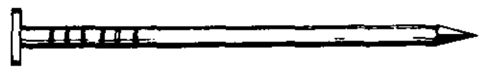
TABLE LVIII. Standard box nails, cement-coated.



Flat head, diamond point, round smooth shank.

Size	Length, in.	Diameter, in.	Head, in.	No./lb
2d	1	.058	.172	1252
3d	1-1/8	.062	.188	978
4d	1-3/8	.067	.203	680
5d	1-5/8	.072	.219	510
6d	1-7/8	.086	.250	315
7d	2-1/8	.086	.250	280
8d	2-3/8	.099	.266	190
9d	2-5/8	.099	.266	172
10d	2-7/8	.113	.297	119

TABLE LIX. Common steel nails, zinc or cement-coated.



Flat head, diamond point

Size	Length, in.	Diameter, in.	Head, in.	No./lb
2d	1	0.072	0.172	847
3d	1-1/4	.080	.230	543
4d	1-1/2	.099	.250	294
5d	1-34	.099	.250	254
6d	2	.113	.266	167
7d	2-1/4	.113	.266	150
8d	2-1/2	.131	.281	101
9d	2-3/4	.131	.281	92
10d	3	.148	.312	66
12d	3-1/4	.148	.312	61
16d	3-1/2	.162	.344	47
20d	4	.192	.406	30
30d	4-1/2	.207	.438	23
40d	5	.226	.469	17
50d	5-1/2	.244	.500	14
60d	6	.262	.531	11

TABLE LX. Mechanically deformed box nail - barbed.

Flat head, diamond point

Size	Length, in.	Diameter, in.	Head, in.	No./lb.
2d	1	.067	.188	940
3d	1-1/4	.076	.219	588
4d	1-1/2	.080	.219	453
5d	1-3/4	.080	.219	389
6d	2	.099	.266	225
7d	2-1/4	.099	.266	200
8d	2-1/2	.113	.297	136
9d	2-3/4	.113	.297	124
10d	3	.128	.312	90
12d	3-1/4	.128	.312	83
16d	3-1/2	.135	.344	69
20d	4	.148	.375	50
30d	4-1/2	.148	.375	45
40d	5	.162	.406	34

TABLE LXI. Nail size and spacing for assembly of nailed open crates.

Fasten		Size and Type of nail	Maximum Spacing, in.	Notes
Part	To Part			
Corner strut of end--(1-in. member)	Corner strut of the side	12d	12	Predrill through sheathing of end and corner strut of end
Corner strut of end--(2-in. member)	Corner strut of the side	20d	12	
Sheathing of side	Corner of the end	8d	6 to 8	Stagger
Edge frame member of top--(through sheathing)	Upper frame member of sides	12d	6, center 60, center	
Edge frame member of top	Upper frame member of sides	8d	6 to 8	Space nails between top sheathing
End strut of top	Upper frame member of end	12d	6	Stagger

TABLE LXII. Nail selection table for nailing sheathing to crate base according to gross weight.

Nail		Wood group of skids		
Type	Penny size	II	III	IV
Common.	7	20	21	16
. . Do.	8 or 9	16	17	13
. . Do.	10	13	14	11
Sinker or cooler.	7	23	26	19
Sinker or cooler.	8 or 9	19	21	16
Sinker or cooler.	10	18	19	14
Corker.	8 or 9	17	19	14
. . Do.	10	15	16	12

NOTE. There shall be not less than two nails per board, and nails shall not be more than 3 in. apart, nor less than 1-1/2 in. apart.
If the moisture content of lumber is greater than 18 percent, the number of nails required shall be increased by one-third.
(Nails per each 1,000-lb gross load)

TABLE LXIII. Spacing of nails for assembly of sides, top and bottom to ends or cleats (wooden boxes)

Size of nails	Spacing when driven into side grain, in.	Spacing when driven into end grain[1], in.
6d	2	1-3/4
7d	2-1/4	2
8d	2-1/2	2-1/4
9d	2-3/4	2-1/2
10d	3	2-3/4
12d	3-1/2	3
16d	4	3-1/2
20d	4-1/2	4

[1]When nails are alternately driven into end grain of end and side grain of cleat (such as nailing sides to ends in styles 2, 2-1/2, 3, 4, 4-1/2 and 7), use spacing schedule based on driving nails into end grain.

TABLE LXIV. Nail spacing for cleated panel boxes.

Type of container	Type of Shipment	Cleat thickness in.	Weight of box contents, lb.	Nail spacing, in.
Plywood Overlaid Veneer Fiberboard	All load Types	All thicknesses		4
	Domestic all load types	9/16 5/8 11/16	0-75	6 6 6
		5/8 11/16 3/4	76-150	5 5 5
		11/16 3/4 13/16	151-300	4 4 3
		7/8	301-400	3
	Overseas all load types	3/4	0-200	4
Plywood (domestic)	All load types	9/16 or 5/8 11/16 or 3/4 13/16 or 7/8		5 4 3
(overseas)	Load types 1 and 2	5/8 or 3/4 13/16 7/8		5 4-1/2 4
	Load type 3	5/8 or 3/4 13/16 7/8		4 3-1/2 3

TABLE LXV. Size and spacing of nails for assembly of the top and bottom members to the sides (wooden boxes).

Thickness of side, in.	Group I	Group II	Group III and IV wood	Spacing in. Minimum	Spacing in. Maximum
Under 3/4	No nailing permitted				
3/4 thru 7/8 incl.	7d	6d	5d	6	8
15/16 thru 1-1/16, incl.	8d	7d	6d	6	8
Over 1-1/16	10d	9d	8d	8	10

TABLE LXVI. Assembly nailing of lumber sheathed nailed crates.

Fasten: Part	Fasten: To part	Nail size and spacing: Lumber sheathing	Nail size and spacing: Plywood sheathing	Notes
Sheathing of side and end	Skid and header (skid base)	Eightpenny minimum size 3-in maximum spacing	Sevenpenny minimum size 3-in maximum spacing	See nailing table 11-15 for number required
	End and side sills (sill base)	2 rows up to 4 x 4 skids 3 rows for 4 x 6 skid (on edge) 3 rows for all sill bases	2 rows up to 4 x 4 skids 3 rows for 4 x 6 skid (on edge) 3 rows for all bases	
Corner strut of end	Corner strut of side	Twentypenny-predrill 12-in. spacing	Twelvepenny 12-in. spacing	Predrill for twentypenny nails, 75 percent of shank diameter
Sheathing of side	Corner strut of end	Eightpenny minimum size 6- to 8-in. spacing	Sevenpenny minimum size 6- to 8-in. spacing	

TABLE LXVII. Nail selection table for nailing sheathing to crate base according to gross weight.

Type of nail	Size of nail	Wood group of skid		
		I	III	IV
Sinker or cooler	7d	23	26	19
	8d or 9d	19	21	16
	10d	18	19	14
	12d	15	16	12
Corker	7d	24	26	19
	8d or 9d	17	19	14
	10d	15	16	12
	12d	15	16	12

NOTE. Nails shall not be less than 2 per board (lumber sheathing) and shall neither be more than 3 inches apart nor less than 1-1/2 inches apart.

(Nails per each 1,000-pound gross load)

e. Nails spaced closely in a line parallel to the grain induce splitting. The first and last nails should be spaced one-half of the specified spacing from the ends of the nailing edge, but not less than three-quarters of an inch. If it is necessary to exceed this spacing because of small knots or checks in the nailing end, or because of the location of joints between boards, the distance between any two adjacent nails should not be greater than one and one-half times the prescribed spacing.

f. If the desired nail size is not available, one size smaller may be used and the nails should be spaced one-fourth of an inch closer than is required for the size of the nail originally specified.

g. At least two nails should be used in each end of each board.

h. Wherever cleats are used in the end construction, approximately one-half of the nails used to secure lengthwise boards, joining top, bottom, or sides to cleat edge, should be driven into the end and the remainder into the cleat (tables LIII, LIV, and LIX to LXVII).

i. All nails should be so driven that no part projects above the surface of the wood. Also, no nail should be over-driven more than one-eighth the thickness of the piece because this tends to crush the wood around the head, thus weakening the joint.

j. The resistance to withdrawal is higher when nails are driven into the side grain than when driven into the end grain of the wood, i.e., face-nailed.

k. When nailing cleats or battens to the sides, top, or bottom, nails should pass through both pieces and be clinched not less than one-eighth of an inch. Clinching, in effect, makes the nail act as a rivet, thus increasing its resistance to withdrawal. Either cement-coated, chemically etched, or bright uncoated nails may be used if they are to be clinched.

5.9.2.1.3 Blocking and bracing. Nails used in blocking and bracing should be cement-coated or chemically etched, particularly when the nails cannot be clinched. Standard cooler, sinker, and box nails are particularly well suited for use with interior packing. They are relatively slender, can be driven into the denser woods, withstand shocks well, and the heads do not break off or pull through the wood easily. Because of the larger head, clout nails are recommended where plywood of one-half inch or less is used. Whenever possible, nails should be applied so that they are subjected to forces of lateral displacement rather than direct withdrawal; i.e., they should be applied so that the direction of the nails will be perpendicular to the direction of the load rather than in line with the direction of the load. If the withdrawal resistance of the nail is known, it is possible to determine the number of nails required to hold a load of a given weight.

5.9.2.2 Corrugated fasteners. When it is necessary to use two or more pieces to form the sides, top, or bottom of a box, the pieces may be butt-joined and fastened together with corrugated fasteners. Although corrugated fasteners contribute little to the strength of the box, especially where the moisture content of the wood is high, they have two main uses: (1) during manufacture, they facilitate handling, and (2) during shipment, they discourage pilferers from cutting nails and sliding intermediate boards out of the way to gain access to the contents. When used, the length of the corrugated fasteners should never exceed three-fourths of the thickness of the piece being fastened.

5.9.2.3 Bolts, screws, and rivets. The selection of proper fastenings for any given job requires close examination of all specifications and limitations, for example:

a. Type of service. Will the assembly be subject to vibration, impact loads, tension, or shear stresses, or a combination of these? Is repeated disassembly required? Self-tapping screws must not be used unless fastening is of a permanent nature. Will the fastener also function as a locator, as in the case of a stud? Will the fastener function satisfactorily unaided, or must dowel pins, keys, or other devices also be used?

b. Materials being joined. Will rivets, self-tapping screws, nut plates, clinch nuts, and through bolts be used to assemble sheet metal parts? Steel fasteners for nonferrous metals may result in electrolysis and corrosion of the metals. Corrosion can be confined to an insert without damage to a screw used with it. Inserts in plastics or soft metals protect against thread damage when frequent disassembly is required.

c. Economy. It is not economical to use too large, too small, or too many fasteners. Lowered product quality and safety can result from too few or too small fasteners. Some common types of bolts and screws are shown in figures 53 and 54. Self-tapping, self-piercing, and drive screws have wide application in sheet metal work, wood, and plastics. A lead hole must be provided for the self-tapping and drive types, but tapping is eliminated. The self-piercing type is hammered through the work material and the protruding end, if any, is turned down or machined off. Lock nuts and lock washers, properly applied, prevent loosening of the assembly under vibration or jarring. The locking action is accomplished by squeezing, gripping, or jamming against the bolt threads.

5.9.2.3.1 Materials for bolts, screws, and nuts. The principal metals used for bolts, screws, and nuts--with their chief qualifications--are listed in table LXVIII. Nylon, polyethylene, and other plastic nuts, screws, and various fasteners are light in weight, immune to corrosion and moisture, tough, resilient, have good dielectric strength, and for many applications, can do a job metal fasteners cannot accomplish. The plastic fasteners are generally at a disadvantage when (1) fastener cost alone is important, (2) requirements of stress and shear are high, and (3) temperature conditions are higher than 350° F.

5.9.2.3.2 Screws. Screws are most commonly used on reusable containers, or if inspection of the contents is anticipated. Data on various screws are provided in tables LXIX to LXXVI.

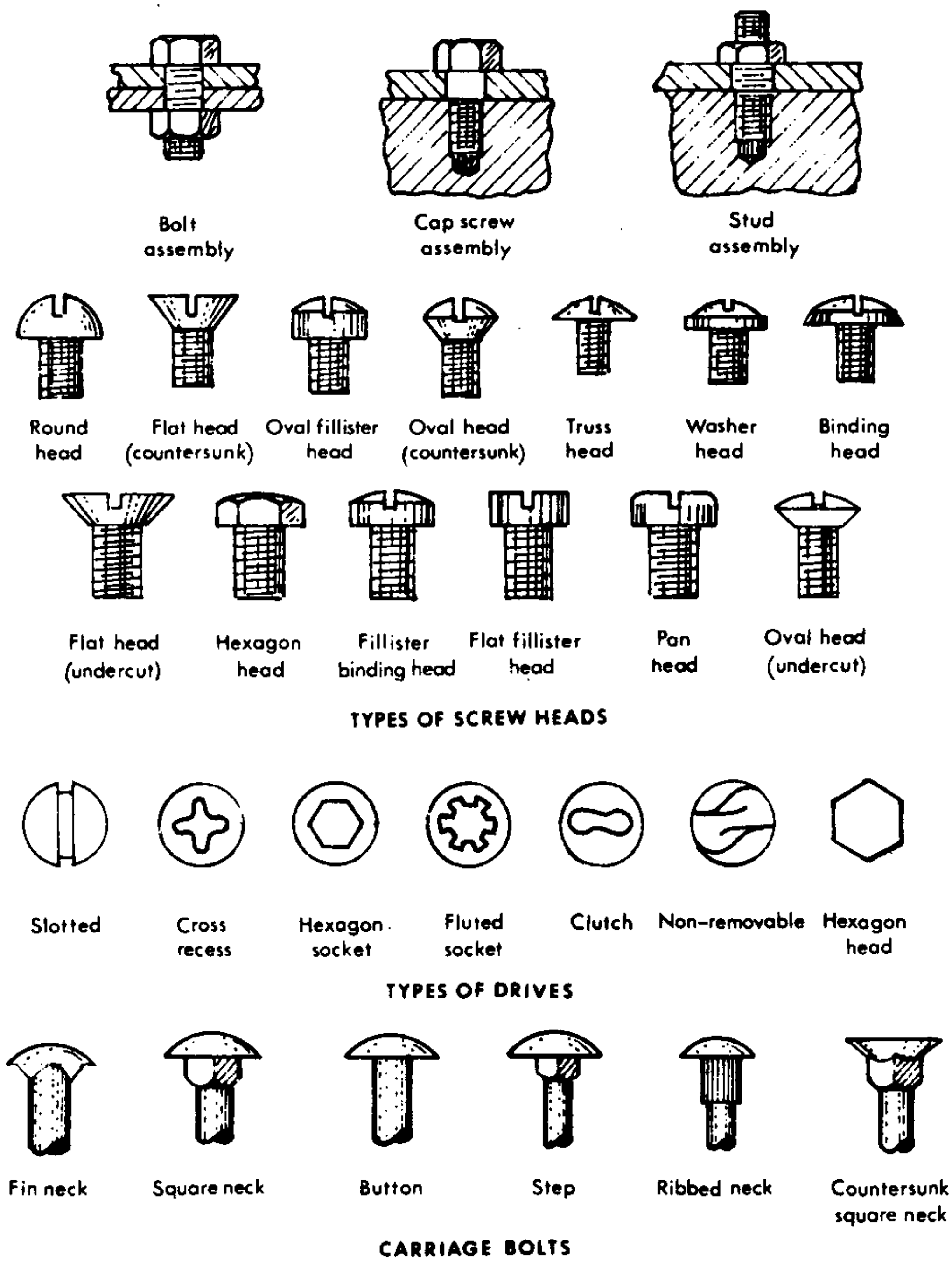


FIGURE 53. Common types of bolt and screw heads.

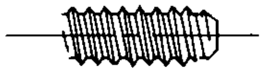
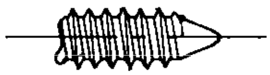
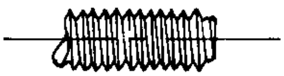
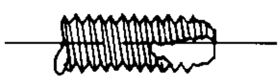
Thread Profiles	SAE and ASA Type	Federal Type		Application
	A	A	Thread Forming Screws	Light gage sheet metal, asbestos comp. impregnated plywood, wood, etc.
	B	B	Thread Forming Screws	Heavy gage sheet metal, non-ferrous castings, plastics, etc.
	BP	BP	Thread Forming Screws	Same as B, but with conepoint to correct for misaligned holes
	C	C	Thread Forming Screws	Standard machine screw thread for thick metals
	D	CS Alternate 1	Thread Cutting Screws	Castings,nonferrous forgings, structural steel, impregnated plywood, etc.
	F	CF	Thread Cutting Screws	Castings, nonferrous forgings, structural steel, impreg-nated plywood, etc.
	F	CF	Thread Cutting Screws	Castings, nonferrous forgings, structural steel, impreg-nated plywood, etc.
	G	CS Alternate 2	Thread Cutting Screws	Castings, nonferrous forgings, structural steel, impreg-nated plywood, etc.
	T	CG	Thread Cutting Screws	Castings, nonferrous forgings, structural steel, impreg-nated plywood, etc.
	BF	BF	Thread Cutting Screws	Thin sections in brittle materials, plastics, die castings
	BG	BG	Thread Cutting Screws	Thin sections in brittle materials, plastics, die castings
	BT	BG	Thread Cutting Screws	Thin sections in brittle materials, plastics, die castings

FIGURE 54. Common types of self-tapping set and drive screws.

TABLE LXVIII. Materials for bolts, screws, and nuts.

Material	Properties	
	Tensile strength (compared to carbon steels)	Corrosion resistance
Carbon steels, SAE 1010 to 1065	---	low
Free-cutting steels, SAE 1111 to 1151	low	low
Stainless steel, type 430	high	high
Monel metal	high	high
Manganese steels	high	low
Nickel steels	high	high
Molybdenum steels	high	low
Vanadium steels	high	low
Chrome-nickel	high	high
Brass	low	high
Copper	low	high
Silicon bronze	comparable	high
Aluminum	low	suscept- ible to salt water
Magnesium	low	suscept- ible to salt water

TABLE LXIX(A). Lag screw size and quantity selection table for bolted open crates for nominal 1-inch longitudinal members and 4-inch skids.

	1/2- by 6-in. lag				1.2- by 5 1/2-in. lag				2/3- by 6-in. lag				2/3- by 5 1/2-in. lag			
Net load, lb.	G[1] I	G II	G III	G IV	G I	G II	G III	G IV	G I	G II	G III	G IV	G I	G II	G III	G IV
8,000	28	24	22	18	32	28	24	22	32	28	26	22	36	32	30	26
7,000	24	22	18	16	28	24	22	18	28	24	22	20	32	28	26	22
6,000	20	18	16	14	24	20	18	16	24	22	18	16	28	24	22	18
5,000	18	16	14	12	20	18	16	14	20	18	16	14	22	20	18	16
4,000	14	12	10	10	16	14	12	10	16	14	12	10	18	16	14	12
3,000	10	10	8	6	12	10	10	8	12	10	10	8	14	12	10	10
	1/2- by 5-in. lag								3/8- by 4 1/2-in. lag							
3,000	18	16	14	12					20	18	16	14				
2,500	14	12	12	10					16	14	12	10				

[1]Refers to the wood group and applies to the skids.

NOTE. If bolts are used, they shall be the same number and diameter as given for lag screws.

TABLE LXIX(B). Lag screw size and quantity selection table for bolted open crates for nominal 2-inch longitudinal members and 4-inch skids.

	3/8- by 7-in. lag				1/2- by 7-in. lag				1/2- by 6½-in. lag				1/2- by 6-in. lag			
Net load, lb.	G[1] I	G II	G III	G IV	G I	G II	G III	G IV	G I	G II	G III	G IV	G I	G II	G III	G IV
16,000	48	44	36	32	56	48	44	36	64	56	48	44	74	68	60	52
14,000	40	36	32	28	48	44	36	32	56	48	44	36	64	60	52	44
12,000	36	32	28	24	40	36	32	28	48	40	36	32	56	52	44	40
10,000	30	26	24	20	34	30	28	24	40	34	32	26	46	42	38	32
9,000	26	24	22	18	30	28	24	22	36	32	28	24	42	38	34	28
8,000	24	22	18	16	28	24	22	18	32	28	24	22	38	34	30	26
7,000	20	18	16	14	24	22	18	16	28	24	22	18	32	30	26	22
6,000	18	16	14	12	20	18	16	14	24	20	18	16	28	26	22	20
5,000	14	14	12	10	18	16	14	12	20	18	16	14	24	20	18	16
4,000	12	10	10	8	14	12	10	10	16	14	12	10	18	16	14	12
3,000	10	8	8	6	10	10	8	8	12	10	10	8	14	12	12	10

[1]Refers to the wood group and applies to the skids.

NOTE. If bolts are used, they shall be the same number and diameter as given for lag screws.

TABLE LXX. Factors for computing lateral withdrawal resistance of lag screws for various held member thicknesses.

Ratio of thickness of member to shank diameter of lag screw	Factor
2	0.62
2-1/2	0.77
3	0.93
3-1/2	1.00
4	1.07
4-1/2	1.13
5	1.18
5-1/2	1.21
6	1.22
6-1/2	1.22

TABLE LXXI. Shank hole and pilot hole sizes for wood screws.

Gauge of Screws Number	Shank clearance holes		Pilot holes for Group IV woods	
	Size of twist bit, in.	Gauge of drill, number	Size of twist bit, in.	Gauge of drill, number
4	7/64	34	1/16	52
5	1/8	31	5/64	49
6	9/64	29	5/64	47
7	9/64	25	3/32	44
8	5/32	20	3/32	40
9	11/64	16	7/64	37
10	3/16	12	7/64	33
11	13/64	7	1/8	31
12	7/32	3	1/8	30

TABLE LXXII. Determination of lead hole size for lag screws.

Diameter of threaded portion of lag bolt, in.	Diameter of lead hole: Groups I, II and III wood, in.	Diameter of lead hole: Group IV wood, in.
1/4	3/16	3/16
5/16	1/4	1/4
3/8	1/4	5/16
1/2	3/8	7/16
5/8	3/8	1/2
3/4	1/2	5/8

TABLE LXXIII. Factors for computing lateral withdrawal resistance of lag screws for loads perpendicular to the grain.

Shank diameter of lag screw, in.	Factor
3/16	1.00
1/4	0.97
5/16	0.85
3/8	0.76
7/16	0.70
1/2	0.65
5/8	0.60
3/4	0.55
7/8	0.52
1	0.50

TABLE LXXIV. Spacing of wood screws for assembly of wooden boxes.

Gauge of screws	Spacing when driven into side grain,[1] in.	Spacing when driven into end grain,[1] in.	Spacing when only top of box is fastened with screws,[2] in.
7 or smaller	2	1-3/4	3
8	2-1/4	2	3-1/4
9	2-1/2	2-1/4	3-1/2
10	2-3/4	2-1/2	3-3/4
11	3	3-3/4	4
12	3-1/2	3	4-1/2

[1]When screws are alternately driven into end grain of end and side grain of cleat (such as nailing sides to ends in styles 2, 2-1/2, 3, 4, 4-1/2, 5, and 7), use spacing schedule based on driving nails into end grain.

[2]Spacing of screws for top and bottom, when driven into sides of boxes, shall be placed 8 to 12 inches apart.

TABLE LXXV. Sizes of wood screws for assembly of wooden boxes.

Thickness of piece holding point of screw, in.	Screw gauge for wood groups			
	I	II	III	IV
3/8	6	5	5	4
1/2	7	6	6	5
5/8	8	6	6	6
3/4	9	8	7	7
13/16	10	9	8	8
7/8	10	9	8	8
1	11	10	9	9
1-1/16	12	10	10	9
1-1/8	12	11	10	10
1-1/4	12	12	11	11
1-5/16	12	12	12	12

NOTE. If the required size of screw is unavailable, use next smaller gauge and reduce spacing one-fourth of an inch.

TABLE LXXVI. Common flat, oval, and round head wood screw sizes.

Length, in.	No. 0 diameter 0.060 in.	No. 1 diameter 0.073 in.	No. 2 diameter 0.086 in.	No. 3 diameter 0.099 in.	No. 4 diameter 0.112 in.	No. 5 diameter 0.125 in.	No. 6 diameter 0.138 in.	No. 7 diameter 0.151 in.	No. 8 diameter 0.164 in.
1/4	FR	FR	FR	FR	FR	---	---	---	---
3/8	FR	FR	FR	FRO	FRO	FR	FR	FR	FR
1/2		FR	FR	FR	FRO	FRO	FRO	FRO	FRO
5/8			FR	FR	FRO	FRO	FRO	FRO	FRO
3/4			FR	FR	FRO	FRO	FRO	FRO	FRO
7/8				FR	FR	FR	FR	FRO	FRO
1				FR	FR	FRO	FRO	FRO	FRO
1-1/4					FR	FR	FRO	FRO	FRO
1-1/2					FR	FR	FRO	FRO	FRO
1-3/4							FRO	FRO	FRO
2							FR	FR	FR
2-1/4							FR	FR	FR
2-1/2							FR	FR	FR
2-3/4									FR

Length in.	No. 9 diameter 0.177 in.	No. 10 diameter 0.190 in.	No. 11 diameter 0.203 in.	No. 12 diameter 0.216 in.	No. 14 diameter 0.242 in.	No. 16 diameter 0.268 in.	No. 18 diameter 0.294 in.	No. 20 diameter 0.320 in.	No. 24 diameter 0.372 in.
1/2	FR	FR	---	---	---	---	---	---	---
5/8	FR	FR	FR	FR	---	---	---	---	---
3/4	FRO	FRO	FR	FR	---	---	---	---	---
7/8	FRO	FRO	FR	FRO	FR	---	---	---	---
1	FRO	FRO	FRO	FRO	FRO	FR	---	---	---
1-1/4	FRO	FRO	FRO	FRO	FRO	FR	FR	---	---
1-1/2	FRO	FRO	FRO	FRO	FRO	FRO	FRO	FRO	---
1-3/4	FRO	FRO	FRO	FRO	FRO	FRO	FRO	FRO	---
2	FR	FRO	FRO	FRO	FRO	FRO	FRO	FRO	---
2-1/4	FR	FR	FR	FRO	FRO	FR	F	F	---
2-1/2	FR	FR	FR	FRO	FRO	FR	FR	FR	---
2-3/4	FR	FR	F	FR	FR	F	F	F	---
3	FR	FR	F	FR	FR	FR	FR	F	F
3-1/2		FR	F	FR	FR	FR	F	F	F
4				FR	FR	FR	F	F	F
4-1/2				FR	F	F	F	F	F
5				FR	F	F	F	F	F

NOTE. F - flat, O - oval, R - round.

5.9.2.3.3 Bolts. Bolts are of two basic types: (1) those which are driven into predrilled holes, and (2) those which require a nut and washer for securing. The type selected will depend on the need for easy removal. Bolts commonly used for blocking and bracing are step bolts, carriage bolts, and machine bolts (fig 53). Step bolts are preferred because of their larger head diameter. U- or J-bolts are used for special conditions where regular bolts cannot be applied. Tie-rods and J-bolts are actually extended bolts--applied in pairs vertically or diagonally--and are used where standard length bolts would not apply. The following general precautions should be observed when bolts are used:

a. When using holes in the item for attachment, the bolt should be the same size as the hole in the item. For critical assembly fittings, however, smaller bolts and bushings should be used to protect the precision tolerances. Lag screws or lag bolts should not be used in either instance.

b. When an item is bolted to the base, the bolt head should be on the outside of the container base or the bottom of the auxiliary base and should bear against a wide washer to decrease the possibility of pulling through the wood.

c. When skids are used, the bolts should extend through the skids and be countersunk in the outer surface of the skid.

d. When the item has strong frame members fairly close to the faces of the container, U- or J-bolts may be used to advantage (fig 55).

e. Tie-rods serve as extended bolts when used to secure items in the container and should be used in the same general manner as other types of bolts. They should be placed vertically or used diagonally in pairs.

f. Many items have attachment points that provide facilities for bolting, but the points are not located on a regular base that can be fastened directly to the container. Where U- or J-bolts or tie-rods can be used, especially constructed brackets, sleeves, or frames made entirely of metal, wood, or a combination of these, can be used to act as intermediate connections between the item and the container. To function satisfactorily, frames must be properly designed to permit ample fastening of the frame to both the item and the container, or in the case of sleeves, to fit the interior of the container snugly. Tables LXXVII through LXXXI list various factors useful in determining sizes and types of bolts to be used for specific applications. Figure 56 illustrates "T" nuts that can be used when fabricating reusable panel boxes.

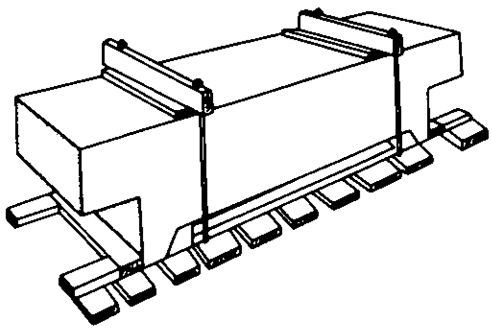


FIGURE 55. Tie-rods and J-bolts.

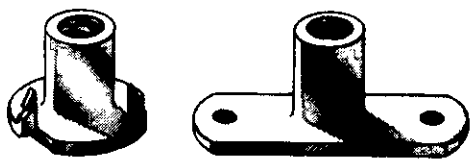


FIGURE 56. "T" nuts used in fabrication of reusable panel boxes.

TABLE LXXVII. Bolt diameter factor.

Diameter of bolt, in.	Diameter factor
1/4	2.50
3/8	1.95
1/2	1.68
5/8	1.52
3/4	1.41
7/8	1.33
1	1.27
1-1/4	1.19
1-1/2	1.14
1-3/4	1.10
2	1.07
2-1/3	1.03
3 or over	1.00

TABLE LXXVIII. Weight of 100 bolts and nuts.

Length under head, in.	Bolts with square heads and nuts Diameter of bolt, in.									Bolts with hexagon heads and nuts Diameter of bolt, in.				
	1/4	5/16	3/8	7/16	1/2	5/8	3/4	7/8	1	1/2	5/8	3/4	7/8	1
1	4	7	11	15	22	37	56	84	122	19	33	52	76	110
1-1/4	4	7	11	16	23	39	59	88	128	20	34	54	80	116
1-1/2	5	8	12	17	24	41	62	93	133	22	36	57	85	121
1-3/4	5	8	13	18	26	43	64	97	139	23	38	60	89	127
2	5	9	14	19	27	45	67	101	144	24	40	63	93	132
Wt. in lb for each additional in. in length	1.4	2.2	3.1	4.3	5.6	8.7	12.5	17.0	22.3	5.6	8.7	12.5	17.0	22.3

NOTE. All weights are given in pounds.

TABLE LXXIX. Suggested allowable lateral loads for bolts-impact loading.

Diameter of bolt, in.	Allowable load, lb
3/8	35
1/2	90
5/8	150
3/4	200

TABLE LXXX. Factors for calculating the weight of large bolts.

Diameter of bolt, in.	1-1/4	1-1/2	1-3/4	2	2-1/2	3
Wt of 1 hex. head and 1 hex. nut	1.7	2.9	4.6	6.8	13.0	22.0
Wt of 1 sq. head and 1 sq. nut	2.0	3.5	5.5	8.1	15.5	26.2
Wt of shank per in. (lb)	0.35	0.5	0.68	0.89	1.4	2.0

5.9.2.4 Strapping. Metal strapping is used as reinforcement for blocking and bracing, and most commonly as reinforcement for exterior containers. Only tempered, high tensile strength, flat steel or round wire strapping should be used for container reinforcement, except in limited instances such as reinforcing a crate corner where an annealed nail-on-type flat steel strapping is usually used (see tables LXXXI through LXXXIV). For overseas shipment, bare metal strapping should not be used because of its lack of corrosion resistance. Nonmetallic strapping may be used for domestic class fiberboard boxes and for fiberboard unit loads under the conditions and limitations specified in MIL-T-35078.

5.9.2.4.1 Reinforcement for blocking and bracing. The use of strapping to tie down an item to the base or other faces of the container is often the only convenient procedure that can be used. Strapping may be either flat steel or round wire. Both kinds of strapping are preferably tensioned and sealed with specially designed tools. If this is not possible, flat strapping can be held in place with anchor plates and round wire strapping with special drive screws and staples. General precautions on the use of metal strapping, which apply to both flat steel and round wire, are:

a. Where possible, the item and the support must be completely encircled. When it is impossible to do this, the two ends of the metal strapping must be anchored.

b. One-piece straps should be used wherever possible.

c. Straps should be placed only on those strong parts of the item that can withstand the impact load and weight of the item.

TABLE LXXXI. Factors for calculating allowable strength in wood fasteners.

Hardwoods	Specific gravity G and powers (1)				Allowable lateral load constant (K)			Basic stresses for bolts (2)		Species group for connector loads (5)
	G	$G^{3/2}$	G^2	$G^{5/2}$	Nails(3)	Screws(3)	Lag Screws(4)	Parallel to Grain	Perpendicular to grain	
Ash:										
Black	.53	.39	.28	.20	1250	2900	1900	850	300	--
Commercial	.61	.48	.37	.29	1700	4000	2200	1450	500	4
Aspen:										
Big Tooth	.41	.26	.17	.11	900	2100	1700	800	150	1
Quaking	.40	.25	.16	.10	900	2100	1700	800	150	1
Basswood, American	.40	.25	.16	.10	900	2100	1700	---	---	1
Beech, American	.67	.55	.45	.37	1700	4000	2200	1600	500	4
Birch:										
Sweet	.71	.60	.50	.42	1700	4000	2200	1600	500	4
Yellow	.66	.54	.44	.35	1700	4000	2200	1600	500	4
Chestnut, American	.45	.30	.20	.14	900	2100	1700	---	---	2
Cottonwood:										
Black	.37	.22	.14	.08	900	2100	1700	---	---	1
Eastern	.43	.28	.18	.12	900	2100	1700	800	150	1
Elm:										
American	.55	.41	.30	.22	1250	2900	1900	1050	250	3
Rock	.66	.54	.44	.35	1700	4000	2200	1600	500	4
Slippery	.57	.43	.32	.25	1250	2900	1900	1050	250	3
Hackberry	.56	.42	.31	.23	1250	2900	---	---	---	--
Hickory:										
Pecan	.65	.52	.42	.34	1700	4000	2200	2000	600	4
True	.74	.64	.55	.47	1700	4000	2200	2200	600	4
Magnolia, southern	.53	.39	.28	.20	1250	2900	---	---	---	--
Maple:										
Black	.62	.49	.38	.31	1700	4000	2200	1600	500	4
Red	.55	.41	.30	.22	1250	2900	1900	---	---	3
Silver	.51	.36	.26	.19	1250	2900	1900	---	---	3
Sugar	.68	.56	.46	.38	1700	4000	2200	1600	500	4
Oak:										
Commercial Red	.66	.54	.44	.35	1700	4000	2200	1350	500	4
Commercial White	.71	.60	.50	.42	1700	4000	2200	1350	500	4
Sweetgum	.53	.39	.28	.20	1250	2900	1900	1050	300	3
Sycamore, American	.54	.40	.29	.21	1250	2900	1900	---	---	3
Tupelo:										
Black	.55	.41	.30	.22	1250	2900	1900	1050	300	3
Water	.52	.37	.27	.19	1250	2900	1900	1050	300	3
Yellow Poplar	.43	.28	.18	.12	900	2100	1700	950	220	2

TABLE LXXXI. Factors for calculating allowable strength in wood fasteners. - Continued

Softwoods	Specific gravity G and powers (1) G	$G^{3/2}$	G^2	$G^{5/2}$	Allowable lateral load constant (K) Nails(3)	Screws(3)	Lag Screws(4)	Basic stresses for bolts (2) Parallel to Grain	Perpendicular to grain	Species group for connector loads (5)
Bald Cypress	.48	.33	.23	.16	1125	2700	1700	1450	300	2
Cedar:										
Alaska	.46	.31	.21	.14	1125	2700	1700	1050	250	2
Atlantic White	.35	.21	.12	.07	900	2100	1500	750	180	--
Northern White	.32	.18	.10	.06	900	2100	1500	750	180	--
Port Orford	.44	.29	.19	.13	1125	2700	1700	1200	250	2
Western Red	.34	.20	.12	.07	900	2100	1500	950	200	1
Douglas fir:										
Coast Type	.51	.36	.26	.19	1375	3300	1900	1450	320	3
Rocky Mountain Type	.45	.30	.20	.14	1125	2700	1700	1050	280	2
Fir:										
Balsam	.41	.26	.17	.11	900	2100	1500	950	150	1
Commercial White	.41	.26	.17	.11	900	2100	1500	950	300	1
Hemlock:										
Eastern	.43	.28	.18	.12	900	2100	1500	950	300	1
Western	.44	.29	.19	.13	1125	2700	1700	1200	300	2
Larch, Western	.59	.45	.35	.27	1375	3300	1900	1450	320	3
Pine:										
Eastern White	.37	.22	.14	.08	900	2100	1500	1000	250	1
Lodge Pole	.43	.28	.18	.12	900	2100	1500	950	220	--
Ponderosa	.42	.27	.18	.11	900	2100	1500	1000	250	1
Red	.51	.36	.26	.19	1125	2700	1700	1050	220	2
Southern Yellow(6)	.59	.45	.35	.27	1375	3300	1900	1450	320	3
Western White	.42	.27	.18	.11	900	2100	1500	1000	250	1
Redwood (old-growth)	.42	.27	.18	.11	1125	2700	1700	1350	250	2
Spruce:										
Engleman	.35	.21	.12	.07	900	2100	1500	800	180	1
Red	.41	.26	.17	.11	900	2100	1500	1050	250	2
Sitka & White	.42	.27	.18	.11	900	2100	1500	1050	250	2

(1) Specific gravity based on weight and volume when oven dryed.
(2) Basic stresses to be used in determining allowable bolt bearing stresses.
(3) Driven perpendicular to the grain of the wood and loaded either parallel or perpendicular to the grain.
(4) Inserted perpendicular to the grain of the wood and loaded parallel to the grain.
(5) Grouping to be used in determining allowable connector loads. Group I woods provide the weakest and Group 4 woods the strongest connector groups.
(6) When graded for density, these species qualify for Group 4 connector loads.

TABLE LXXXII. Number of straps and their direction to use on corrugated and solid fiberboard boxes.

Direction of bands (1)					
Lengthwise		Girthwise		Horizontal (2)	
Outside width of box, in.	Number of bands, min (3)	Outside length of box, in.	Number of bands, min (3)	Outside depth of box, in.	Number of bands, min (3)
Up to 9	None	Up to 20 in.	1 (3)	Up to 18	None
9 to 18	1 (3)	20 to 30 in.	2 (3)	18 to 30 incl.	1
Over 18 to 30	2 (3)	Over 30 to 48	3 (3)	Over 30 to 48	2
Over 30 to 48	3	Over 48 to 60	4		
Over 48 (4)		Over 60 (4)			

(1) Lengthwise - encircling top, bottom, and ends. Girthwise - encircling top, bottom, and sides. Horizontal - encircling sides and ends. See figures for designation of top, bottom, and end faces. Note that the location of the openings determines the designation of the panels, rather than normal storage position.

(2) Horizontal bands are only occasionally required. Where contents exert severe pressure on vertical score lines, bonds should be used.

(3) Full telescope-style boxes, having covers not otherwise sealed to bodies, will usually require use of one or more additional bands, both lengthwise and girthwise, when dimensions approach the upper range of the size brackets listed above. Additional bands, when required, will be specified by the procuring agency.

(4) As directed by the procuring agency.

TABLE LXXXIII. Metallic and nonmetallic strapping requirements of fiberboard boxes.

Gross weight of container and contents	QQ-S-781, size of flat steel strapping, class 1 or grade 2 standard, finish A or B		PPP-S-760 size nonmetallic strap		QQ-S-781 size (gauge of round steel strap, class 2)		
Pounds	Type I nailless	Type III twist tie	Type II polyolefin	Type III nylon	Type IV power machine	Type V	Type VI
Up to 35, incl.	1/4 x 0.015 5/16 x 0.012 3/8 x 0.010	0.138 x 0.025 0.063 x 0.024 1/	3/8 x 0.015	7/16 x 0.017	1/4 x 0.015	16-1/2	16-1/2
Over 35 to 70, incl.	3/8 x 0.015	0.138 x 0.025	3/8 x 0.015	7/16 x 0.017	3/8 x 0.015	16	15
Over 70 to 110, incl.	3/8 x 0.020 1/2 x 0.015		1/2 x 0.015 3/8 x 0.020	1/2 x 0.015	3/8 x 0.020 1/2 x 0.015	14	13
Over 110 to 225, incl.	1/2 x 0.020 5/8 x 0.015		1/2 x 0.020	1/2 x 0.020	1/2 x 0.020 5/8 x 0.015	13	12

1/ 0.063 x 0.024-inch strapping shall be allowed only for V2s sleeve boxes and shall conform to QQ-S-781 except that it shall have a tensile strength of 135 psi, a breaking strength of 205 pounds, and a joint strength of not less than 170 pounds.

TABLE LXXXIV. Minimum gauge of round wire for various weights of wooden boxes.

Net weight of contents		Gauge of wire when different number of wires are used			
		Two straps		Three (or more) straps	
Exceeding	Not exceeding	90,000/120,000 psi tensile strength	130,000/160,000 psi tensile strength	90,000/120,000 psi tensile strength	130,000/160,000 psi tensile strength
Pounds		Inch	Inch	Inch	Inch
0	70	0.0720 (15 gauge)	0.0625 (16 gauge)	0.0720 (15 gauge)	0.0625 (16 gauge)
70	125	.0800 (14 gauge)	.0720 (15 gauge)	.0800 (14 gauge)	.0720 (15 gauge)
125	175	.0915 (13 gauge)	.0800 (14 gauge)	.0915 (13 gauge)	.0800 (14 gauge)
175	250	.0915 (13 gauge)	.0915 (13 gauge)	.0915 (13 gauge)	.0915 (13 gauge)
250	400	.1055 (12 gauge)	.0990 (12-1/2 gauge)	.0915 (13 gauge)	.0915 (13 gauge)
400	1000			.1055 (12 gauge)	.0990 (12-1/2 gauge)

TABLE LXXXV. Minimum sizes of flat metal straps for various weights of wooden boxes.

Net weight of contents		Dimensions of flat metal straps when different numbers of straps are used			
Exceeding	Not exceeding	Solid two straps	Plywood two straps	Solid three or more straps	Plywood three or more straps
Pounds		Inch	Inch	Inch	Inch
0	70	3/8 by 0.015	3/8 by 0.020	3/8 by 0.015	3/8 by 0.020
70	125	3/8 by 0.020	3/8 by 0.020	3/8 by 0.020	3/8 by 0.020
125	175	1/2 by 0.020	1/2 by 0.020	1/2 by 0.020	1/2 by 0.020
175	250	5/8 by 0.020	5/8 by 0.020	5/8 by 0.020	5/8 by 0.020
250	400	3/4 by 0.020		3/4 by 0.020	3/4 by 0.020
400	1000			3/4 by 0.023	3/4 by 0.023

d. Where strapping passes over a sharp edge of the item, corner protectors may be required to protect the strapping from fracturing.

e. Protecting materials should be used between the item and the strap if the strap might harm or scratch the item.

f. Strapping should be arranged on the container, where possible, to further reinforce blocking and bracing or anchoring of the item within the container.

g. Annealed strapping should be used only for lightweight items because it stretches readily.

5.9.2.4.2 Reinforcement of exterior containers. The following general precautions are advisable:

a. Use strapping of an acceptable type conforming to the appropriate military specification.

b. Use strapping of correct size and strength.

c. Use the correct number of straps depending upon the weight, contents, and style of container, as specified in the appropriate container specification.

d. Locate the strapping correctly.

e. Staple straps to boards or cleats when thickness is five-eighths of an inch or more. Staples should be cement coated or chemically etched and should not be spaced more than 6 inches apart. Overdriving of the staples should be avoided since any creasing of the strap might weaken it, and any fracturing of the strap coating might permit corrosion.

f. All straps must be applied at right angles to the edges of the box over which they pass.

g. Use correct tensioning tools designed for the particular type and style of strap.

h. Apply sufficient tension so that straps will sink into edges of the container but do not overtension to the point that the strapping is weakened or the container is damaged. Conversely, the straps must not be so loose as to engage another box and interfere with the handling.

i. Avoid applying straps over voids where they will be a hazard to handling personnel and where they will not add to the strength of the container.

j. Do not apply straps on the bottom surface of skids. Notch the skid for the straps or place the straps so that they are between the skids.

k. Strap the boxes just before shipping since most boxes shrink during long periods of storage. At the time of shipment, any previously applied straps should be examined, and if found to be loose, the containers should be restrapped.

5.9.2.5 Wood fastenings. Wood fastenings used with bolts are suitable for many different types of applications. The withdrawal load of a round drift bolt from the side grain of seasoned wood is given by the formula:

$$P = 6000\ G^2D$$

where

P = ultimate withdrawal resistance per lineal inch of penetration
G = specific gravity of wood
D = shank diameter, inches.

5.9.2.6 Stapling and stitching. Wire stitches and staples are widely used in fabricating wooden containers, but only rarely for the fastening and closure of the containers at the point of use.

5.9.2.7 Twine. The principal use of twine is in the baling of items or products that can be packaged by consolidating small items or compressing bulky items into a single, compact unit for shipment, e.g., tents, bedding, tarpaulins, clothing, or any other soft compressible item. The outer wrap or cover usually consists of burlap or Osnaburg cloth in the form of tubes, bags, or sheets. Closures are made by sewing, strapping, or tying. If the closure is made by sewing, or the tying is by use of twine, then the closure will be accomplished by securely sewing or tying with jute or cotton twine.

5.9.3 Closures. The use and considerations for the function of tapes and adhesives as closures are given in 5.10.

5.9.3.1 Factors involved. Adhesives are most economical to use depending on the type of sealing equipment used. Use of an adhesive depends primarily upon the following factors:

a. Type of surface.

b. Rate of setting, which depends upon the speed of application as well as the time under compression and tension factors of the container.

c. Specific end-use requirements such as ease of opening.

5.9.3.2 Classifications of tapes. Tapes are classified by the type of adhesive used:

a. Gummed tapes. Water- or solvent-activated adhesive.

b. Pressure-sensitive tapes. Use of an adhesive which adheres under pressure.

c. Heat-activated tapes. Heat and pressure used to provide a bond.

5.10 Tapes and adhesives. Tapes function primarily as closures, but are also used in the bundling, binding, and strengthening of packages. Tapes are also used as a means of sealing against entry of moisture. Adhesives are used exclusively for closure purposes. This section provides data to aid in the use of tapes and adhesives for packaging operations. The different types of tapes and adhesives available are discussed, and their characteristics are given.

5.10.1 Types of tapes. The two main types are:

a. Pressure-sensitive tapes. (Pressure-sensitive tapes may be further categorized as cloth-backed, pressure-sensitive; paper-backed, pressure-sensitive; and film-backed, pressure-sensitive.)

b. Solvent-activated tapes.

5.10.1.1 Pressure-sensitive tapes. Pressure-sensitive tapes are those which in dry form are aggressively and permanently tacky at room temperature, and adhere firmly to a variety of dissimilar surfaces upon contact without the need of more than firm finger or hand pressure. They require no activation by water, solvent, or heat in order to exert a strong adhesive holding force toward such materials as paper, cellophane, glass, wood, and metals.

Some tapes have a sufficiently cohesive and elastic nature so that, despite their aggressive tackiness, they can be handled with the fingers and removed from smooth surfaces without leaving a residue.

5.10.1.1.1 Cloth-backed, pressure-sensitive tapes. Cloth-backed tapes have backings of cotton fabric, acetate cloth, or glass cloth. They are usually provided with rubber-based adhesives, are nondrying, and form a good bond to various surfaces when pressed with the fingers. The specifications covering cloth-backed tapes are given in table LXXXVI.

5.10.1.1.2 Paper-backed, pressure-sensitive tapes. Paper tapes are furnished with either a creped or a smooth backing. Rope fiber paper is generally used for the smooth-backed paper tapes. Use of this fiber results in a backing that is stronger, stiffer, and more rigid than the crepe-backed paper tapes. However, the creped tapes have greater elongation, and greater conformability over irregular surfaces. Backings of paper tapes are usually treated with a releasing agent to prevent the adhesive from sticking to itself and to make unwinding easier. The properties of various paper-backed tapes are given in table LXXXVII. Specifications covering these tapes are given in table LXXXVI.

5.10.1.1.3 Filmed-backed, pressure-sensitive tapes. Film tapes are used for the closure of cartons, for identification, and for reinforcing and strapping of bundles. Tapes of this type are furnished with backings of cellulose acetate, polyethylene, or other polyesters. Film tapes are versatile; there is great flexibility in developing tapes with specific desirable characteristics, such as conformability over irregular surfaces, adhesion to and removability from metallic surfaces at low temperature, and adhesion to painted surfaces. Specifications covering film-backed tapes are given in table LXXXVI.

5.10.1.2 Solvent-activated tapes. Solvent-activated tapes are nonpressure-sensitive and require water or solvent activation. The most common type of solvent-activated tape is gummed, water-activated tape. This tape is made of various weights of paper stock coated on one side with a water-soluble adhesive. Gummed, water-activated tapes are used primarily for closing the flaps and seams of cartons. The specification covering gummed, water-activated tapes is given in table LXXXVI.

5.10.2 Consideration in choosing a tape. The primary considerations in choosing a tape for a particular application are:

a. Surface to which tape is to be adhered. The tape must adhere to the surface being taped under all anticipated conditions of transportation and storage.

b. Removability. If adhered to the surface of an item, the tape must be removable without disturbing the item or impairing its function.

c. Application conditions. Application conditions include temperature and humidity. These factors are important inasmuch as they change the state of the adhesive side of the tape.

d. Weight and size of the package. The weight and size of the package determine the strength required of the tape.

e. Transportation and storage conditions. The tape must not deteriorate or lose its adhesiveness during transport and storage.

f. Cost. The cost of the tape must be kept at a minimum, but the primary consideration is to choose a tape which adequately protects the package and the packaged item.

5.10.3 Tape characteristics. Physical characteristics of the various tapes are given in table LXXXVI.

5.10.4 Types of adhesives. There are three principal classes of adhesives: thermoplastic adhesives, thermosetting adhesives, and miscellaneous water-base adhesives. The specific types of adhesives within each class are given in table LXXXVIII. The materials commonly bonded by these adhesives are given in table LXXXIX.

5.10.5 Consideration in choosing an adhesive. The considerations involved in choosing an adhesive are similar to those for selecting a tape (5.10.2).

5.10.6 Adhesive characteristics. Physical and chemical characteristics of the various adhesives are given in tables XC through XCV. The military and Federal specifications covering adhesives are listed in table XCVI.

TABLE LXXXVI. Characteristics of tapes.

Tape specification	Application	General characteristics
Pressure-sensitive		
Cloth Tapes		
PPP-T-60, Type IV, Class 1	Intended for sealing containers. For applications less critical than PPP-T-60, Type III tapes	Woven cotton backing
Paper Tapes		
PPP-T-76 (one type only)	Closure of fiberboard containers	Water-resistant; opaque
PPP-T-42 (one type only)	Light duty bundling, holding, and packaging; temporary closing of chipboard and fiberboard boxes; not intended as a substitute for PPP-T-76	Creped
Film Tapes		
PPP-T-60, Type III, Class 1	High strength characteristics; maximum resistance to elements; waterproofing; second vaporproofing; exterior use	Polyester backing; waterproof and vaporproof; color as specified
PPP-T-60, Type III, Class 2	Attaching and protecting labels; sealing containers	Same as PPP-T-60, Type III, Class 1, except transparent
PPP-T-70 (one type only)	Closure and sealing of domestic containers; label attaching and label covering to protect labels from moisture and weather	Transparent; water and weather-resistant; bursting strength 35 lb/sq in min
PPP-T-97, Type I	Reinforcing fiberboard or fiberboard-surfaced containers; strapping; bundling; other miscellaneous uses; interior use	Acetate fiber and/or polyester; transparent; element reinforced with longitudinal glass fibers; nonweatherproof; high elongation; low tensile strength

TABLE LXXXVI. Characteristics of tapes. - Continued

Tape specification	Application	General characteristics
Pressure-sensitive		
PPP-T-97, Type II	Same as PPP-T-97, Type I	Same as PPP-T-97, Type I, except lower elongation and medium tensile strength; may be opaque or transparent
PPP-T-97, Type III	Same as PPP-T-97, Type I	Same as PPP-T-97, Type I, except lower elongation and high tensile strength
PPP-T-97, Type IV	Same as PPP-T-97, Type I, except that it is for exterior use	Opaque, element reinforced with longitudinal glass fibers; weatherproof; low elongation; high tensile strength
L-T-99, Type I	Interior labeling and identification	Acetate fiber, transparent; color as specified
L-T-99, Type II	Edging of documents	Same as L-T-99, Type I
L-T-99, Type III	Interior and exterior labeling and identification	Same as L-T-99, Type I
MIL-T-22085, Type II	Protection of aircraft and missiles during storage, handling, and shipments; exterior sealing and preservation	Oil- and weather-resistant; no material specified for backing
MIL-T-22085 Type III	Same as Type II but requires overcoating with strippable, sprayable coating, for long-term exterior exposure	Weather resistant; not oil resistant; no material specified for backing

TABLE LXXXVI. Characteristics of tapes. - Continued

Tape specification	Application	General characteristics
Pressure-sensitive		
MIL-T-43036 (one type only)	Sealing fiber containers and slip cover metal containers	Polyester backing; filament reinforced; waterproof; watervaporproof; medium tensile strength
Paper Tapes		
PPP-T-45, Type I	Sealing closures of fiber boxes and other containers; securing wrappers of packages; banding tubes, wire, hose, etc.	Water-activated gum; opaque; element reinforced with glass, rayon, or sisal filaments in the machine and cross directions; asphaltic binder
PPP-T-45, Type II	Same as PPP-T-45, Type I	Same as PPP-T-45, Type I, except nonasphaltic binder
PPP-T-45, Type III	Sealing closures of fiber boxes and other containers, securing wrappers of packages; banding unwrapped bundles of paper and paper products	Water-activated gum; opaque; not reinforced lightweight for light packages
Grade A	Light duty, for lightweight packages	
Grade B	Medium duty, for medium-sized packages	
Grade C	Heavy duty, for heavy, bulky packages	

TABLE LXXXVII. Properties of paper-backed tapes.

Backing	Thick-ness (mils)	Tensile strength (lb/in. width)	Elongation (% at break)	Tear resis-tance	Conform-ability	Adhesion to steel (oz/in. width)
Crepe 30 lb	7-10	15-20	10-15	Low	Excel-lent	20-40
Crepe 40 lb	9-11	25-30	8-12	Med.	Excel-lent	20-30
Crepe 70 lb	20	40-55	30	High	Excel-lent	20-30
Flat-back	6-8	25-30	5-7	High	Good	25-40
Flat-back High Strength	9-15	50-60	8	High	Good	25-35

NOTE. The values of this table were compiled from many different sources. They are approximate and can vary widely depending on the test used. Refer to Pressure Sensitive Tapes, H.R. Clauser, Editor, Materials and Methods 43: 123-38, March 1956, page 126.

TABLE LXXXVIII. Classification of adhesives.

Thermoplastic adhesives	Thermosetting adhesives
Rubber Natural rubber GR-S Neoprene Nitrile Butyl Reclaimed rubber Rubber derivatives	Resin Urea-formaldehyde Melamine Acid-catalyzed phenolic Resorcinol and phenol-resorcinol Phenolic resin Polyester Epoxy Polyurethane
Resin	Rubber-resin Neoprene-resin Nitrile-resin
Cellulose Cellulose nitrate Cellulose acetate Ethyl cellulose	Thiokol
Vinyl Polyvinyl acetate Polyvinyl alcohol Vinyl vinylidene Vinyl butyral	Modified Phenolic Resin Blends Vinyl phenolics Vinyl-formal-phenolic Vinyl butyral-phenolic Nylon-phenolic Epoxy-phenolic Modified acrylate
Miscellaneous Shellac Manila gum Rosin Limed rosin Cumarone-indene Polyamide resins	**Miscellaneous water-base adhesives**
Acrylic	Vegetable Starch and dextrene Soybean flour and zein
Oleoresin	Animal Base Glue (hide, bone, fish) Blood albumen Casein Casein-latex
Asphalt	Inorganic Sodium silicate Magnesium oxychloride Litharge-glycerine

TABLE LXXXIX. Materials commonly bonded by adhesives.

Adhesive(1)	Material Bonded									
	Metals	Plastics	Rubber	Glass	Wood(2)	Ceramics	Leather	Textiles	Paper	Fibrous Compo-sition
Thermoplastic adhesives										
Rubber										
Natural rubber	-	-	-	-	-	-	X	X	-	-
GR-S	X	X	X	-	X	-	-	X	X	X
Neoprene	X	X	X	-	X	-	X	X	-	-
Nitrile(3)	X	X	X	X	X	X	X	X	X	X
Butyl (3)	X	-	X	-	X	-	X	X	-	-
Reclaimed rubber(3)	X	-	X	-	X	-	X	X	-	-
Rubber derivatives	X	-	X	-	-	-	-	-	-	-
Resin										
Cellulose nitrate	X	X	-	X	-	-	X	X	-	-
Cellulose acetate	-	X	-	-	-	-	-	-	X	-
Ethyl cellulose	-	-	-	-	-	-	-	X	X	-
Polyvinyl acetate	X	X	-	X	X	-	X	X	X	-
Polyvinyl alcohol	-	-	-	-	-	-	-	X	X	-
Vinyl vinylidene	-	-	-	-	-	-	-	X	-	-
Vinyl butyral	-	-	-	X	-	-	-	-	-	-
Shellac	X	-	-	-	X	-	-	X	-	-
Manila gum	-	-	-	-	X	-	-	-	-	-
Rosin	-	-	-	-	-	-	-	-	X	-
Limed rosin	-	-	-	-	X	-	-	-	-	X
Cumarone-indene	-	-	-	-	X	-	-	X	-	-
Polyamide resins	-	-	-	-	-	-	-	-	X	-
Acrylic	-	X	-	-	-	-	-	-	-	-
Oleoresin	-	-	-	-	X	-	-	-	X	X
Asphalt	X	-	-	X	X	-	-	X	X	X
Thermosetting adhesives										
Resin										
Urea-formaldehyde	-	-	-	-	X	-	-	-	-	-
Melamine	-	-	-	-	X	-	-	-	-	-
Acid-catalyzed phenolic	X	-	-	-	X	-	-	-	-	-
Resorcinol and phenol-resorcinol	-	X	-	-	X	-	X	X	X	X
Phenolic resin	X	-	X	X	X	-	-	-	-	-
Polyester	X	X	-	-	-	X	-	-	-	-
Epoxy	X	X	X	X	X	X	-	-	-	-
Polyurethane	X	X	X	X	X	X	-	X	X	X
Rubber-resin										
Neoprene-resin	X	X	-	-	X	-	-	-	-	-
Nitrile-resin	X	-	-	-	-	-	-	-	-	-
Thiokol	X	X	X	X	X	-	-	X	-	-

TABLE LXXXIX. Materials commonly bonded by adhesives. - Continued

Adhesive (1)	Material Bonded									
	Metals	Plastics	Rubber	Glass	Wood (2)	Ceramics	Leather	Textiles	Paper	Fibrous Compo-sition
Thermosetting adhesives (Cont)										
Modified Phenolic Resin Blends										
Vinyl formal-phenolic	X	-	X	-	X	-	-	-	-	-
Vinyl butyral-phenolic	X	X	X	-	X	-	-	-	-	-
Epoxy-phenolic	X	X	X	X	X	-	-	-	-	-
Miscellaneous water-base adhesives										
Starch and dextrene	-	-	-	X	-	-	-	-	X	-
Soybean flour and zein	-	-	-	-	X	-	-	-	-	-
Glue (hide, bone, fish)	-	-	-	-	X	-	X	X	X	-
Blood albumen	X	-	-	-	X	-	X	X	X	-
Casein	-	-	-	-	X	-	-	-	-	-
Casein-latex	X	X	-	-	X	-	-	-	-	-
Sodium silicate	-	-	-	-	-	-	-	-	X	-
Magnesium oxychloride	-	-	-	X	-	X	-	-	-	-
Litharge-glycerine	-	-	-	-	-	X	-	-	-	-

(1) This list is not exhaustive nor does it include adhesive tapes and films or sealers. The information is general and not necessarily applicable to all forms of the adhesive or the material.

(2) Includes cork.

(3) Recommended where it is necessary to bond to painted metal surfaces.

TABLE XC. Characteristics of thermoplastic rubber adhesives.

Adhesive	Strength	Dead-load	Tack	Resistance to deteriorators: Water	Oil	Gaso-line	Heat	Cold	Aging
Rubber Base									
Natural Rubber	G	P	E	E	P	P	P	G	F
GR-S	F	P	F	E	P	P	F	G	F
Neoprene	E	G	P to G	E	G	G	G	G	G to E
Nitrile	E	F	P to G	E	E	E	G	G	G
Butyl	F	P	G	E	P	P	P	G	E
Thiokol	F	P	F	E	E	E	F	E	E
Reclaimed rubber	G	P	G	E	P	P	P	G	F
Rubber Derivatives									
Cyclized	G	F	G	E	P	P	F	M	G
Chlorinated	G	F	G	E	G	G	M	M	G

NOTE. E = Excellent, G = Good, M = Moderate, F = Fair, P = Poor.

TABLE XCI. Characteristics of several thermoplastic resin adhesives.

Adhesive	Commonly available form	Resistance to Deteriorators			Special characteristics	Application
		Water	Grease	Oils		
Shellac	Solvent solution (alcohol), mastic (hot melt)	Good	Good	Good	Resists hydrocarbon solvents; softened by heat; useful as primer over metals; difficult to wet prior to applying other adhesives; as tough as manila gum.	Porous materials; some metals.
Manila gum	Solvent solution (alcohol), with fillers, mastic	Good	Good	Good	Tougher than hard synthetic resins that are alcohol soluble; releases solvent quickly; develops strength rapidly.	
Rosin	Solvent solution, mastic (hot melt)	Poor	Poor	Poor	May be plasticized; poor aging properties; subject to oxidation.	Temporary holding uses.
Limed rosin	Mastic	Good	Good	Good	Heat resistance is good (better than that of rosin cements); fair aging properties; becomes brittle; saponified by alkali; develops strength rapidly.	
Cumarone-indene	Solvent solution (Toluol or Xylol), mastic	Good	Poor	Poor	Low bond strengths; films are hard, tough; softens at elevated temperatures; resists alkali.	Wood, felt and cloth (compatible with waxes).
Polyamide resins	Solvent solution, mastic (hot melt)	Poor (1)	Good	Good	Flexible, tough mastics; non-blocking at room temperatures; heat seal at about 150° F.	Glass and paper (not used alone extensively; usually in combination with other resins).

(1) Improves when combined with shellac.

TABLE XCII. Characteristics of several thermosetting resin adhesives.

Type	Form	Additive	Pot life	Setting temperature, °F.(2)	Curing temperature, °F.(3)	Resistance to deteriorators(1): Water	Solvents	Fungus	Weather	Heat	Cold	Application
Urea-formaldehyde	Powder	Water	1 to 24 hr	70 to 210	70 to 210	F to G	E	E	M	P to M	G to E	Wood (interior).
	Liquid	Hardener										
Melamine	Powder	Water	24 to 48 hr	240 to 280	240 to 280	E	E	E	G	E	G	Wood (exterior).
Acid-catalyzed phenolic	Liquid	Hardener	1 to 6 hr	70 to 210	70 to 250	E	E	E	E	E	E	Wood (exterior); Metal to wood.
Resorcinol and phenol-resorcinol	Liquid	Hardener	1 to 6 hr	70 to 210	70 to 210	E	E	E	E	E	E	Wood (exterior); Plastics; leather; textiles; fiberboard; wood to metal.
Phenolic resin	Liquid	------	Indefinite	250 to 300	250 to 300	E	E	E	E	E	E	Wood (exterior); metals; glass.
	Film	------	--------									
	Powder	Water	Indefinite									
Polyester	Liquid	Hardener	5 min. to 24 hr	70 to 220	70 to 220	G	E	E	G	G	G	Polyester laminates; Some metals; ceramics.
Epoxy	Liquid	Hardener	1/2 hr to 6 months	70 to 250	70 to 500	F to G	E	E	G	F	G	Metals; glass; wood; ceramics; plastics; some rubbers.
	Powder	------	Indefinite	250 to 500	250 to 500	F to G	E	E	G	G	G	
	Paste	------	1/2 hr to 4 months	250 to 500	250 to 500	F to G	E	E	G	G	G	
Polyurethane	Liquid	Solvents	Up to 48 hr	70 to 355	70 to 355	F to G	G	E	G	G	E	Rubber; metal; most plastics; wood; paper; cork; ceramics; textiles, glass.
	Liquid	------										

(1) E = Excellent, G = Good, M = Moderate, F = Fair, P = Poor.
(2) Lower if acidic setting agents are added.
(3) Cures at the higher temperatures with acid hardeners added.

TABLE XCIII. Characteristics of several thermosetting modified phenolic-resin and rubber-resin adhesives.

Adhesive	Form	Drying required	Curing temperature °F.	Resistance to deteriorators(1)				
				Water	Oil	Gasoline	Heat	Cold
Neoprene-phenolic (resin)	Liquid	Yes	325 to 500	E	E	E	G	E
	Film	No						
Nitrile-phenolic (resin)	Liquid	Yes	325 to 500	E	E	E	E	P to G
	Film	No						
Vinyl-phenolic	Liquid	Yes	240 to 500	E	E	E	G	G
	Film	No						
Nylon-phenolic (polyamide-phenolic)	Liquid	Yes	325 to 500	G	E	E	F to M	G
Epoxy-phenolic (epoxy modified phenolic)	Liquid	Yes	200 to 330	G to E	G	G	E	G
	Film	No						

(1)E = Excellent, G = Good, M = Moderate, F = Fair, P = Poor.

TABLE XCIV. Characteristics of several vegetable base and animal base adhesives.

Adhesive	Form	Preparation	Pot life	Setting Characteristics	Resistance to deteriorators: Water	Weather	Fungus	Heat	Special Characteristics
Vegetable starch(1)	Powder Water solution	Water added Generally mixed hot	Many days to indefinite if protected from fungus and water.	Sets at room temperature or is cold-pressed; Sets quickly; Develops tack rapidly as water evaporates.	Poor	Poor	Poor	Poor	Applied by hand or machine; low strength; light color, non-staining; low cost.
Soybean and vegetable proteins	Powder	Add water, mix cold	Several hours	Sets as water evaporates; cold press or use heat at 180° to 250°F.	Fair to good	Poor	Poor	Poor	Low cost.
Animal-base glue (hide glue)(1)	Powder Flake	Add water Add water	Indefinite if protected from water, fungus and heat	Sets at room or high temperatures; bonds form before glue cools and gels; sets quickly; good tack.	Poor	Poor	Poor	Poor	Excellent solvent resistance; applied by hand or machine; great strength with wood; excellent gap-filling properties.
Blood albumen	Powder	Add water	Several hours to 1 day	Sets quickly at at 180° F. by loss of water and coagulation.	Fair	Poor to Fair	Poor	Fair	Light-colored odorless, tasteless, non-toxic; inexpensive; moderate durability.
Casein(1)	Powder	Add water	1 to 24 hours	Sets at room temperature as alkali reacts and water evaporates; can be hotpressed.	Fair to moderate	Poor	Poor	Fair	Good solvent resistance; good durability; fair gap-filling properties.

(1) Resistance can be improved by compounding with other materials.

TABLE XCV. Characteristics of several vinyl adhesives.

Type	Form	Resistance to deteriorators					Special Characteristics	Application
		Water	Gasoline	Grease	Oils	Fungus		
Polyvinyl acetate	Solvent solution	Moderate	Excellent	Excellent	Excellent	Good	Films are water-white, transparent, light stable; poor weather and heat resistance; indefinite pot life; sets at room temperature.	Metals, wood, glass, plastics leather, cloth
	Emulsion	Fair(1)	Good	Good	Good	Good	Tasteless, odorless; poor weather and heat resistance; indefinite pot life; sets at room temperature.	Wood, paper.
Polyvinyl alcohol	Water solution	Fair(2)	Excellent	Excellent	Excellent	Can be induced by treatment	Tasteless, odorless.	Wood, paper.
Vinyl vinylidene	Solvent solution	Excellent	Excellent	Excellent	Excellent	Moderate	Colorless, transparent.	Textiles.

(1) Adequate for most interior uses.
(2) Adequate to prevent delamination of paper.

TABLE XCVI. Numerical list of adhesive specifications.

Specification number	Title
MIL-A-3316	Adhesives, Fire-resistant, Thermal Insulation
MIL-A-5540	Adhesive, Polychloroprene
MIL-A-8576	Adhesive, Acrylic Base, for Acrylic Plastic
MIL-A-13374	Adhesive, Dextrin, for use in Ammunition Containers
MIL-A-14042	Adhesive Epoxy
MIL-A-22010	Adhesive, Solvent Type, Polyvinylchloride
MIL-A-22397	Adhesive, Phenol and Resorcinol Resin Base (For Marine Service Use)
MIL-A-22895	Adhesive, Metal Identification Plate
MIL-A-24179	Adhesive, Flexible Unicellular-plastic Thermal Insulation
MIL-A-25463	Adhesive, Metallic Structural Sandwich Construction
MIL-A-45059	Adhesive for Bonding Chipboard to Terneplate, Tinplate, and Zincplate
MIL-A-46106	Adhesive-sealant, Silicon, RTV, General Purpose (For Electrical and Mechanical Sealing)
MIL-A-52194	Adhesive Epoxy (For Bonding Glass Reinforced Polyesters)
MMM-A-100	Adhesive, Animal Glue
MMM-A-105	Adhesive and Sealing Compounds, Cellulose Nitrate Base, Solvent Type
MMM-A-121	Adhesive, Bonding Vulcanized Synthetic Rubber to Steel
MMM-A-122	Adhesive, Butadiene-Acrylonitrile Base, General Purpose
MMM-A-125	Adhesive, Casein-Type, Water- and Mold-resistant
MMM-A-130	Adhesive, Contact
MMM-A-134	Adhesive, Epoxy Resin, Metal to Metal Structural Bonding
MMM-A-138	Adhesive, Metal to Wood, Structural
MMM-A-139	Adhesive, Natural or Synthetic-Natural Rubber
MMM-A-150	Adhesive for Acoustical Materials
MMM-A-178	Adhesive, Paper-lable, Water-resistant
MMM-A-179	Adhesive, Paper-lable, Water-resistant, Water Emulsion Type

TABLE XCVI. Numerical list of adhesive specifications. - Continued

Specification number	Title
MMM-A-180	Adhesive, Polyvinyl, Acetate Resin Emulsion (Alkali Dispersable)
MMM-A-181	Adhesive, Phenol, Resorcinol, or Melamine Base
MMM-A-182	Adhesive, Rubber
MMM-A-187	Adhesive, Epoxy Resin Base, Low and Intermediate Strength, General Purpose
MMM-A-188	Adhesive, Urea-resin-type Liquid and Powders
MMM-A-189	Adhesive, Synthetic-rubber Thermoplastic, General Purpose
MMM-A-193	Adhesive, Vinyl Acetate Resin Emulsion
MMM-A-250	Adhesive, Water-resistant (For Closure or Sealing Fiberboard Boxes)
MMM-A-260	Adhesive, Water-resistant (For Sealing Waterproofed Papers)
MMM-A-1058	Adhesive, Rubber Base (In Pressurized Dispensers)
MMM-A-1617	Adhesive, Rubber Base, General Purpose

5.11 Marking.

5.11.1 General. Markings applied to unit, intermediate, and exterior containers identify the packaged item and give other important information regarding the item. Lack of proper markings on unit, intermediate, or exterior containers will cause serious difficulties and problems in the supply system. A unit, intermediate, or exterior container is not complete until it has been properly identified. Some of the requirements for lettering, waterproofing, and securing of labels are discussed below.

5.11.2 Military and commercial marking.

5.11.2.1 Military marking. Military marking of unit, intermediate, and exterior containers will comply with MIL-STD-129 which requires that the following identification markings appear on all unit and intermediate containers (see fig 57 for illustration):

a. National stock number.

b. Manufacturer's part number (as applicable).

c. Item description.

d. Quantity and unit of issue.

e. Contract number (delivery order number, when specified) or purchase order number.

f. Level of protection and date.

Exterior container identification and contract data markings for containers under 10 cubic feet are illustrated in figure 58.

5.11.2.2 Commercial marking. Marking of commercial packaging is specified in MIL-STD-1188.

5.11.3 Requirements. Unless otherwise specified, marking requirements are identical for all levels of packing. The color of all markings shall be black except when applied to surfaces on which black is not legible--then the color used shall provide a definite contrast. The hand lettering or writing of military markings is not permitted unless specifically authorized except for piece number, total pieces, and weight and cube information. Hand writing of commercial markings is authorized.

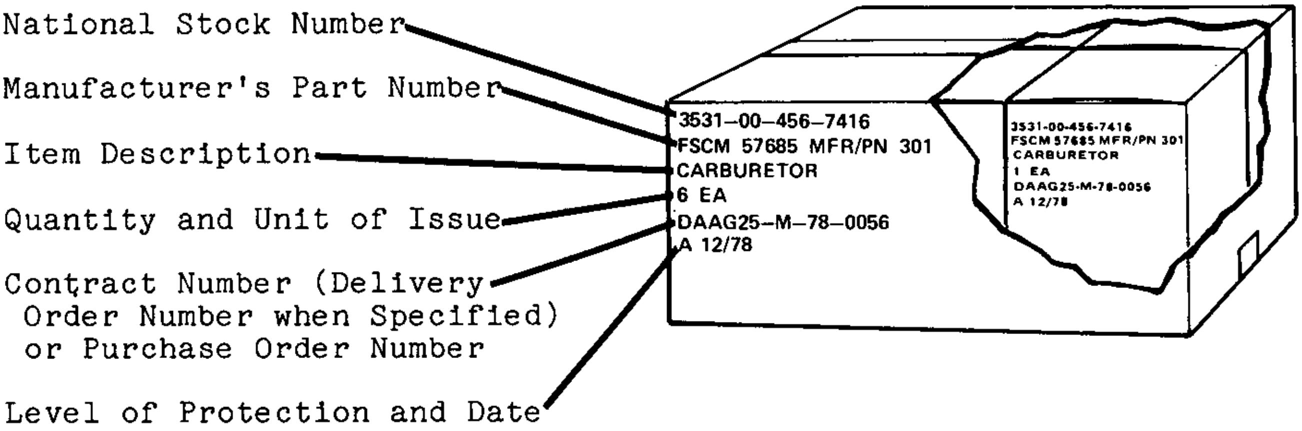
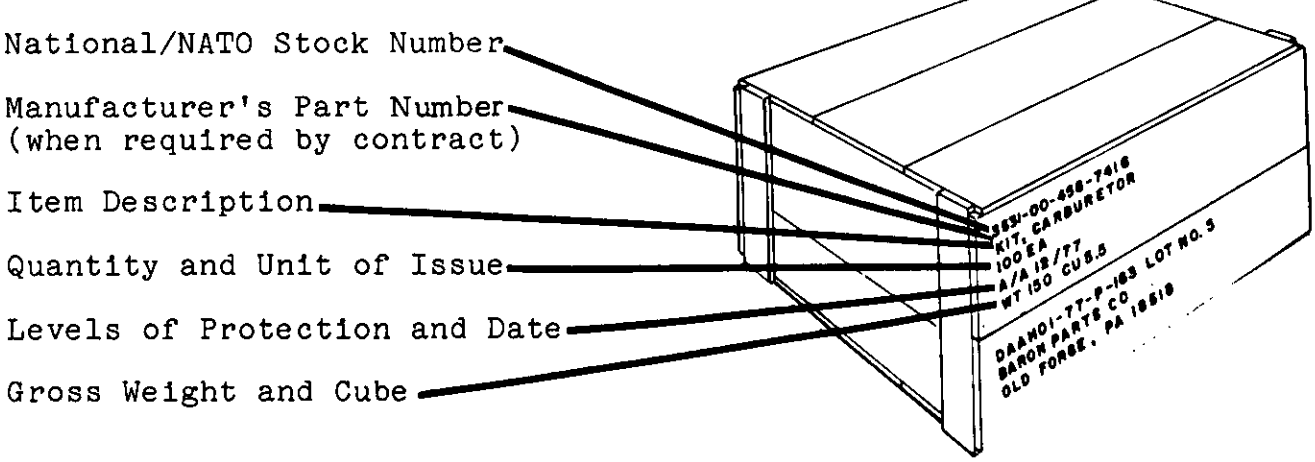


FIGURE 57. Unit and intermediate container identification markings.

Exterior Container Identification Marking



Exterior Container Contractor Data Marking

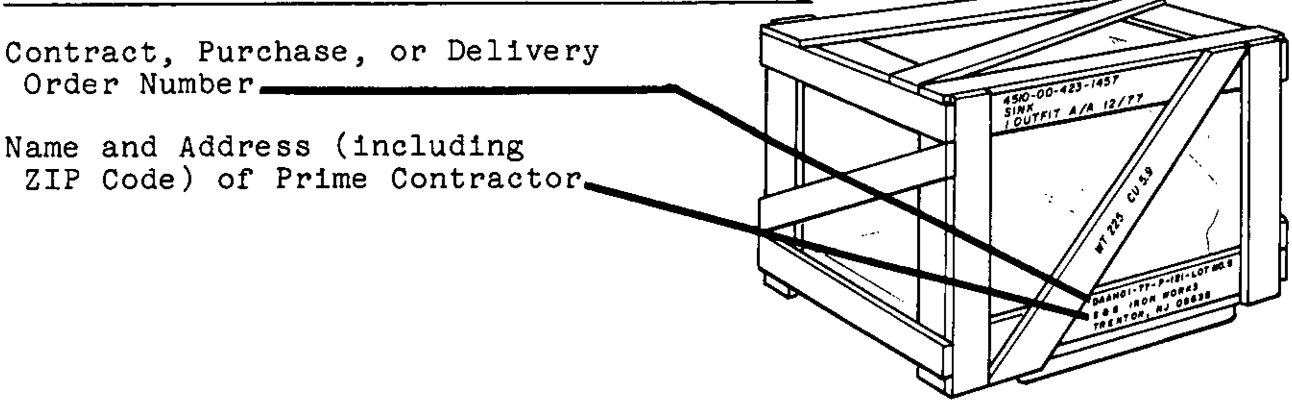


FIGURE 58. Exterior container identification and contract data markings (containers under 10 cubic feet).

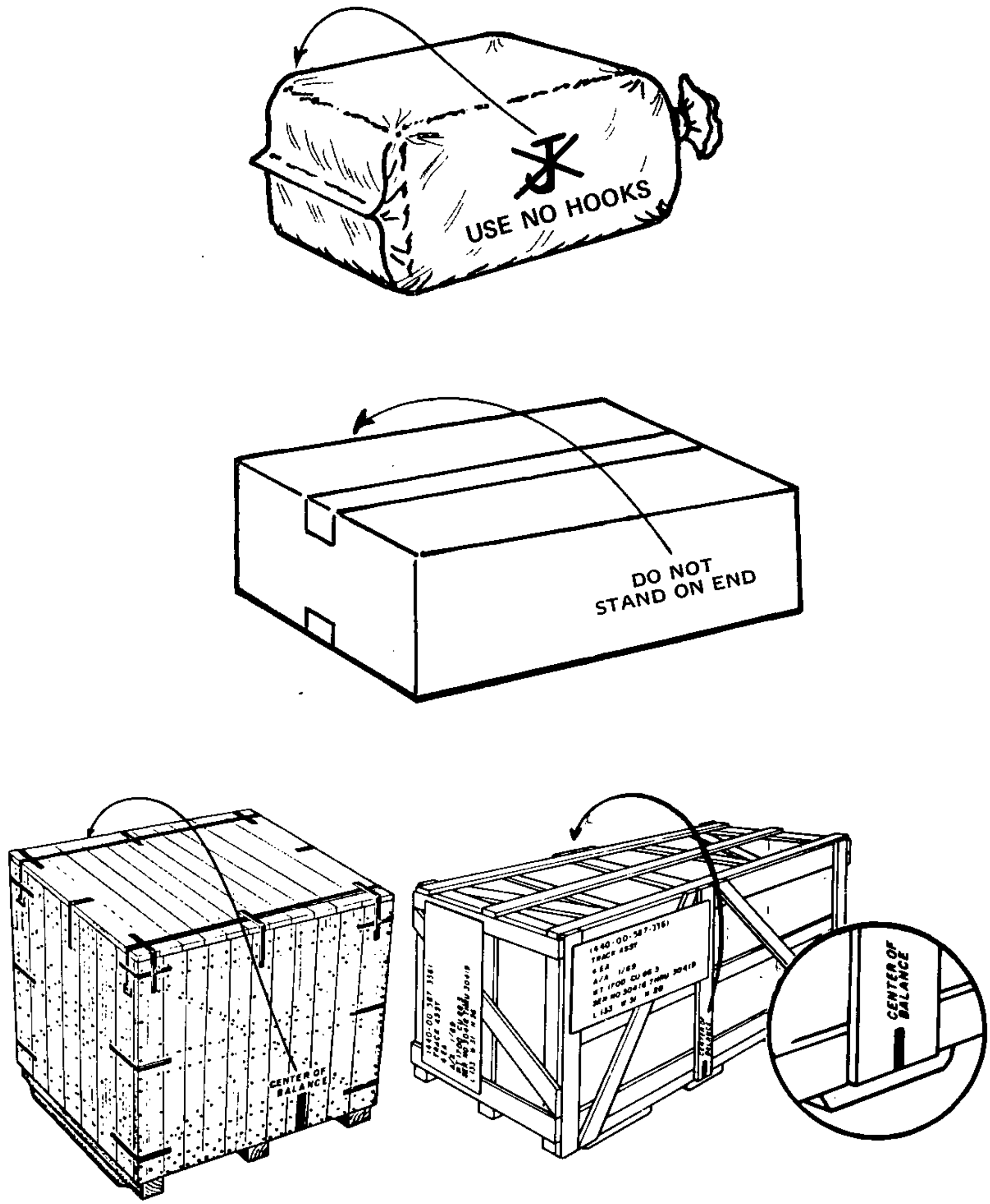


FIGURE 59. Examples of special and precautionary handling markings.

5.11.4 Labels. Labels are often used to apply identification and special markings to containers. Required markings on labels shall be printed, typed, or reproduced. The size of labels shall be consistent with the size of the pack, and the lettering shall be of a size which will permit ready identification. Pressure-sensitive labels may be used on containers other than wood. Labels for Level A packs will be secured with water-resistant label adhesive conforming to MMM-A-105, MMM-A-178, or MMM-A-179. Labels for level A packs shall be waterproofed by coating the entire outer surface of the label with waterproof lacquer, varnish, clear acrylic coating compound, or label adhesive.

5.11.5 Special marking. Special markings will comply with the requirements of MIL-STD-129 and the contract or order. Examples of special markings are shown in figure 59. The examples show typical handling and special markings which are required under certain circumstances. MIL-STD-129 must be consulted for full qualification of markings.

5.11.6 Precautionary label (Method II). The Method II label is used to prevent unnecessary opening of the Method II package, which would result in decreasing the effectiveness of the protection afforded the item. If space for a Method II label (fig 60) or stamp is not available on the unit or intermediate container, the words "METHOD II PACKAGE - DO NOT OPEN UNTIL READY FOR USE" in letters as large as possible will be placed adjacent to the identification markings.

NOTE: BACKGROUND AND LETTERING ARE COLORED RED.
THE ARROW AND SQUARE ARE COLORED WHITE.

FIGURE 60. Method II label.

5.11.7 MIL-STD-129. The previous paragraphs have briefly covered the marking requirements as specified by MIL-STD-129. The details are not covered since the standard is already given wide distribution. However, what has been presented in this section was done solely to bring about an awareness of the importance of marking and any considerations which may be required in pack design. MIL-STD-129 should be consulted for the marking procedures and materials for general supplies, petroleum and steel products, household goods, subsistence items, ammunition, and radioactive materials. The standard provides the requirements for the uniform marking of military supplies and equipment for shipment and storage. It accommodates the requirements for coded and in-the-clear data, and the forms required by Military Standard Requisitioning and Issue Procedures (MILSTRIP) and Military Standard Transportation and Movement Procedures (MILSTAMP) for movement processing.

5.12 Methods of humidity control. Earlier sections of this handbook discuss deterioration, its causes, and various packaging methods used by the military to combat deterioration of items. This chapter describes methods of preserving items through humidity control.

5.12.1 Control of humidity level. Items can be protected from the harmful effects of high humidity in one of two ways: (1) by having a barrier "wall" interposed between the surface of the item and the surrounding atmosphere, or (2) by controlling the humidity level of the atmosphere surrounding the surface of the item. The imposing of a barrier between the item and the atmosphere is usually accomplished by inclosure in a hermetically sealed container, inclosure in waterproof- and watervaporproof-type barrier materials, or by treating the item with contact preservatives and surface coating. When the use of a barrier is impossible or undesirable and the item under consideration required environmental protection, then the humidity must be controlled.

5.12.1.1 Satisfactory humidity level. Equipment for the control of humidity in storage space must be operated not to exceed 50 percent relative humidity. If the relative humidity falls below 30 percent, there is a tendency for rubber cable coverings and other insulating materials on electronic equipment to dry out and crack. Other materials such as wood, cotton, and plastic are weakened or deteriorated by excessively low humidities.

5.12.1.2 Types of controlled humidity. There are two basic types of controlled humidity: static dehumidification and dynamic dehumidification. In determining which type to use in a particular instance, each must be evaluated as to its advantages,

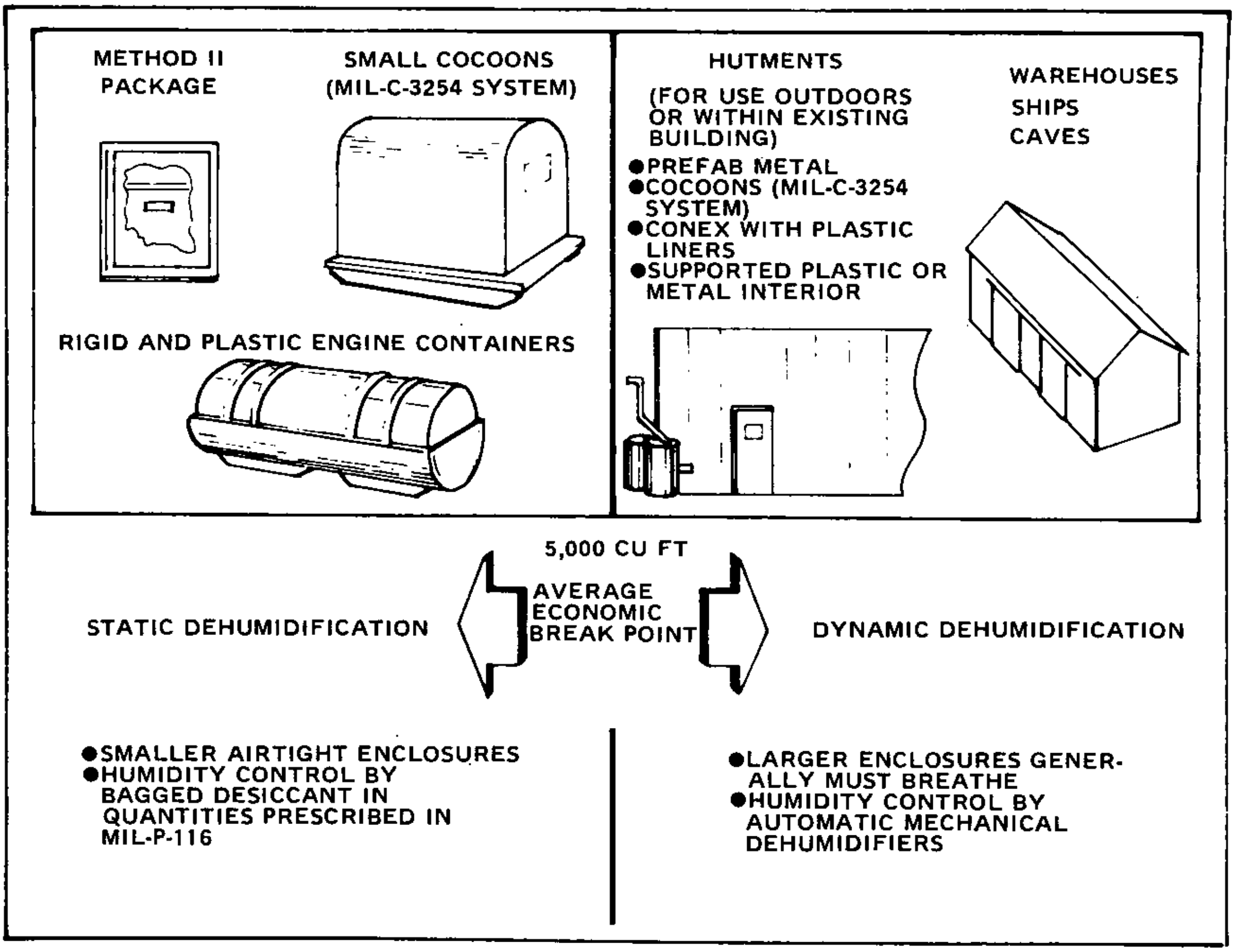


FIGURE 61. Static vs dynamic dehumidification.

disadvantages, and comparative economical value in the specific area of preservation or application involved. Figure 61 presents some of the considerations in selecting the type of dehumidification.

5.12.1.2.1 Static dehumidification. Static dehumidification for performance of Method II preservation is generally accomplished by placing a chemical agent (usually a desiccant) in the space to be dehumidified. This agent either absorbs or adsorbs water from the surrounding atmosphere. Inasmuch as all such materials have a limit to their ability to take water from the atmosphere and hold it, a means must be provided for preventing a continuous resupply of moisture-laden air or free water from reaching the area being dried by the chemical agent. This function is served by either sealed containers or sealed barrier wraps. For military packaging purposes, an effective barrier must have a water-vapor transmission rate of no more than 0.05 to 0.07 gram per 100 square inch surface area in 24 hours. Existing container and barrier materials differ in their watervapor transmission rates and, consequently, also differ in their efficiency in maintaining a desired moisture level in a package over a period of time. The most commonly used barriers for this purpose, in their order of effectiveness, are rigid and semirigid metals, usually steel or aluminum; plastic metal-plastic laminated flexible barriers; semirigid combinations of foil-plastic and paper; laminated plastic films; and single-ply plastic films. In the case of single-ply unsupported plastic film, new materials are now available which are equal to the plastic-foil flexible combinations. These new plastic materials, however, cost approximately four times as much as the plastic-foil combinations and so are not used as extensively. In the use of flexible barriers, the item to be unit packed is inclosed with desiccant in a heat-sealed barrier material. The inclosed air volume in barrier packs should be kept to a practical minimum, consistent with good packaging practices. Sufficient cushioning must be provided to prevent the item from puncturing the barrier and destroying its watervapor protection. Sufficient barrier material must also be provided to permit opening and resealing the pack during use. Sealed metal containers used as barriers are of three types: pressurized, free breathing, and valve-controlled breathing. Each type has advantages and disadvantages in weight, effectiveness of protection, and life span. The order of preference in weight is free breather, controlled breather, and pressurized. The order of preference in effectiveness of protection and life span is pressurized, controlled breather, and free breather. From this it is evident that the requirements conflict. The choice of the proper container, then, must be carefully considered with regard to length of storage needed, severity of environment to be encountered, and costs of manufacturing and shipping as related to container weight. The various aspects of these containers are discussed in detail in 5.8. Rigid and semirigid containers of materials other than metal are also used. These can include fiber drums, plastic containers, rubber containers, etc. Containers of these types (with the exception of fiber drums) are usually of special design for one specific application. Desiccation is the same as for metal containers. The amount of desiccant provided in barrier packs is dependent upon the surface area of flexible barrier packs and upon the volume of rigid containers (see 5.12.3 for determination of amount of desiccant required). When dunnage or cushioning is used within the pack, additional desiccant must be provided to compensate for the moisture trapped in the dunnage material. In free-breather or controlled-breather containers, the desiccant must not only dry out the initial container atmosphere, but also the air breathed in during the container storage duration.

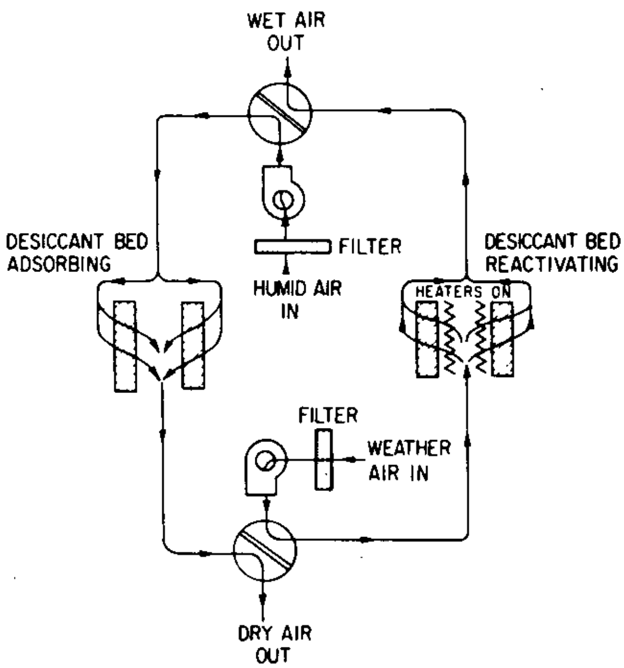


FIGURE 62. Dehumidification machine employing two desiccant beds.

5.12.1.2.2 Dynamic dehumidification. Dynamic dehumidification involves either the continuous or intermittent processing of the air volume in an inclosure in such a way that the relative humidity is maintained constant at some acceptable level. The three processes by which dynamic dehumidification can be accomplished are:

a. Dehumidification machines. These machines employ one or more desiccant beds, and the necessary air ducts, filters, fans, and heaters. The air is first filtered to remove dirt and dust, then drawn over the desiccant bed where moisture is removed, and finally returned to the space being dehumidified. If only one desiccant bed is used, it must be reactivated periodically, and, consequently, the machine operated intermittently. If two beds are used (fig 62), one can be reactivated while the other is in operation, and the machine is thus capable of continuous operation. Internal heaters and outside air are used for the reactivation process. Dehumidification machines are relatively simple in design and operation. They are capable of removing moisture efficiently at temperatures from 0° to 150° F. (-18° to 66° C.), making them ideal for use in unheated building.

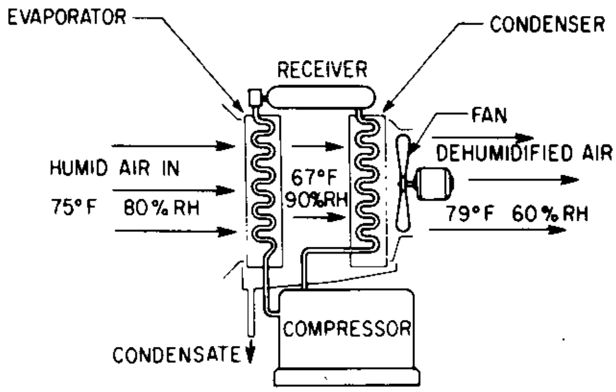


FIGURE 63. Dehumidification by refrigeration.

b. Refrigeration. Dehumidification by refrigeration (fig 63) involves the passing of the air to be dehumidified over cooling coils. As the air is cooled, its moisture-holding capability drops to the point where condensation takes place and free water is released. This is the dew point. The water collects on the cold surface in the form of frost. After passing the cooling coils, the air is warmed by being passed over some type of heating element before it is returned to the area being dehumidified. The relationships among temperature, relative humidity, and absolute humidity can be determined from figure 64. The use of refrigeration for dehumidification is feasible only in those cases where the temperature of the space to be dehumidified does not fall below about 60° F. (16° C.), such as in tropical or semitropical climates, or heated warehouses.

c. Heating. The use of heating to accomplish dehumidification merely involves the raising of the air temperature in the space being dehumidified. This does not remove any moisture from the air, but it does lower the relative humidity (fig 64). Because of the relatively high temperatures normally required, dehumidification by heating is usually impractical.

5.12.2 Desiccants. Numerous materials are available as desiccants for moisture control. Some of these materials are silica gel, clay, alumina, bauxite, charcoal, calcium sulfate, and zeolites. Of these, silica gel and clay are the most commonly used in present military packaging. Silica gel is an amorphous form of silicon dioxide. It is synthetically manufactured to a

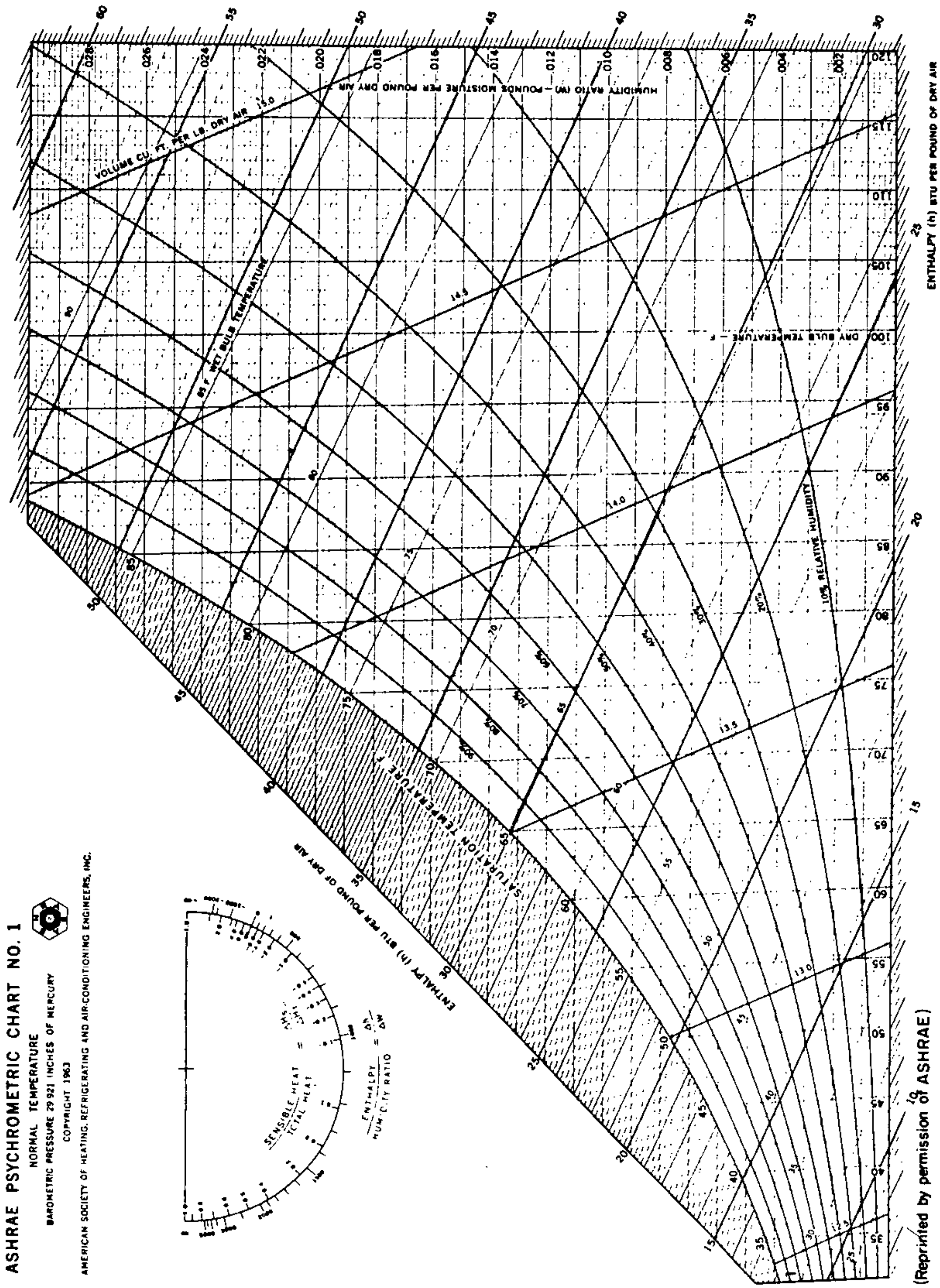


FIGURE 64. Psychrometric chart.

uniform grain and capillary size. Clay is a complex structure of natural crystalline and amorphous materials. Both desiccants are inert and have a high adsorption capability and rate. The adsorption is a result of capillaries in the materials which attract watervapor, condense it, and hold it as a liquid by surface adsorption and capillary condensation. Zeolites, commonly known as molecular sieves, are crystalline metal aluminasilicates and have been known as naturally occurring minerals for many years. Natural sources, however, are scarce and it has been only recently that molecular sieves have been synthesized and commercially produced. Because of their recent emergence, their application in military packaging has been limited. Molecular sieves will probably have an increased use in the future because of their adsorption capacity and rate which are higher than those of other desiccants. The higher capacity permits the use of smaller desiccant charges. However, this must be balanced off against the presently higher cost of the molecular sieve. Desiccants used for static dehumidification are supplied in bags of different sizes up to a maximum size of 80 units of desiccant per bag. Desiccants for dynamic dehumidification are supplied in bulk form. Silica gel, clay, and molecular sieves are all acceptable desiccants. The moisture adsorption rate of desiccant is not uniform under all conditions, but depends on several variables such as: (1) the amount of moisture the desiccant has already absorbed, (2) the ambient temperature, and (3) the humidity (vapor pressure) of the atmosphere. Because of this variable adsorption rate, and the varying abilities of different types of desiccants to adsorb moisture, requirements are based on desiccant units rather than weight or volume. A desiccant unit is defined as that quantity of desiccant that an equilibrium at 25° C. adsorbs (3.0 grams of moisture at 20 percent relative humidity and 6.0 grams of moisture at 40 percent relative humidity). The requirements of MIL-D-3464 are summarized in table XCVII. Desiccants specified for military packaging must be capable of being reactivated after use. Reactivation consists of heating the desiccant to a sufficiently high temperature to drive off accumulated moisture. The reactivation temperature varies with the type of desiccant used. The reusable life of desiccant is limited by this heating and by the handling involved which cause physical deterioration of both the bag and the desiccant.

5.12.3 Desiccant calculations. To protect the contents of a package adequately against corrosion, it is imperative that a sufficient amount of desiccant be provided to adsorb the initial moisture in the container materials, and in the air when the container is sealed; and to remove moisture during transportation and maintain a moisture-free environment during storage. The relationships for determining the exact quantity of desiccant required for a specific application are difficult to determine accurately, but satisfactory empirical formulas have been developed:

a. Units of desiccant for use within a barrier other than a sealed rigid metal barrier--

$$U = CA + XD$$

b. Units of desiccant for use within sealed rigid metal barriers--

$$U = KV + XD$$

where

U = number of units of desiccant to be used

C = 0.011 when area of barrier is given in in.^{2}

C = 1.6 when area of barrier is given in ft^2

K = 0.0007 when volume is given in in.^{3}

K = 1.2 volume within barrier in in.^{3} or ft^3

V = volume within barrier in in.^{3} or ft^3

X = 8 for hair felt, cellulosic material (including wood), and other material not categorized below

X = 6 for bound fibers (animal hair, synthetic fiber, or vegetable bound with rubber)

X = 2 for glass fiber

X = 0.5 for synthetic foams and rubber

D = pounds of dunnage (other than metal) within barrier

5.12.4 Hygroscopic humidity indicators. Humidity indicators are included as a check on the condition of the dehumidified package. Humidity indicators used in military packaging include those conforming to MS-20003 and MIL-I-26860. Figure 65 shows hygroscopic humidity indicators.

TABLE XCVII. MIL-D-3464 desiccant requirements.

Requirements	Value
Desiccant Unit (The quantity of desiccant which adsorbs in equilibrium at 25° C. the indicated quantity of water vapor.)	(1) 3.00 grams at 20% relative humidity (2) 6.00 grams at 40% relative humidity
Unit Weight (Weight constituting a desiccant unit.)	Less than or equal to 50 grams
Unit Adsorption Capacity (Weight of water vapor adsorbed by unit weight in equilibrium at 25° C.)	(1) 3.00 grams at 20% relative humidity (2.85 grams when bagged)(1) (2) 6.00 grams at 40% relative humidity at manufacture for delivery (5.70 grams when bagged)(1)
Unit Volume (Quantity of desiccant constituting a desiccant unit.)	Less than or equal to 45.0 milliliters
Unit Content (Number of desiccant units contained in each bag.)	95% of number of units indicated on bag label
Unit Adsorption Rate (16 unit bag or smaller.)	(1) 0.25 gram/desiccant unit/7 hr at 40% relative humidity (2) 0.90 gram/desiccant unit/7 hr at 80% relative humidity
Requirements After Reactivation Adsorption Capacity Adsorption Rate Condition	 (1) 90% unit adsorption capacity retained (2) 80% unit adsorption rate retained (3) Reactivation temperature 245° F. (118.3° C.) min. Reactivation time: 24 hr max.

(1) Reductions in adsorption capacities for bagged desiccant are allowances for manufacturing errors such as desiccant loss during bagging.

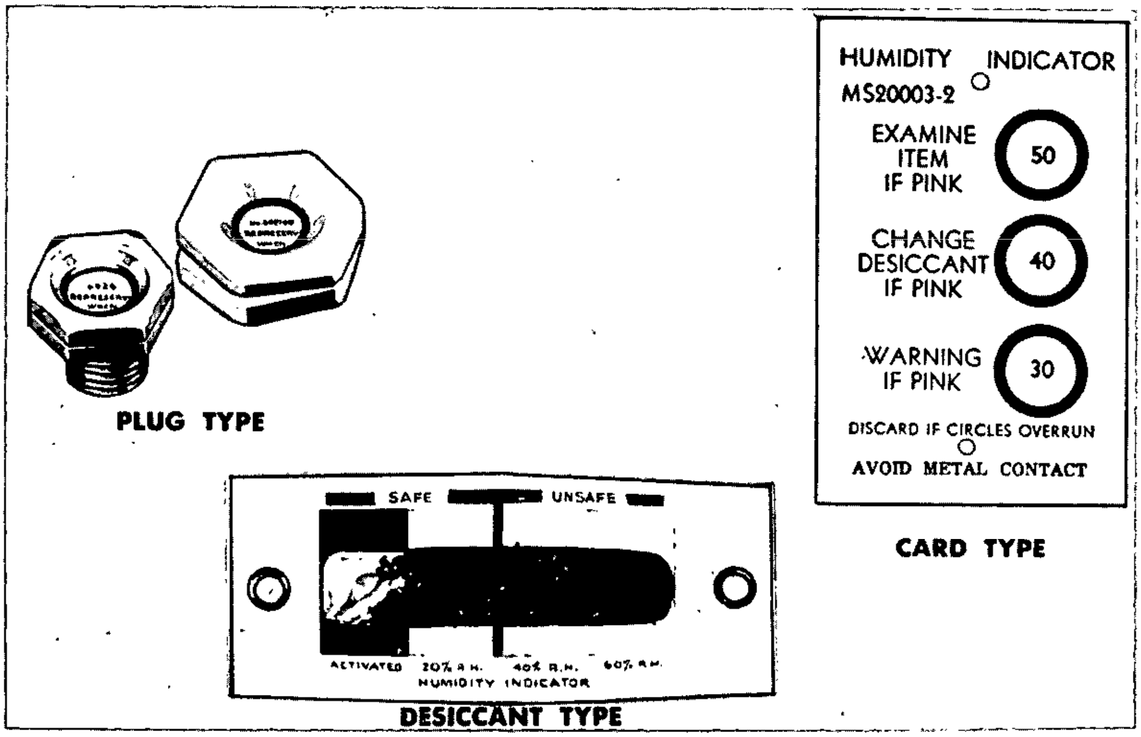


FIGURE 65. Hygroscopic humidity indicators.

5.12.4.1 MS-20003 humidity indicator. The humidity indicator conforming to MS-20003 is constructed of blotting paper on which are inclosed three sensitive areas. The three areas indicate the following information:

a. Top. Turns pink when relative humidity is 50 $\pm$ 5 percent at 73.5 $\pm$ 2° F.

b. Center. Turns pink when relative humidity is 40 $\pm$ 5 percent at 73.5 $\pm$ 2° F.

c. Bottom. Turns pink when relative humidity is 30 $\pm$ 5 percent at 73.5 $\pm$ 2° F.

5.12.4.2 MIL-I-26860 humidity indicators. The humidity indicators conforming to MIL-I-26860 are externally mounted color-change indicators for determining the relative humidity within rigid containers or moisture-vaporproof envelopes or bags. These indicators are of two types:

a. Type 1. For mounting in threaded boss.

b. Type 2. For mounting with self-contained locking device or in threaded boss.

Indicators are designed so that the indicating element is exposed to the contained atmosphere. Only common hand tools are required to install and remove the plugs from rigid or flexible containers. The type 1 indicators are suitable for installation in threaded plug openings of engine cyclinders. The type 2 indicators are suitable for attachment in metal containers or barrier materials.

5.12.5 Electrical humidity indicators. The electrical humidity indicating system consists of an electrical sensing element assembly--composed of an electrical sensing element, a barrier seal, and an electrical conductor--which is incorporated as an integral part of the package at time of fabrication. The electrical conductor extends from within the package through the vaporproof barrier to the outside of the exterior container. By use of a portable indicating instrument, determination of the moisture level can be made by contact with the electrical conductor on the container.

5.12.6 Humidity indicator and control systems. The atmosphere of storage facilities using dynamic dehumidification should be continuously checked to insure the maintenance of proper storage conditions. This can be accomplished by a monitor and recorder system linked to sensor devices. In this system, two pens mark a spring or electrically driven chart. One sensor element drives one pen to record humidity while a second sensor drives the other pen to record temperature. The system provides a continuous record of humidity and temperature during the storage term. Humidity sensing and driving devices may be of the capacitive type, hygroscopic film type, or hygroscopic hair type. Temperature sensing devices are usually bi-metal strips or thermistors (temperature sensitive resistors). These same types of sensors can also be used to actuate humidistats or thermostats to operate the humidity and temperature control equipment. Indicator and control system sensors should be checked periodically for accuracy by comparing their readings with those of laboratory grade hygrometers. The dry- and wet-bulb temperatures obtained from the hygrometer are interpreted on a psychrometric chart (fig 64) to obtain the true relative humidity value.

5.13 Transportation environments. The most damaging environments encountered by packaged items during transportation are shock and vibration. The shocks and vibrations to be expected depend on the particular mode of transportation. The effect of these environments on the item being transported is further dependent upon the manner in which the item is packaged and the stowage technique used. Techniques used for protecting packaged items against the harmful effects of shock and vibration include blocking and bracing; use of cushioning materials, either elastic (resilient) or nonelastic (crushable); and use of shock and vibration isolation systems.

5.13.1 Transportability criteria. MIL-HDBK-157 and MIL-STD-1366 cover fundamental transportability criteria for the development of items of materiel prepared for shipment and for the evaluation of the transportation capabilities of commercial nondevelopmental items. Included are data concerning dimension and weight limitations, restraint, shock and vibration, and test plan development so that the materiel meets the requirements for transportability by the required transport mode or modes.

5.14 Natural environments.

5.14.1 Climatic conditions. Climatic conditions vary widely from point to point over the surface of the Earth. Furthermore, at any particular location, daily as well as yearly variations in these conditions occur, and in many instances the variations are extreme. It is beyond the scope of this handbook to present detailed information on weather conditions around the world. Studies of the frequency of occurrence of climatic extremes on a regional basis have been completed to provide guidance for realistic consideration of climatic conditions in the research and development of materiel. Data from these studies pertinent to military packaging are included in the paragraphs which follow.

5.14.1.1 Climatic extremes for military materiel. Climatic extremes for consideration in the research and development of materiel are specified in Quadripartite Agreement 200, Climatic Factors Affecting Design Criteria, and MIL-STD-210 documents. AR 70-38 includes a map which shows the areas of occurrence of eight climatic categories. Although not specifically intended for application to packaging, the map and the associated explanatory material are included here since they are the best available information on the regional occurrence of climatic extremes of concern in the field of military packaging. Included on the map are graphs which show the diurnal cycles of extreme temperature and humidity conditions in the indicated areas of occurrence of the eight climatic categories. The following discussion of the delimitation of the climatic categories and application of the map is included to avoid misinterpretation of the data and misuse of the map.

a. Category 1, Wet-Warm, and Category 2, Wet-Hot. The areas designated as Wet-Warm and Wet-Hot are the humid tropical regions of the world. Wet-Warm conditions occur under the forest canopy and Wet-Hot conditions occur in the same area, but in the open. Both Wet-Warm and Wet-Hot areas are differentiated on the basis of occurrence of the conditions. In the areas identified on the maps as "Nonseasonal," the conditions can be expected to occur at any time during the year, whereas in the areas identified as "Seasonal," they occur only during the rainy season. In the Seasonal areas, temperatures higher than the 95° F. (35° C.) Wet-Hot limit may occur during the dry season. For example, in most of Southeast Asia, Wet-Hot conditions prevail during the wet monsoon season, but during the dry monsoon season, the higher temperatures associated with Intermediate Hot-Dry conditions apply.

b. Category 3, Humid-Hot Coastal Desert. The desert areas on the immediate coast of the Persian Gulf and Red Sea designated as Humid-Hot are characterized at times by a relatively high temperature of 100° F. (38° C.) combined with extremely high amounts of water vapor in the air near the ground (dew point 86° F. 30° C.)). Occasionally, higher temperatures occur in these areas, but not in combination with as high a humidity.

c. Category 4, Hot-Dry. The areas designated as Hot-Dry were delimited on the basis of the occurrence of high temperatures. During the hottest month in a normal year, the temperature may be expected to be above the Intermediate Hot-Dry extreme of 110° F. (43° C.) and is expected to be hotter than 125° F. (52° C.) no more than 1 percent of the time in the most extreme part of the area.

d. Category 5, Intermediate Hot-Dry, and Category 6, Intermediate Cold. Intermediate Hot-Dry and Intermediate Cold conditions apply in the area which remains when the other climatic categories are delimited. Intermediate Hot-Dry conditions occur primarily near the boundary of the Hot-Dry category, and Intermediate Cold conditions occur near the boundary of the Cold category. Temperatures warmer than 110° F. (43° C.) and colder than -25° F. (-32° C.) are rare in the Intermediate areas. Parts of the area with Intermediate conditions are not subject to high temperatures or to low temperatures.

e. Category 7, Cold, and Category 8, Extreme Cold. The areas designated as Cold and Extreme Cold were delimited on the basis of the occurrence of low temperatures. In the Cold areas, the temperature during the coldest month in a normal year may be expected to be colder than the Intermediate Cold extreme of -25° F. (-32° C.)

but colder than the Cold extreme of -50° F. (-46° C.), for no more than 1 percent of the time in the most extreme part of the area. In the Extreme Cold areas, temperatures during the coldest month in a normal year may be expected to be colder than the Cold extreme of -50° F. (-46° C.) but colder than -70° F. (-57° C.) no more than 1 percent of the time in the most extreme part of the area.

5.14.1.2 Explanatory material on climatic extremes. For a complete discussion of the derivation of the conditions in each category, AR 70-38 should be consulted; however, a brief excerpt of explanatory material follows:

a. Category 1, Wet-Warm. Wet-Warm conditions are found under the canopy of heavily forested tropical areas. The extreme feature of the category is the long duration of high relative humidity at moderate temperatures.

b. Category 2, Wet-Hot. Wet-Hot conditions are found in the same general areas where Wet-Warm conditions occur, but in the open rather than under the forest canopy. Wet-Hot conditions characterized by high temperatures accompanied by high humidities and intense solar radiation may be found outside the areas designated, but only for short periods in a season of 3 months or less.

c. Category 3, Humid-Hot Coastal Desert. Humid-Hot Coastal Desert conditions are limited to the immediate coasts of bodies of water having a high surface temperature such as the Persian Gulf and the Red Sea. These areas experience very large amounts of watervapor associated with the air near the ground. The high temperatures, high humidities, and intense solar radiation of these areas comprise a stress which must be recognized for men and some classes of materiel.

d. Category 4, Hot-Dry. Hot-Dry conditions are found in the deserts of Northern Africa, the Middle East, West Pakistan and India, the Southwest United States, Northern Mexico, and Australia. These are the hottest areas of the world with accompanying intense solar radiation, but humidities are normally low and dryness is an additional problem.

e. Category 5, Intermediate Hot-Dry, and Category 6, Intermediate Cold. The inclusion of these categories results from Army policy that many general-purpose items of military equipment need not be designed to withstand the extremes of the hottest and/or coldest categories, but rather may be designed to withstand less extreme intermediate conditions which are experienced in the more populated areas of the world. Therefore, many military items are designed to withstand the Category 5 maximum temperature of 110° F. (43° C.) and the Category 6 minimum temperature of -25° F. (-32° C.).

f. Category 7, Cold, and Category 8, Extreme Cold. These two categories of cold are set forth to afford flexibility in the design of material for use in cold areas. Cold conditions with a minimum temperature of -50° F. (-46° C.) occur throughout a relatively large area in the Northern Hemisphere north of 45° N. latitude and away from moderating maritime effects. Extreme Cold conditions with a minimum temperature of -70° F. (-52° C.) are found in relatively remote areas of North America and Eurasia (Antarctica is excluded from consideration by international agreement).

5.14.2 Other natural environmental factors. In addition to the climatic hazards, other natural environmental factors are of concern to the packaging engineer. These factors are covered in the paragraphs which follow.

5.14.2.1 Altitude (pressure and temperature). Both atmospheric pressure and temperature vary widely with altitude. Nominal values of both, which can be considered for application to packaging, are given in table XCVIII. The figures are the best estimates available at the 1 percent level, i.e., lower temperatures and pressures can be expected no more than 1 percent of the time. Seasonal and geographical variations in pressure and temperature exist but can be neglected for packaging purposes. The reasons for considering altitude are: (1) materiel is transported through mountain passes where the temperatures and pressures for elevations as high as 15,000 feet may apply, and (2) materiel transported by air may be subjected to temperature and pressure which exist at 50,000 feet should there be a failure of cabin environmental regulation.

5.14.2.2 Blowing sand, dust, and snow. During transport or outdoor storage, packaged items may experience an environment of blowing sand, dust, or snow. If the item is such that its operation would be impaired by an accumulation of these small particles, the package must shield against their penetration. Furthermore, the package material must withstand the erosive effect of the particles. Design criteria for blowing sand, dust, and snow are presented in table XCIX. No data are given for the abrasive characteristics of the various particles since this depends on their hardness and shape.

TABLE XCVIII. Nominal values of temperatures and pressure vs altitude.

Height or elevation, ft	Pressure, mb	Temperature °F.	Temperature °C.
10,000	660	-42	-41
15,000	520	-53	-47
20,000	410	-68	-56
30,000	255	-87	-66
40,000	160	-98	-72
50,000	100	-105	-76

TABLE XCIX. Design limits for blowing sand, dust, and snow.

Item	Limit
Blowing Sand	Particles 0.01 to 1.0 mm in diameter, with predominant diameters between 0.15 and 0.3 mm. Wind 40 mph (35 knots) at height of 5 ft. Sand concentration, 10 lb per ft cross section distributed with few grains at 5 ft height and two-thirds of grains lower than 1 in. Sand stirred up by aircraft or vehicles may produce heavier concentration at higher levels.
Blowing Dust	Particles 0.0001 to 0.01 mm in diameter with a concentration of 6 x 10^{-9} g/cc. Dust stirred up by aircraft or vehicles may produce heavier concentrations. Dust velocity of 40 mph (35 knots) at height of 5 ft.
Blowing Snow	When blown by strong winds, snow crystals are broken and abraded in roughly equidimensional grains with rounded or subangular corners. Particles occur in greatest numbers in size range of 0.02 to 0.4 mm diameter. Smaller sizes tend to occur at lower temperatures.

5.14.2.3 Wind loading. Wind loading, which is the force exerted by wind on exposed objects, can sometimes cause damage to the packaged items. Strong winds can tear loose canvas or other protective coverings used for outdoor storage. Strong winds can also interfere with handling operations by blowing over containers, and making the loading and unloading of vehicles hazardous. Wind loading can be especially severe during transport by open conveyance as a result of the increase in relative wind speed due to motion of the vehicle. Wind speeds presently specified for military design purposes are given in table C. The actual force exerted on an object by the wind is a function of the square of the wind speed and its direction, and the frontal area and configuration of the object. For objects of simple shape, a flat surface perpendicular to the direction of the wind, the force F can be calculated using the equation

$$F = C_N S \left(\frac{pV^2}{2}\right)$$

where F = force, lb

C_N = shape factor, dimensionless

S = area perpendicular to wind, ft^2

p = air density, slug/ft^3

V = wind velocity, fps

In the case of a flat plate, which corresponds to one face of a square or rectangular box or package, C_N varies between 1.16 and 2.0. This variation is shown in figure 66, where a and b are the

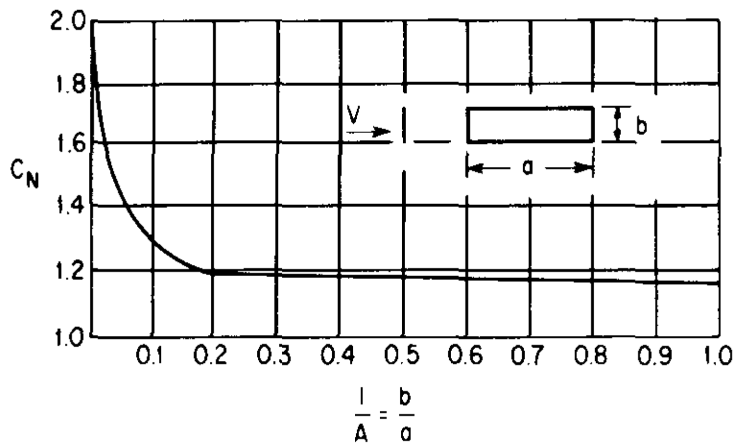


FIGURE 66. Variation of shape factor C_N5.

TABLE C. Maximum wind speeds for military design purposes.

	Ordinary(1)				Ordinary(2)			
	Steady		Gusts		Steady		Gusts	
	MPH	Knots	MPH	Knots	MPH	Knots	MPH	Knots
Portable(3)	40	(35)	60	(52)	60	(52)	90	(78)
Temporary(4)	50	(43)	75	(65)	70	(61)	105	(91)
Semipermanent(5)	65	(57)	100	(87)	80	(70)	120	(104)

The above conditions apply to a height of 10 ft above ground. For wind speed at other heights, the ratio to that at 10 ft is as follows:

Height in feet.......	2	5	10	15	25	50	75	100
Ratio to 10 ft wind..	0.71	0.89	1.00	1.07	1.13	1.24	1.29	1.32

	Steady		Gusts	
	MPH	Knots	MPH	Knots
10 ft above the water	85	75	115	100

(1) Ordinary Conditions: applies to many inland areas.
(2) Extreme Conditions: applies to mountain or coastal areas where storms of hurricane intensity occur.
(3) Life expectancy 2 yr.
(4) Life expectancy 5 yr.
(5) Life expectancy over 5 yr.

dimensions of the side or face perpendicular to the wind flow. For more intricately shaped objects, the value of C_N can be obtained from standard reference works.

5.14.2.4 Ozone. Ozone is of concern to the packaging engineer because of its harmful effects on natural rubber and synthetic elastomers. Ozone (O_3) is a form of molecular oxygen. Any high-energy input to O_2 can cause the formation of O_3. At sea level, the concentration of ozone in the atmosphere varies considerably with latitude, season of the year, local weather conditons, and availability of easily oxidizable gases, smoke, or other finely divided organic matter suspended in the air. Ozone concentrations are found to be exceptionally high when atmospheric conditions exist which favor the transmission of ozone from the upper atmosphere. Ozone is also generated by electrical equipment. Limited data exist on the regional variations of ozone concentration at the Earth's surface. Furthermore, much of the existent data are in disagreement. This is probably due to the fact that various measurements, although made at the same locations, were taken at different times and with different measuring devices. From the data available, average ozone concentration appears to vary from negligible amounts to about 0.06 part per million parts of atmosphere. At certain locations throughout the United States, much higher concentration has been recorded. Concentrations of 0.2 to 0.3 part per million parts of atmosphere are not uncommon in these areas. The region of highest ozone concentration in the United States seems to be in the area of Los Angeles, California, with concentrations as high as 0.8 part per million having been recorded.

5.14.2.5 Microorganisms. Most microbiological forms have an optimum growing temperature in the range of 59° to 95° F. (15° to 35° C.), although there are some forms that will grow at nearly 32° F. (0° C.) and others that will grow at very high temperatures. The average optimum conditions for fungi are a temperature of about 86° F. (30° C.) and a relative humidity of 95 to 100 percent. Below 70 percent relative humidity, there is little opportunity for fungal growth. Although microorganisms exist over a large part of the Earth's surface, they are only a severe environmental problem in regions possessing the right combinations of temperature and relative humidity (5.2).

5.14.2.6 Rodents and insects. Little quantitative data can be specified concerning rodents and insects as part of a package environment. This is principally because of the wide variety of types and geographic distribution of these pests. Whenever it is suspected that rodents or insects might constitute packaging problems, information can be obtained from documents such as Deterioration of Materials, Causes and Preventive Techniques. Rodents and insects are discussed in 5.2.

5.14.3 Combinations of environmental factors. Although they are dealt with individually in preceding paragraphs, the natural environmental factors do not occur singly. Inherent properties of the atmosphere--such as temperature, humidity, and pressure--are present at all times. They interact with each other as well as with other natural environments that may be present. Consequently, when considering natural environmental factors from the standpoint of their effects, the manner in which each factor alters the effects of the others must be taken into account. To analyze the practical cominations of the factors, it is best to examine them in pairs. Then any one of a pair can be paired off with another, and this process repeated to determine possible combinations. The combinations of these factors and the manner in which each combination may intensify, neutralize, or add nothing to the individual effects are:

a. High temperature and humidity. High temperature tends to increase the rate of moisture penetration. The general deterioration effects of humidity are increased by high temperatures.

b. High temperature and low pressure. Each of these environments is dependent on the other. For example, as pressure decreases, outgassing of constituents of materials increases; and as temperature increases, the rate of outgassing increases, hence, each tends to intensify the effects of the other.

c. High temperature and salt spray. High temperature tends to increase the rate of corrosion caused by salt spray.

d. High temperature and solar radiation. This is a natural combination that causes increasing effects on organic materials.

e. High temperature and fungi. A certain degree of high temperature is necessary to permit fungi and microorganisms to grow; but, above 160° F. (71° C.), fungi and microorganisms cannot develop.

f. High temperature, and sand and dust. The erosion rate of sand and dust may be accelerated by high temperature. However, high temperatures reduce sand and dust penetration.

g. Low temperature and humidity. Absolute humidity normally decreases with temperature but low temperature induces moisture condensation, and, if the temperature is low enough, frost or ice.

h. Low temperature and low pressure. This combination can accelerate leakage through seals, etc.

i. Low temperature and salt spray. Low temperature reduces the corrosion rate of salt spray.

j. Low temperature and solar radiation. Low temperature will tend to reduce the effects of solar radiation.

k. Low temperature, and sand and dust. Low temperature increases sand and dust penetration.

l. Low temperature and fungi. Low temperature reduces fungi growth. At subzero temperatures, fungi will remain in suspended animation.

m. Low temperature and ozone. Ozone effects are reduced at lower temperatures, but concentration increases with the lower temperatures.

n. Humidity and low pressure. Humidity increases the effects of low pressure, particularly in relation to electronic equipment. However, the actual effectiveness of this combination is determined largely by the temperature of the environment.

o. Humidity and salt spray. High humidity may dilute the salt concentration, but it has no bearing on the corrosive action of the salt.

p. Humidity and fungi. Humidity helps the growth of fungi and microorganisms, but adds nothing to their effects.

q. Humidity, and sand and dust. Sand and dust have a natural affinity for water, so this combination increases deterioration.

r. Humidity and solar radiation. Humidity intensifies the deteriorating effects of solar radiation on organic materials.

s. Humidity and ozone. Ozone reacts with moisture to form hydrogen peroxide which has a greater deteriorating effect on plastic and elastomers than the additive effects of moisture and ozone themselves.

t. Solar radiation and low pressure. This combination adds nothing to the overall effects.

u. Solar radiation and fungi. Because of the resulting heat from solar radiation, this combination probably produces the same combined effect as high temperature and fungi. Further, the unfiltered radiation is an effective fungicide.

v. Solar radiation and ozone. This combination increases rate of oxidation of materials.

w. Fungi and ozone. Fungi are destroyed by ozone.

5.14.4 External vs internal package environment. The conditions existing inside a closed package or container are not necessarily the same as the ambient environment. Internal package temperatures may be significantly higher than the ambient temperature and, if the package is sealed, external temperature variations result in changes in the pressure and relative humidity inside the package. To determine the internal environment of a package, an engineering analysis must be carried out. The factors involved in this analysis are the external environment, the package material and configuration, and the conditions existing inside the package at the time of packaging.

5.15 Testing and inspection. Military supplies and equipment must be protected against damage due to force and exposure. Since the prime objective of packaging is to extend the useful life span of an item, the protected item must remain in that state of protection without depreciation until it is placed into service. The paragraphs which follow illustrate the requirement for thorough and efficient inspection and test procedures.

5.15.1 Damage mechanisms.

5.15.1.1 Force. Damage may result from hazardous forces encountered in transportation, handling, and storage.

5.15.1.1.1 Transportation hazards. Transportation hazards involve forces encountered through rail, truck, boat, or air shipments. Damage can result from:

a. Abrupt starts and stops.

b. Vibration and shock.

5.15.1.1.2 Handling forces. Handling forces involve those damaging forces received through loading, unloading, and handling during storage operations. Examples of handling where damage often occurs are:

a. Manual handling - dropping and puncture.

b. Forklift truck handling - dropping and puncture.

c. Cargo nets - dropping, crushing, and wracking.

d. Grab hooks - crushing and puncture.

e. Slings - crushing, dropping, and wracking.

f. Conveyors - jarring, smashing, and dropping.

5.15.1.1.3 Storage forces. Storage forces involve those forces resulting from the crushing effect of superimposed loads through stacking.

5.15.1.2 Exposure. Exposure to the different climatic conditions and weather hazards--such as high humidity, rain, salt spray, extreme cold, dry intense heat, and the cycling of these weather conditions--will tend to accelerate the breakdown or deterioration of unprotected items. Moisture in its different forms is the main damaging factor in climatic exposure. Exposure hazards are controlled by preservation and packing of the unit, and by using water-resistant exterior containers and waterproof or watervaporproof barrier materials.

5.15.1.3 Counteraction of packs to hazards. Items which are packed properly will resist damaging effects of force and exposure.

5.15.1.3.1 Counteracting Force. Force is counteracted by:

a. Using rigid shipping containers.

b. Immobilizing the item within the container through anchoring, blocking, and bracing.

c. Damping forces through the use of cushioning materials.

d. Reinforcing shipping containers with metal and nonmetallic strappings.

5.15.1.3.2 Counteracting Exposure. Exposure is counteracted by the use of:

a. Water-resistant shipping containers.

b. Waterproof and watervaporproof barrier materials in various applications.

5.15.2 Types of tests. Testing of unit packs and exterior containers should be started as soon as possible after initiation of item development. Some of the tests most commonly used in proving design adequacy include the vibration, rough handling, and cyclic exposure tests. One or more of these tests are usually applicable to the design of military packaging. The documents most generally used for test guidance are MIL-P-116, MIL-STD-810, MIL-STD-1186, Federal Test Method Standard 101, and DOD-adopted Industry Standards, i.e., American Society for Testing and Materials (ASTM). Tests designed to evaluate the sealing and protective qualities of the packaging material, as well as the methods of packaging, are briefly outlined in the paragraphs which follow. Tests for evaluating the effectiveness of the pack and material to resist the forces of handling while maintaining their designed protective qualities are included.

5.15.2.1 Vacuum chamber technique. Package test samples will be held at ambient conditions for at least 4 hours prior to testing. The sample bag, package, or can is submerged in water contained in a vacuum vessel, up to a maximum depth of 1 inch above the sample. A vacuum is then drawn within the following limits: (1) heat-sealed packages and metal containers, 8.5 inches of mercury; and (2) rigid containers other than all metal, 5.5 inches of mercury. The minimum elapsed time for this test, while under observation for leakage of air, is 30 seconds. The sample must be inverted and tested again. Figure 67 shows the vacuum chamber test configuration. A steady or recurring succession of bubbles from any surface or seam shall be cause for rejection.

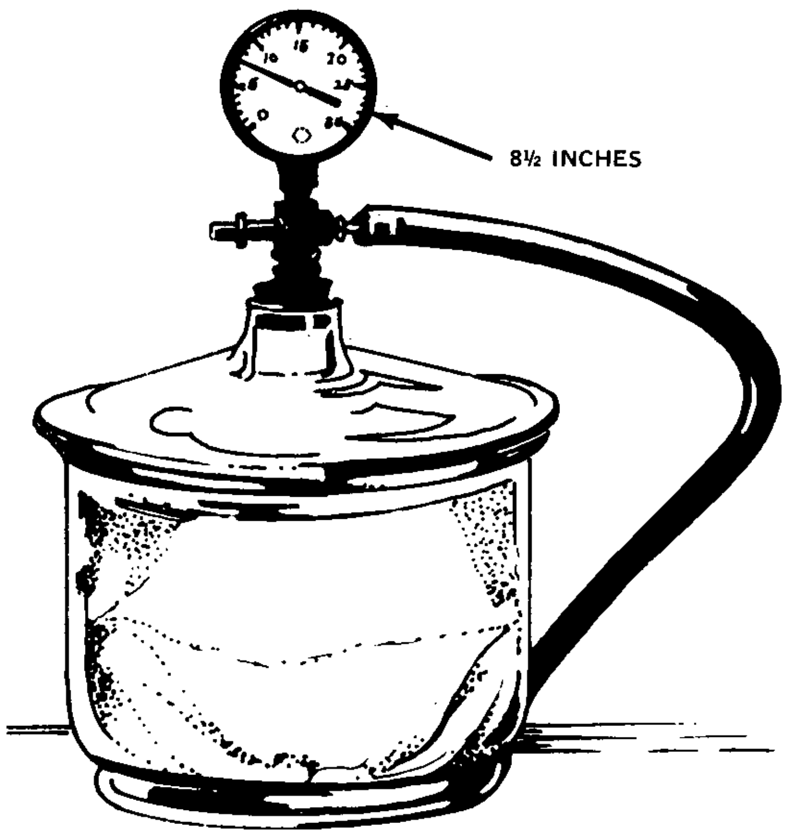
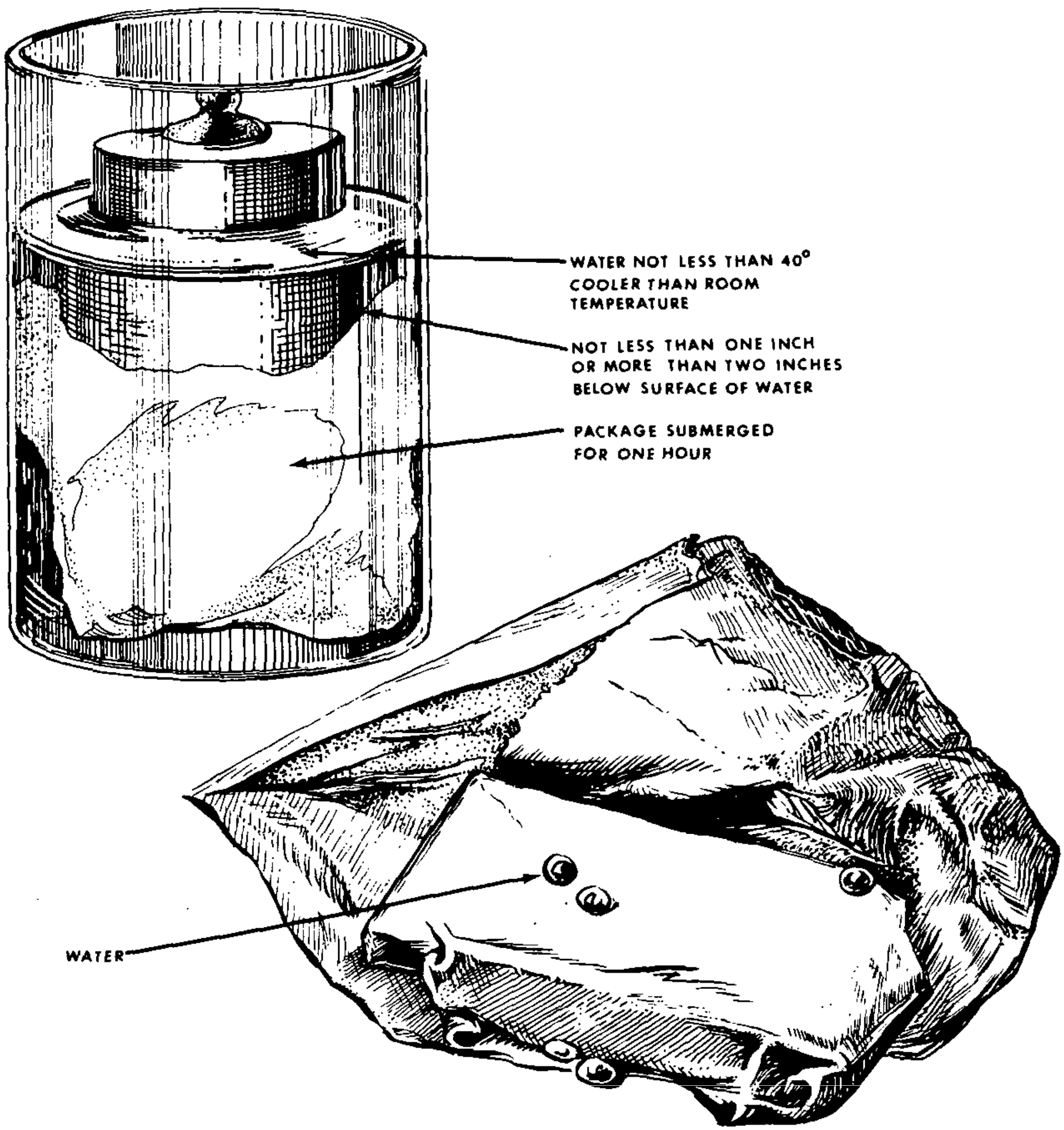


FIGURE 67. Vacuum chamber techniques for heat-sealed packages.

5.15.2.2 Hot water technique. This test procedure will be used when the size or shape of the package precludes the use of the vacuum vessel. The test sample will be held at ambient conditions for at least 4 hours prior to start of testing. The package will be immersed no more than 1 inch (25 mm) below the surface, in water which has been heated to 50° F. (10° C.) above the temperature at which the package was conditioned. The package is rotated so as to check each surface for air leakage. Observation of each seam and face of the package should be for at least 15 seconds with a total elapsed time not to exceed 8 minutes. A steady or recurring succession of bubbles from any seam or surface shall be cause for rejection.

5.15.2.3 Submersion (or immersion) technique. Completed package is conditioned at ambient conditions for at least 4 hours prior to performance of the submersion test. When conditioning has been completed, the package is immersed for 1 hour in water at a temperature approximately 40° F. (40° C.) cooler than the package. The package will be immersed in not less than 1 inch (25 mm) nor more than 2 inches below the surface of the water. After removal, the package is opened and inspected. There must be no evidence of moisture within the package. Figure 68 depicts criteria for submersion test.



EVIDENCE OF LEAKAGE

FIGURE 68. Submersion technique.

5.15.2.4 Vacuum retention technique. The flexible barrier inclosing the item will be sealed except for an opening at one end to accommodate a tube connected to a vacuum-producing apparatus. A vacuum of 5 $\pm$ 0.5 inches of water, measured by gauge or water manometer or 9 $\pm$ 1 mm of mercury, is drawn on the sealed package and the tube closed. Loss of vacuum as indicated by the measuring device will not exceed 25 percent of the original vacuum after remaining undisturbed for an elapsed time of 10 minutes. The vacuum retention test is depicted in figure 69.

5.15.2.5 Pneumatic pressure technique. Through an air connection installed in the container wall, dry air is introduced to create an internal pressure of 4- or 5-pound gauge pressure per square inch. The air supply is then closed. Any loss of gauge pressure over a 30-minute period will be cause for rejection. Evidence of leakage is detected either by loss of pressure or by observance of air bubbles either during immersion of the pressurized container in water or after coating the outer surface of the container with a water-soap solution.

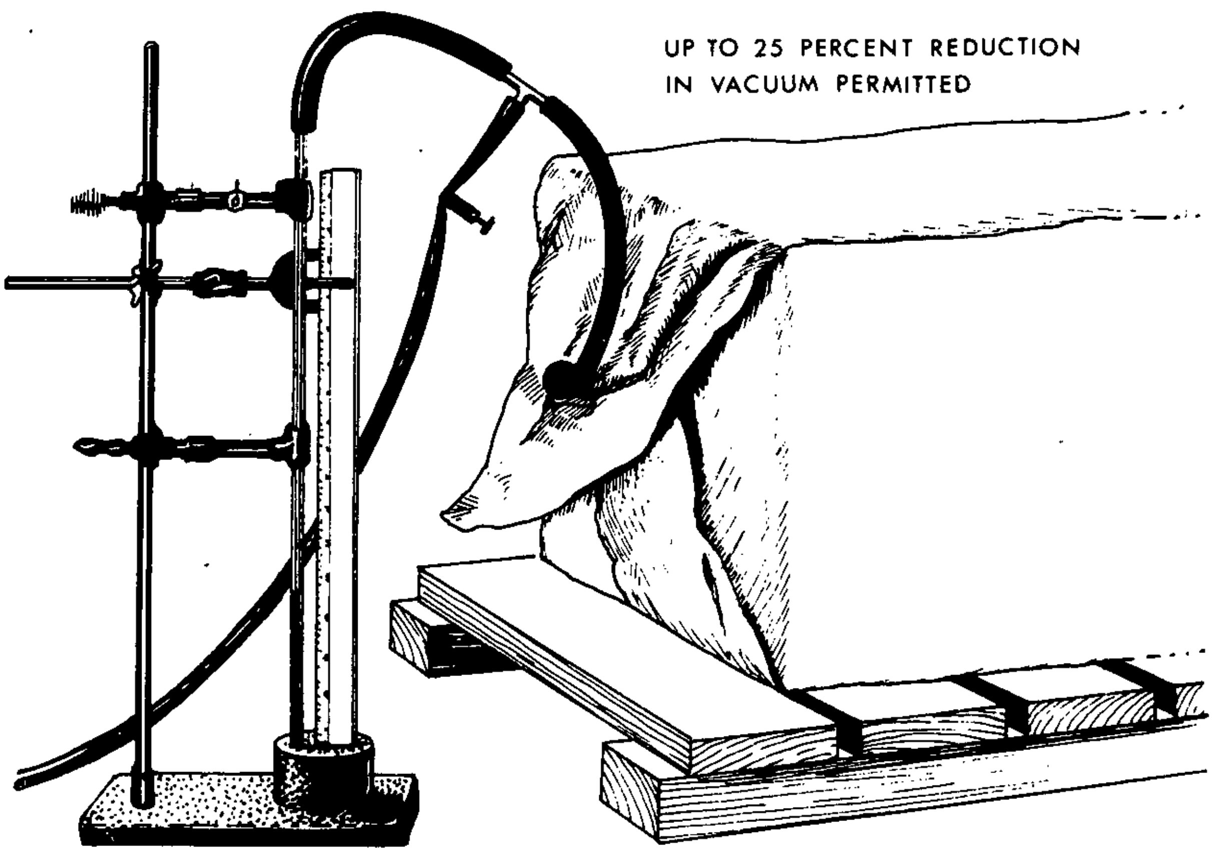


FIGURE 69. Vacuum retention technique.

5.15.2.6 Cyclic exposure test. Completed packages are given the cyclic exposure test A or B only when specified in the contract or order. Packages are allowed to stand undisturbed overnight in preparation for application of the test, and are subjected to the following continuous cycle of varying temperatures and water spray.

TEST A

Preparation for test

Overnight at 120° to 130° F.
(49° to 54° C.)

First day of test

Two hours of water spray at
50° to 60° F.
(10° to 16° C.)
Two hours at -10° to 0° F.
(-23° to -18° C.)
Two hours of water spray at
120° to 130° F.
(49° to 54° C.)
Two hours of water spray at
50° to 60° F.
(10° to 16° C.)
Overnight at 35° to 50° F.
(2° to 10° C.)

Second day of test

Four hours at 120° to 130° F.
(49° to 54° C.)
Two hours of water spray at
(50° to 60° F.
(10° to 16° C.)
Two hours at 35° to 50° F.
(2° to 10° C.)
Overnight at 120° to 130° F.
(49° to 54° C.)

TEST B

Preparation for test

Overnight at 120° to 130° F.
(49° to 54° C.)

First day of test

Two hours of water spray at
50° to 60° F.
(10° to 16° C)
Four hours at 120° to 130° F.
(49° to 54° C.)
Two hours water spray at
50° to 60° F.
(10° to 16° C.)
Overnight at 120° to 130° F.
(49° to 54° C.)

Second day of test

Same as first day

Third day of test

Same as first day

TEST A (continued)

Third day of test

Two hours of water spray at
50° to 60° F.
(10° to 16° C.)
Two hours at -10° to 0° F.
(-23° to -18° C.)
Three hours at 35° to 50° F.
(2° to 10° C.)
Overnight at 120° to 130° F.
(49° to 54° C.)

After completion of testing, the package is opened and examined. No evidence of moisture or corrosion is permitted.

5.15.2.7 Heat-seal test. Sections of the heat-seal 1 inch (25 mm) in width, cut perpendicular to the line of the seal, are taken from test specimens or package barriers. The section is then positioned between the jaws of testing clamps. A static load is applied slowly and uniformly without impact and allowed to act for a period of 5 minutes. Figure 70 illustrates the heat-seal test procedure. Partial separation of the heat-seal is acceptable within the first 2 minutes of the test to allow areas of partial fusion adjacent to the actual seal to pull apart. Delamination of laminated barrier material after application of the static load will be cause for rejection. Any separation of the heat sealed area during the final 3 minutes of the test will be cause for rejection.

5.15.2.8 Rough handling tests. The rough handling tests listed in table CI will be conducted in accordance with the applicable test methods. Graduated drop and impact test heights will be listed in table CII. The particular tests employed usually depend upon the size, shape, and weight of the package. Completed packages as prepared for shipment are given the rough handling test when specified by contract or order. If the rough handling tests should be required, they will precede applicable tests specified to detect leaks, inadequate seals or closures, and preservation retention. Refer to figure 71 for the rough handling tests described in subsequent paragraphs. Applicable specifications should be consulted for details involving specific tests such as construction of test media, measurements, etc.

5.15.2.8.1 Vibration test. Test packs are vibration tested on standard packaging laboratory vibration machines. The machines are variable in adjustment allowing control of the speed or number of cycles per minute, the amplitude, and the type of motion desired. The duration of the test and the procedures for accomplishment are specified in ASTM Test Method D-999 and

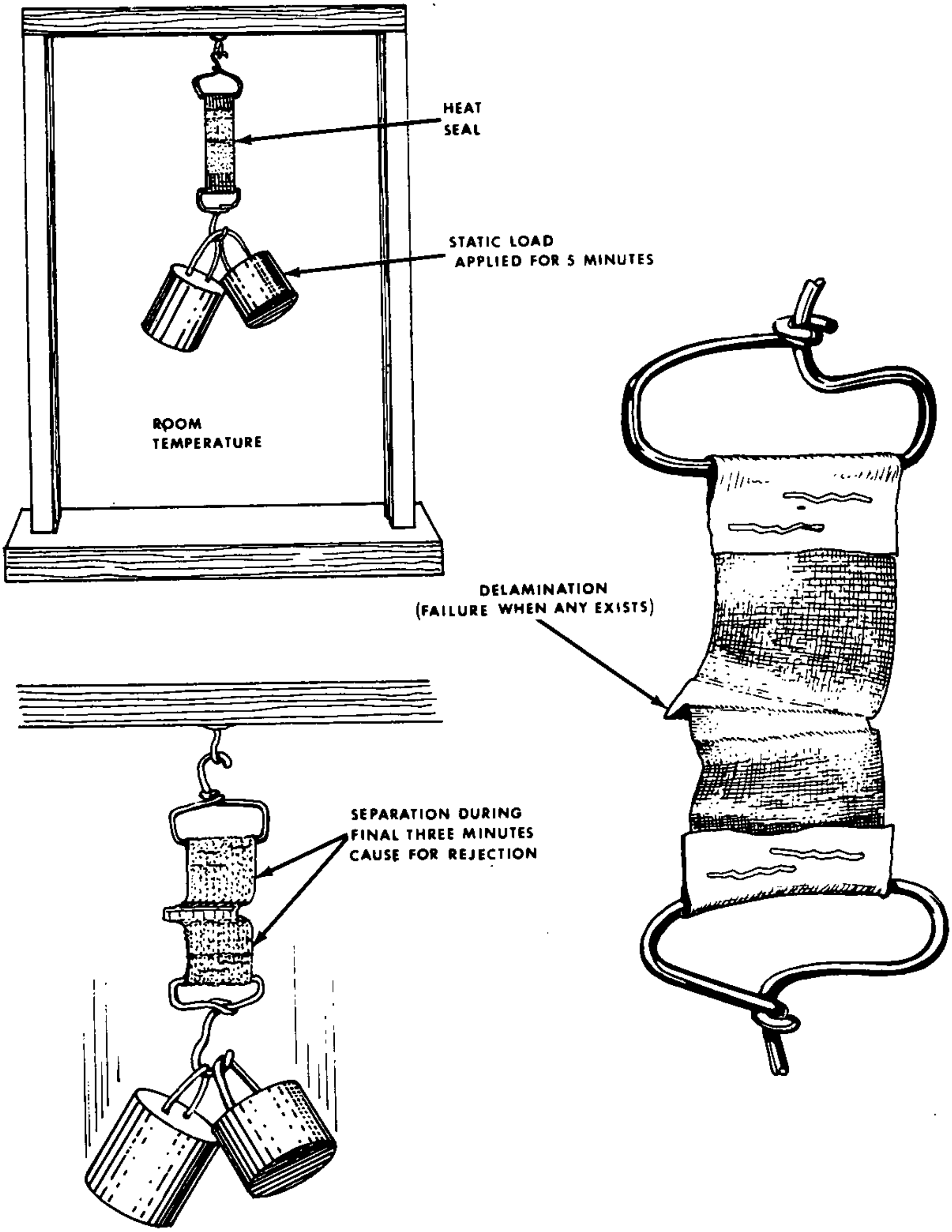


FIGURE 70. Heat-seal test.

TABLE CI. Rough handling tests.

Vibration Test Compression test Incline-impact test Revolving drum test Drop test (free-fall)	Edgewise-drop test Cornerwise-drop test Pendulum-impact test Simulated contents test

TABLE CII. Graduated drop and impact test heights.

Gross weight of container and contents	Edgewise-drop test (2 drops each end)	Cornerwise-drop test (2 drops on each of 2 diagonally opposite corners of bottom)	Impact test (1 impact on each of 2 opposite ends) use either test	
Pounds	Height of drop, (in.)	Height of drop, (in.)	Pendulum drop (in.)	Incline impact (ft)
150 through 250	30	30	14	7.0
Over 250 through 500	24	24	11	5.5
Over 500 through 1,000	18	18	8	4.0
Over 1,000	12	12	5	2.5

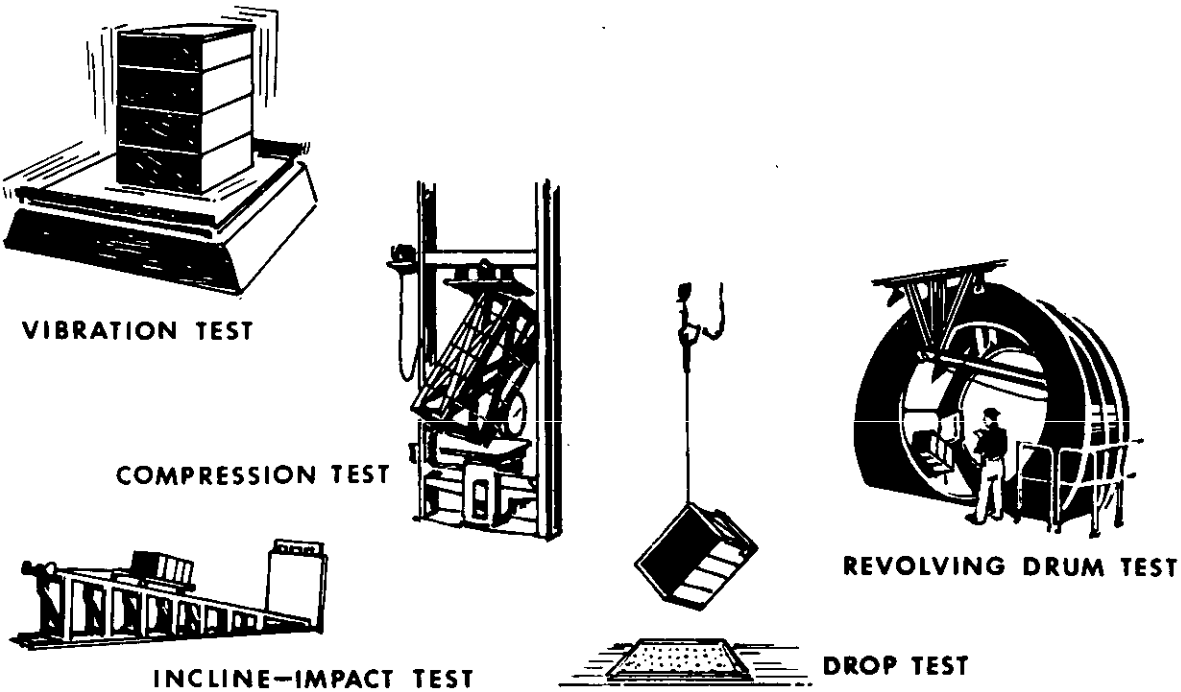


FIGURE 71. Examples of container tests.

FED-STD-101, Methods 5019 and 5020. The effects of testing will frequently produce deterioration or partial crushing of the unit or interior packaging which reduces resistance to other shocks, such as impact from dropping, jolting, or bumping. This may also disclose weakness in assembly of the packed item. The tests simulate the forces and motions peculiar to railroad cars, motor trucks, aircraft, coolies, pack-saddles, etc. Both the item and the container shock mitigation systems and susceptibility to vibration-induced damage must be considered. MIL-STD-810 and MIL-STD-1186, which are primarily concerned with the background item, should be consulted for additional guidance.

5.15.2.8.2 Compression test. The compression test, when accomplished in accordance with ASTM Test Method D-642, provides information for measuring the ability of a container to resist external compressive loads applied to its faces, and the ability of a container to resist external compressive loads applied to diagonally opposite edges or corners. The containers are usually void of content during testing. These test procedures are suitable for boxes, crates, barrels, drums, kegs, and pails made of metal, wood, plastic, fiberboard, and combinations of these materials. This test is in accordance with FED-STD-101, Method 5013.

5.15.2.8.3 Incline-impact test. Test packs are mounted on a movable platform dolly which rides down a plane inclined 10 degrees and strikes a fixed hard backstop. The dolly is released from a predetermined distance from the backstop and allowed to free-travel the distance down the incline. The impact shock is transmitted through the dolly to the package and simulates abuses encountered in freight cars or trucks when the vehicles are subjected to sudden starts or stops. The magnitude of impact shocks are varied by the use of different release points along the incline. FED-STD-101, Method 5023, specified testing procedures for packs subjected to this test. The procedures for accomplishment are also specified in ASTM Test Method D-880.

5.15.2.8.4 Revolving drum test. This test involves the use of a hexagonally shaped revolving drum 7 or 14 feet in diameter. The item being tested is inserted into the drum and allowed to tumble and slide. Any weakness of the item can be determined due to this simulated rough handling test. It may also be used as a comparison of containers and alternate containers or for comparing banded versus unbanded containers. The procedures for accomplishment are also specified in ASTM Test Method D-782.

5.15.2.8.5 Drop test (free-fall). The free-fall drop test should allow a free unobstructed fall of the container at the orientation and direction desired. The lifting or holding device must not damage or weaken the container and a level steel or cement surface will be provided to absorb all shock without displacement. Weight, size, level of pack, and kind of container shall determine the height from which the item is dropped. Test Method 5007 of FED-STD-101 must be consulted for proper procedure. The drop test depicted in figure 72 is primarily used to simulate the fall of an item dropped by personnel from a height they would normally use to lift and carry an item of that size. The container is dropped from a height of 30 inches systematically on all corners. In the event the container is a drum, barrel, or keg, the ends are marked off in quarters for application of the test to each section. The procedures for accomplishment are also specified in ASTM Test Methods D-777 and D-1083.

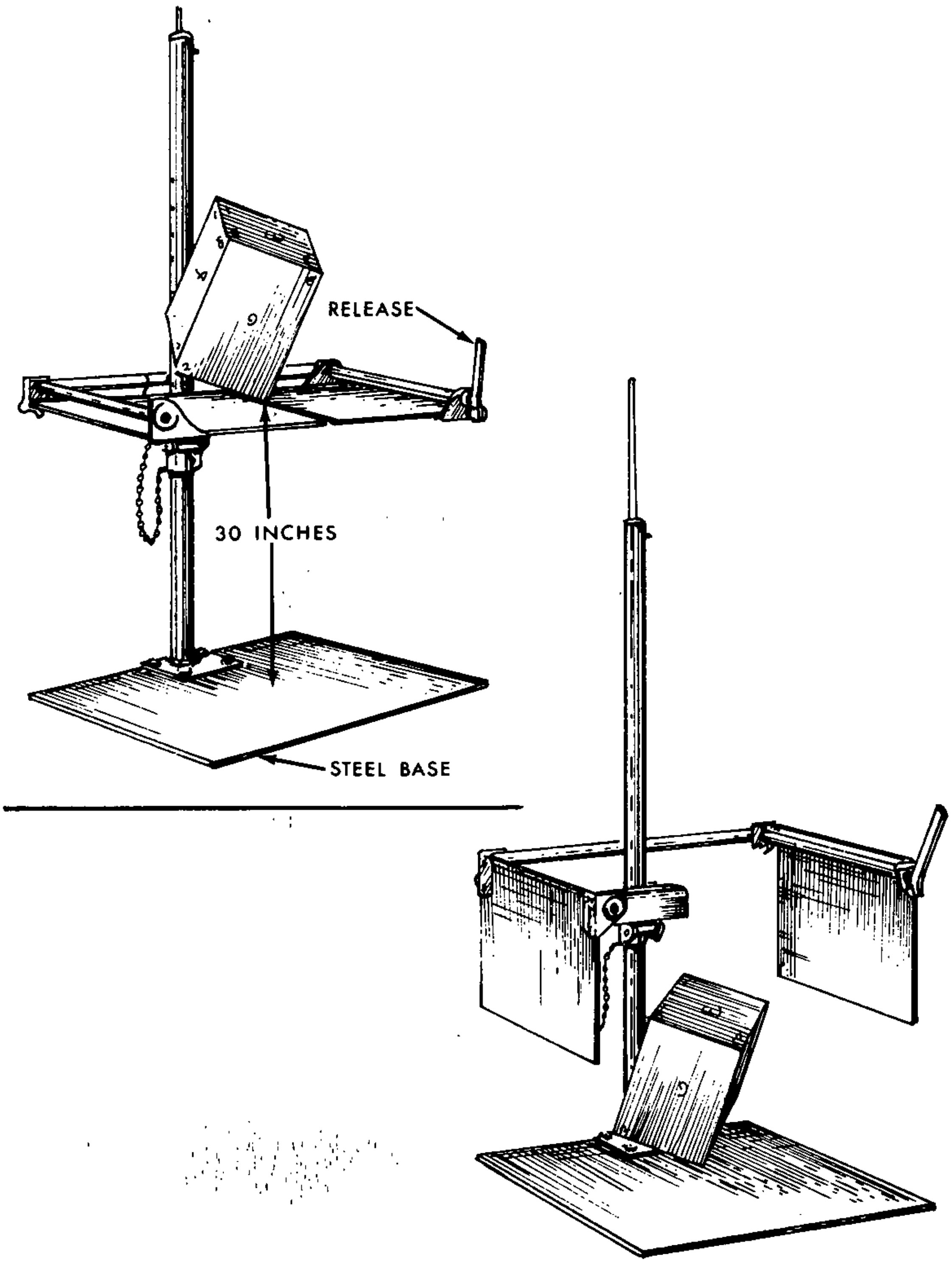


FIGURE 72. Free-fall drop test.

5.15.2.8.6 Edgewise drop test. The test illustrated in figure 73 should be accomplished in accordance with Test Method 5008, FED-STD-101. The container is placed on one edge and is allowed to freely fall the height as indicated in table CII. The drop surface should be steel, concrete, or stone and of sufficient mass to absorb shock without deflection. The test is applied twice to opposite ends of the container. If the size of the container and the location of the center of gravity are such that the drop tests cannot be made from the prescribed height, the height of the drops should be the greatest obtainable. Test procedures are also specified in ASTM Test Method D-775.

5.15.2.8.7 Cornerwise drop test. Packs are tested in accordance with Test Method 5005 of FED-STD-101. The pack is supported at one corner by a block 5 inches in height and another block at the other corner of the same side 12 inches in height. The lowest point is rested to a height as specified in table CII and then allowed to fall freely. The drop surface should be steel, concrete, or stone and of sufficient mass to absorb shock without deflection. The block positions are indicated in figure 74. If, because of size or shape, the test cannot be conducted properly, the edgewise test as described in 5.15.2.8.6 may be substituted.

5.15.2.8.8 Pendulum impact test. The test as depicted in figure 75 is conducted in accordance with Test Method 5012, FED-STD-101. The container is swung as a pendulum against a nominal 8- by 8-inch or larger timber resting horizontally on the floor, and securely blocked and fastened to prevent any movement. Table CII indicates the height-weight ratio for this test. The opposite end should also be subjected to one impact. Specifications in relation to rigging and suspension may be found in Test Method 5012, FED-STD-101.

5.15.2.8.9 Rail impact test. The test shall be accomplished in accordance with appendix A of MIL-STD-1186. The test is primarily for large items that, when shipped by rail, would be secured directly to the rail car floor.

5.15.2.9 Determination of preservative retention. Samples will be examined, where applicable, for retention of the preservative compounds. Evidence of failure of the item to retain compound, or evidence of corrosion--particularly at points of contact of the item with the barrier--will be cause for rejection.

5.15.3 Environmental container testing. In addition to the tests of unit protection, containers may be exposed to laboratory simulated environmental extremes. Before any of these tests are specified, the logistic pattern of the packaged item should be studied, if possible, to be sure that an actual requirement exists.

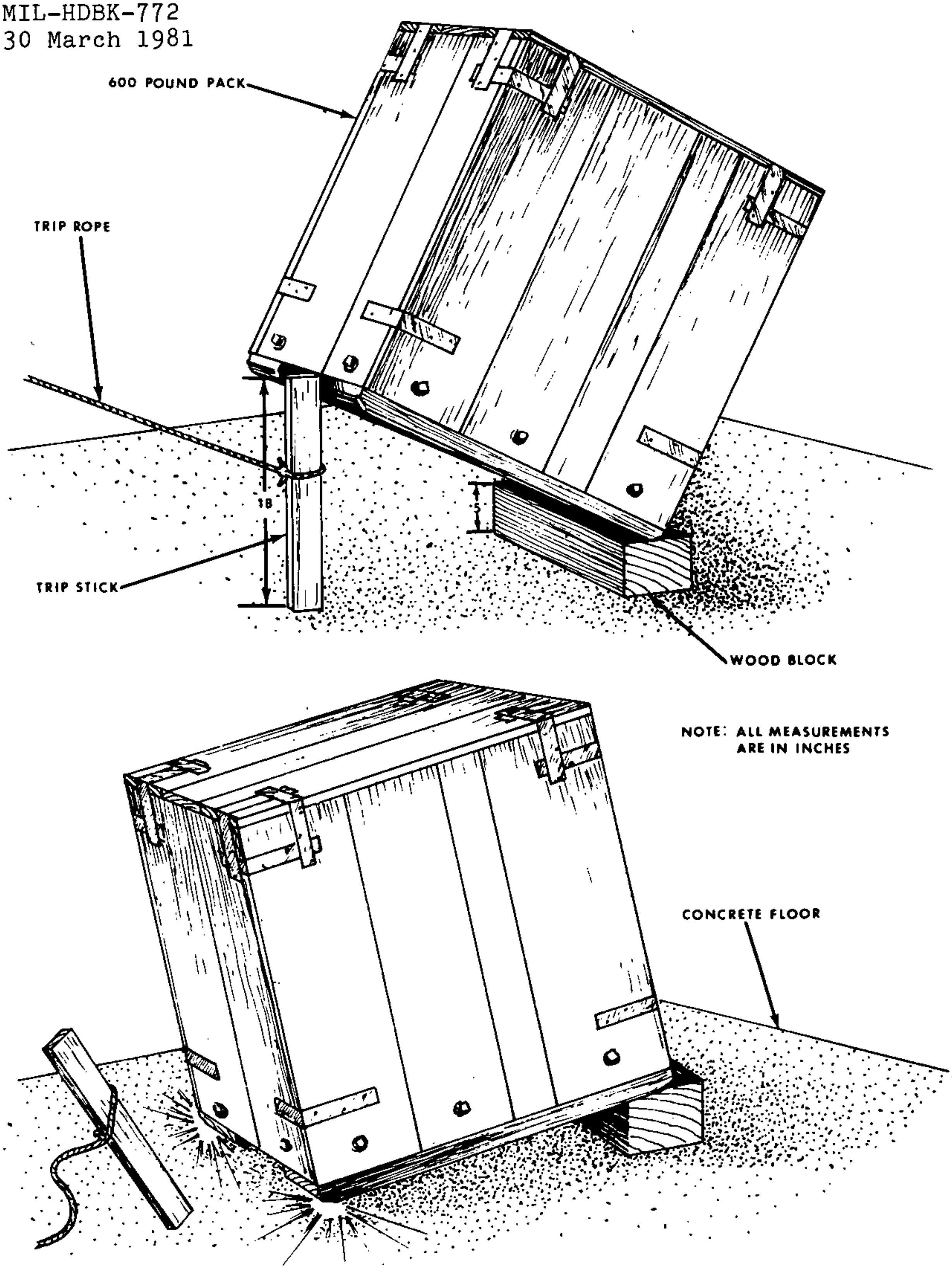


FIGURE 73. Edgewise drop test.

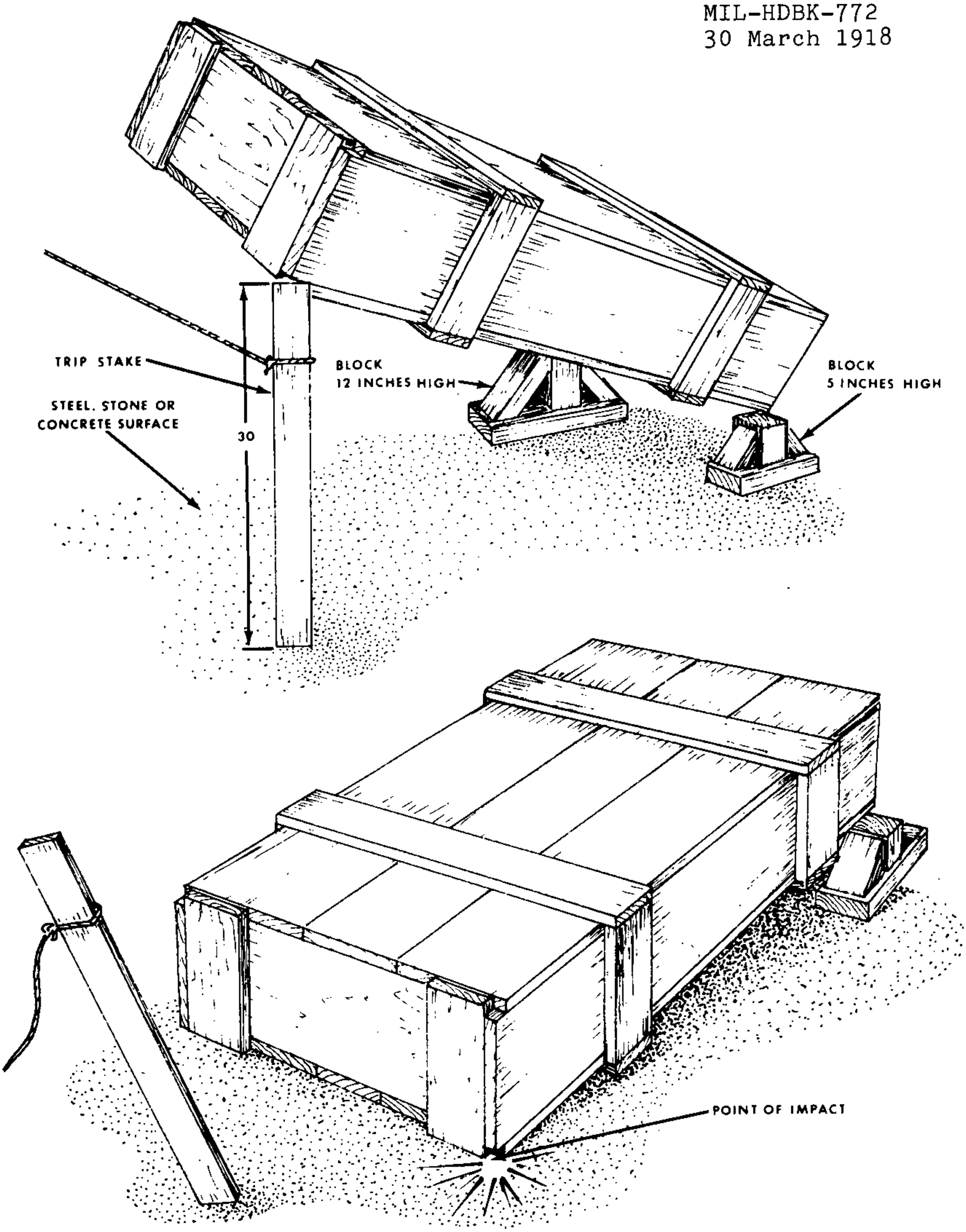


FIGURE 74. Cornerwise drop test.

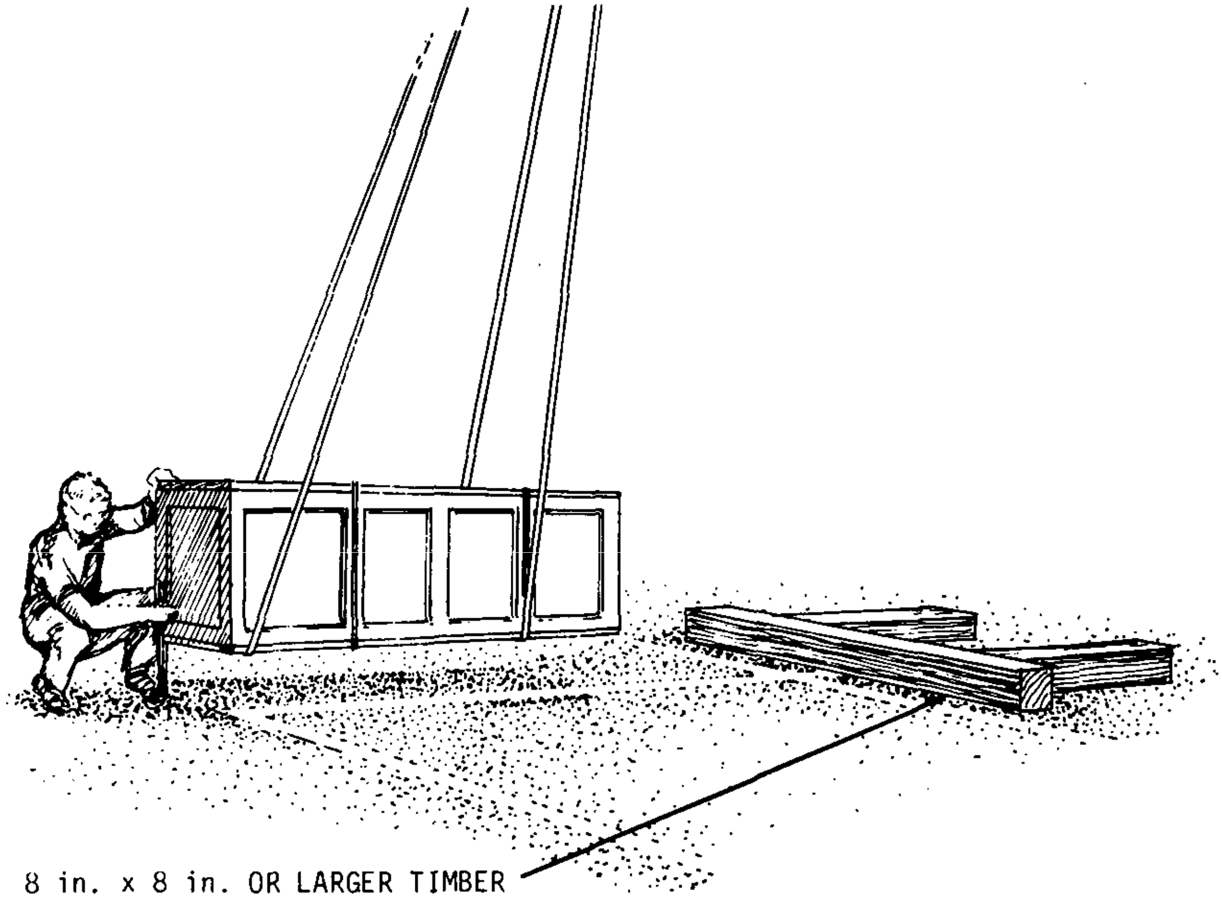


FIGURE 75. Pendulum impact test.

The value of some of the tests described may be questionable because, theoretically, a properly sealed container should require no additional information on the container's ability to protect its contents.

5.15.3.1 Salt spray. This test requires exposure of the container to a spray of fog of concentrated saline solution for at least 48 hours. The test is intended to prove the ability of a container to withstand, and to protect its contents from, corrosive salt atmospheres. It is frequently used when there is some doubt as to the resistance of untried materials or finishes to corrosive salt atmospheres.

5.15.3.2 Sand and dust. In this test, the container is exposed to a mixture of sand and dust moving at velocities of 100 to 2,500 feet per minute in a dry atmosphere. The purpose is to simulate sandstorm conditions. The test can be useful for unsealed containers with interior suspension systems or cushioning that may be damaged by sand and dust accumulations. The test can also be useful for sealed containers in evaluating exterior functional components and moving parts.

5.15.3.3 Humidity. This test is designed to simulate the hot humid conditons of the tropics, but test conditions are more severe than those encountered in nature. The purpose of the test is to determine the ability of the mateials, finishes, and components to resist deterioration and to function properly under extremely humid conditions.

5.15.3.4 Rain. The purpose of this test is to determine the effectiveness of covers or cases used to shield the contents from the elements. The rain test is useful for covered, but unsealed, containers.

5.15.3.5 Temperature extremes. High and low temperature tests are conducted to determine the effects of extreme temperatures on the parts and operation of the container. It is frequently required that shock and vibration tests be conducted at the extreme operating temperature.

5.15.3.6 Altitude. This test is primarily used to determine the ability of the container to withstand large, sometimes rapid, changes in differential pressure such as would develop during ascent or descent in unpressurized aircraft. An altitude test may also be used to determine the ability of a container to operate satisfactorily in mountainous regions where the atmospheric pressure is low.

5.15.3.7 Fungi. The purpose of this test is to determine resistance to fungi that attack most organic and some inorganic substances. This test is unnecessary for complete containers because the resistance of most materials and finishes to fungi is already known. If new or untried materials or finishes are used, the test may be conducted on samples of the materials or finishes.

5.15.4 Simulated contents. In order to avoid unnecessary damage or destruction of valuable commodities and to avoid possible hazards to personnel conducting the rough handling tests, simulated contents of the same dimensions, weight, and physical properties as the actual contents may, at the discretion of the procuring agency, be substituted in the tests. Also, a shock-recording instrument of an acceptable type should be appropiately installed within the shipping container being tested.

5.15.5 Disposition of samples after test and inspection. All samples used for inspection and tests will be reprocessed as necessary. They may, after reprocessing in accordance with the original method of preservation and packing, be considered a part of the original lot. When the packaged item may have been damaged as a result of testing, it will be inspected and, if required, operationally checked, as necessary, for determination of its serviceability.

5.15.6 Interpretation of results. The previous paragraphs have briefly described a number of methods that have been devised for subjecting containers and packaging to hazards similar to those encountered in the field. Both laboratory and field testing are necessary since there are certain conditions inherent in each method of testing that cannot be duplicated in the other. Because containers in the storage and shipment cycle are subjected to various and constantly changing storage and shipping hazards, it is difficult to develop complete data for their design by merely observing the containers in service. Examinations of failures will reveal the weaknesses and suggest the specific principles of design to overcome such failures. However, laboratory tests are necessary to simulate field hazards since service tests are not performed under controlled conditions. Each test has been designed to reproduce one or more of the stresses and environmental hazards encountered in the field. Evaluations of all test results will provide the data necessary to produce balanced packaging, construction, and workmanship. All materials and components which comprise the method of preservation and packaging must be free from damage or evidence of displacement, and there should be no evidence of failure on part of the item in retaining preservation compounds.

5.16 Limitations imposed by distribution system. This section describes the limitations placed on a packaged item by the logistic and distribution pattern of the supply system through which the package moves. A listing of the Government and commercial agencies that regulate the shipment of the package is provided to aid the packaging engineer in meeting all the applicable regulations. The limitations imposed during the transportation, storage, and handling of the package as they govern the design of the overall package are discussed. The determination of the quantity per unit package and types of procurement as they affect the packaging engineer are also discussed.

5.16.1 Regulating agencies. Regulations have been formulated by Government and commercial agencies to insure safety in handling, storage, and transit of packaged items and to reduce damage to a minimum. The established Government rules/policies may be found in appropriate Federal tariffs, such as the DOT regulations, and in related military regulations and standards. The regulations of the commercial carriers may be found in the official publications of these agencies. The regulating agencies are covered separately below. In addition to the individual regulations prescribed by the various regulating agencies, separate regulations appropriate to all carriers have been established for explosive and dangerous materials. These regulations incorporate the specific regulations of the agencies concerned with the preservation, packing, transportation, and dispatch of dangerous materials. The following publications apply to the preservation, packing, marking, and transportation of dangerous and hazardous materials:

a. Code of Federal Regulations, Title 49-Transportation, Parts 170 to 190, Superintendent of Documents, US Government Printing Office, Washington, DC 20402. DOT regulations for the preparation of explosives and other dangerous materials for transportation by rail freight, rail express, rail baggage, water and common, contract, or private carrier on public highways. Includes commodity list of articles, container specifications, packing instructions, marking requirements, billing and shipping forms, and required inspection procedures.

b. Code of Federal Regulations, Title 46-Shipping, Part 146. Superintendent of Documents, US Government Printing Office, Washington, DC 20402. DOT regulations for transportation of explosives and other dangerous materials by water.

c. CG 108, Rules and Regulations for Military Explosive and Hazardous Materials, Superintendent of Documents, Government Printing Office, Washington, DC 20402. Regulation promotes safety in the handling, stowage, and transportation of military explosives aboard vessels on any navigable waters within the limits of the jurisdiction of the United States including its territories and possessions, except the Panama Canal Zone. Increases effectiveness of the International Convention for the Safety of Life at Sea, 1960, relative to the carriage of dangerous goods.

d. AFR 71-9/TM 38-250/NAVSUP PUB 505 (Rev)/MCO P4030.19D/DLAM 4145.3, Preparation of Hazardous Materials for Military Air Shipment. Regulates the preparation, packing, marking, labeling, handling, data/certification, and stowing of explosives and other dangerous materials being shipped by military aircraft.

e. Explosive Pamphlet No. 6, Bureau of Explosives, Association of American Railroads, 1920 L Street, NW, Washington, DC 20036. Illustrates methods for loading and bracing carload (CL) and less-than-carload (LCL) shipments of explosives and other dangerous materials to conform with DOT regulations for the transportation of explosives and other dangerous articles.

f. Explosive Pamphlet No. 6A, Bureau of Explosives, Association of American Railroads, 1920 L Street, NW, Washington, DC 20036. Illustrates methods for loading and bracing CL and LCL shipments of loaded projectiles, bombs, etc., to conform with DOT regulations for the transportation of explosives and other dangerous articles.

g. Explosive Pamphlet No. 6C, Bureau of Explosives, Association of American Railroads, 1920 L Street, NW, Washington, DC 20036. Illustrates approved methods for loading and bracing trailers and less-than-trailer shipments of explosives and other dangerous articles via trailer-on-flatcar (TOFC) or container-on-flatcar (COFC) to conform with DOT regulations for the transportation of explosives and other dangerous articles.

h. US Postal Laws, Postal Services Publication 11, US Postal Service, Washington, DC 20260. Contains regulations governing the shipment of explosive and radioactive material in the US mails.

i. Restricted Articles Regulations, International Air Transport Association, 500 Fifth Avenue, NY, NY 10036. Lists the conditions under which the various airlines will accept explosives and other dangerous materials for air transportation.

j. Dangerous and Explosive Articles Tariffs, National Classification Board, 1616 P Street, NW, Washington, DC 20036. Contains applicable DOT regulations relating to the transportation of dangerous and explosive articles by motor freight.

5.16.1.1 Departments of Defense, Army, Navy, and Air Force; the Marine Corps; and the Defense Logistics Agency. The Departments of Defense, Army, Navy, and Air Force; the Marine Corps; and the Defense Logistics Agency, regulate all items of military materiel and equipment during design, engineering, and construction so that the quantities of the final product required for military use can be efficiently transported by available modes of transportation. The policy and criteria of the Department of Defense with respect to the transportability of items of materiel are given in Department of Defense Engineering for Transportability, AR 70-44/OPNAVINST 4600.22B/AFR 80-18/MCO 4610.14C/ DLAR 4500.25.

5.16.1.2 Department of Transportation. The Department of Transportation (DOT) regulates all common carriers engaged in transportation in interstate commerce and in foreign commerce that takes place within the United States. The DOT is authorized to promote safe, adequate, economical, and efficient service; to foster sound economic conditions in transportation and among the several carriers; and to encourage establishment and maintenance of reasonable charges for transportation services, without unjust discrimination, undue preferences or advantages, or unfair or destructive competitive practices. The DOD also acts as the liaison agency between states to insure uniformity in state regulations. The DOT is concerned principally with developing, coordinating, and preserving a national transportation system by water, highway, rail, and other means that is adequate to meet the needs of the commerce of the United States. The regulations of the DOT are contained both in Government and commercial publications.

5.16.1.2.1 Government publications. The title and contents of the Government publications are:

a. Interstate Commerce Acts Annotated Supplements, Superintendent of Documents, US Government Printing Office, Washington, DC 20402. Contains a compilation of Federal laws relating to the regulations of carriers subject to the Interstate Commerce Act, with digests of pertinent decisions of the Federal Courts and the DOT, and the text of, or reference to, general rules and regulations.

b. Code of Federal Regulations, Title 49-Transportation, Parts 100 to 199, Superintendent of Documents, US Government Printing Office, Washington, DC 20402. Contains all the Federal laws relating to transportation including shipping, transportation, and storage regulations.

5.16.1.2.2 Commercial publications. The regulations of the DOT may also be found in the following commercial publications:

a. Bureau of Explosives Tariff No. BOE-6000, Association of American Railroads, Transportation Building, Washington, DC 20006. An up-to-date version of Code of Federal Regulations, Title 49-Transportation, and CG 108. Note: CG 108 incorporated into Section 146 of Tariff 31.

b. Uniform Freight Classifications, Uniform Classification Committee, Room 1106, 222 S. Riverside Plaza, Chicago, IL 60606. Contains a list of CL and LCL ratings, participating carriers and terminals, and 60 rules and regulations for packaging various commodities.

5.16.1.3 United States Postal Service. The Postal Service regulates all postal material and its shipment including the admissibility, the collection, the processing, the dispatch, and the delivery of mail. The regulations of the Postal Service are contained in both Government and numerous commercial publications. The titles and contents of the Government publications are:

a. US Postal Service Manual, US Postal Service, 475 L'Enfant Plaza West, SW, Washington, DC 20260. Explains the services available, and prescribes the rates, the fees, and the conditions under which postal services are available to the public for domestic and international use.

b. US Domestic Mail Manual (DMM), US Postal Service, 475 L'Enfant Plaza West, SW, Washington, DC 20260. Contains all regulations which affect public use of domestic mail service, including rates, fees, classification, and physical limitations.

c. US Postal Laws, Publication 11, July 1968, US Postal Service, 475 L'Enfant Plaza West, SW, Washington, DC 20260. Consists of a compilation of laws affecting the Postal Service. Contains all of Title 39 of the Code of Federal Regulations, as well as pertinent parts of Titles 2, 5, 6, 7, 15, 16, 17, 18, 22, 26, 28, 31, 38, 40, 41, 45, 48, 49, and 50.

d. Code of Federal Regulations, Title 39-Postal Service, Superintendent of Documents, US Government Printing Office, Washington, DC 20402. Contains a majority of the laws affecting postal service.

e. Directory of International Mail, US Postal Service, 475 L'Enfant Plaza West, SW, Washington, DC 20260. Contains detailed information about postage rates, services available, prohibitions, import restrictions, and other conditions governing mail to other countries. Countries are listed alphabetically, with the specific requirements applicable to the mail sent to each country. The regulations of the Postal Service may also be found in Leonard's Guide, Parcel Post and Express Freight, issued for each principal city in the United States. This guide contains information on domestic and international postal regulations along with an alphabetical index of parcel post zones by state and city or town.

5.16.1.4 United States Coast Guard. The functions of the Coast Guard embrace, in general terms, saving and protecting life and property; maritime law enforcement, providing navigational aids to maritime commerce and to transoceanic air commerce; promoting the efficiency and safety of the American Merchant Marine; and readiness for military operations. The Coast Guard is charged with the enforcement or assistance of enforcement of all applicable Federal laws upon the high seas and waters subject to the jurisdiction of the United States. The Coast Guard publishes regulations and educational pamphlets dealing with navigation, safety, and inspecion of vessels. CG 108, Rules and Regulations for Military Explosives and Hazardous Materials, covers hazardous materials and is similar to Code of Federal Regulations, Title 49-Transportation, Parts 170 to 190, and Bureau of Explosives Tariff No. BOE-6000. The majority of Coast Guard regulations can be found in Code of Federal Regulations, Title 46-Shipping, Chapter 1, 1968, Superintendent of Documents, US Government Printing Office, Washington, DC 20402.

5.16.1.5 American Trucking Association. The National Freight Traffic Association, Inc., publishes ratings, rules, and regulations for the transportation of materiel by motor carrier. These requirements can be found in the National Motor Freight Classification and are in addition to the Government regulations. The Association's guidance does not cover loading, blocking, or bracing of commodities for highway transportation. For information, the applicable military specification should be consulted. The National Motor Freight Classification can be obtained from the National Classification Board, 1616 P Street, NW, Washington, DC 20036.

5.16.1.6 Association of American Railroads (AAR). The AAR establishes rules for transportation of materiel by rail. These rules can be found in the publications of the Freight Loading and Container Section and the Mechanics Division of the AAR. An index of these publications can be obtained on request from the Secretary, Freight Loading and Container Bureau, AAR, 59 East Van Buren Street, Chicago, IL 60606.

5.16.1.7 Civil Aeronautics Board and Federal Aviation Agency. The Civil Aeronautics Board (CAB) and the Federal Aviation Agency (FAA) regulate all phases of air commerce. The CAB is responsible for the economic regulations of air carriers, establishment and control of international civil aviation within the United States, and the promotion of safety in civil aviation. The FAA is responsible for originating safety regulations, the promotion of civil aviation through research and development, the establishment and operation of air navigation facilities, air traffic management, and encouragement of civil aviation abroad. The regulations of the CAB and FAA are contained in both Government and numerous commercial publications. Chapters I, II, III, and V of Code of Federal Regulations, Title 4-Aeronautics and Space, 1968, (Superintendent of Documents, US Government Printing Office, Washington, DC 20402) makes reference to FAA regulations, CAB regulations, and NAS regulations.

5.16.1.8 Federal Maritime Board and Maritime Administration. The Federal Maritime Board is responsible for the regulation and control of rates, services, practices, agreements of common carriers by water including rates, fares, classifications, tariffs and practices, and shipping in foreign trade. The Federal Maritime Board also investigates discriminatory practices, and subsidizes ship construction. The Maritime Administration is charged with the administration and execution of shipbuilding, shipping, port development, and other programs authorized by law. Many of its actions are based on decisions made by the Federal Maritime Board. The rules and regulations of the Federal Maritime Board and Maritime Administration are contained in Code of Federal Regulations, Title 46-Shipping, Chapters II, III, and IV, Superintendent of Documents, US Government Printing Office, Washington, DC 20402.

5.16.2 Transport limitations. In a majority of cases, the packaging engineer must design the package without full knowledge of the conditions and forces to which the packaged item will be exposed while it is being transported. Military forces deployed throughout the world can be supplied by truck, railroad, ship, and aircraft. While in transit, the packaged item is handled many times between manufacturing facility, storage activity, and from one mode of transportation to another until it finally reaches the ultimate user. Modern equipment for handling supplies is still not available in many areas, and thus it is not uncommon to unload supplies by hand. Primitive forms of transportation--such as animals, bicycles, and humans--are sometimes necessary in remote and inaccessible places. The packaging engineer must be concerned with all these limitations imposed by the transportation system to insure that the packaged item reaches its destination safely. The constraints imposed on the shipping containers, applicable to each transportation mode, or intermodal cargo, are described in MIL-STD-1366. Other design limitations are referenced in MIL-A-8421 and MIL-HDBK-157.

5.16.3 Quantity per unit pack (QUP). The QUP is established by the managing activity. The unit of issue is usually established by the supply support requesting activity. This information then permits the packaging personnel to assign the QUP based upon this unit of issue. The assigned unit of issue established for a particular item name is based on considerations assigned in the following order: (1) common commercial practice, (2) requirements of using personnel, and (3) usability in supply system. The packaging engineer must take into consideration these basic requirements prior to any planning in the design of the unit pack. Also, the following criteria must be considered in relation to the QUP:

a. Items assigned a unit of issue stated in terms of length or weight--such as foot, yard, ounce, etc.--are usually assigned a QUP of "bulk."

b. Items classified collection-type--such as kits, bags of hardware, and sets--are assigned a QUP of "1."

c. All other items are assigned a QUP in accordance with overall supply effectiveness and economy taking into consideration the following as applicable:

(1) QUP prescribed in fully coordinated military or Federal specifications for the items.

(2) Guidelines established by existing specifications for similar type items.

(3) Chemical and physical characteristics including weight and size of item, construction and functional aspects, and the fragility and critical or noncritical nature of the items.

(4) Retail commercial practices for similar items.

(5) Requirements for given items at the using echelon based upon available supply management data.

(6) Mortality of the item(s).

(7) Quantities to afford ease of accountability and maintenance of items in the military supply system, including uniform quantities for inventory and storage.

(8) Unit cost of item (excluding packaging cost) in accordance with the following guidelines:

Unit Cost	QUP
Up to and including $.10	100
$.10 to $.25	50
$.25 to $.50	25
$.50 to $1.00	10
$1.00 to $1.01 and up	1

5.16.4 Storage limitations. After manufacture, the packaged item usually remains in storage until it is needed. While in storage, the item must be protected from the adverse effects of the natural environment. Some natural storage spaces, such as cool, dry caves, provide ideal long-term storage for most items. However, man-made structures are the most common means for storing materiel since natural shelters are not commonly found. In some areas, no protection is available and the item must be stored outside. The limitations imposed on the package by the types of storage, the required care and maintenance, the time in storage and item shelf life, the standard layout and dimensions for stored materiel, and the stacking requirements are described separately in 5.16.4.1 through 5.16.4.5.

5.16.4.1 Types of storage. All military materiel must be packaged so that it is capable of withstanding the effects of extreme environmental conditions during storage. The various types of storage that the packaging engineer must contend with are controlled humidity or equivalent rating when such rating has been approved by higher authority (inspection frequency - 60 months), controlled temperature warehouse (inspection frequency - 30 months), noncontrolled temperature warehouse (inspection frequency - 24 months), shed/transitory shelter (inspection frequency - 12 months) and open storage (inspection frequency - 6 months). It should be noted that above cited inspection frequencies are for materiel not covered by storage serviceability standards.

a. Controlled humidity structural storage. Consists of structures in which the atmosphere is maintained at a relative humidity of 50 percent or less. Controlled humidity storage in structures provides the highest degree of protection.

b. Dehumidified nonstructural storage. Consists of complete or partial sealing of the packaged item with a mechanical dehumidification where the relative humidity should not exceed 50 percent or static dehumidification of each item, singly or in series, in which the relative humidity of the atmosphere within the interior areas does not exceed 40 percent.

c. Special structural storage. The storage of explosive materials is controlled by the potential hazards of the materiel. Materiel of an explosive nature must be stored in standard ammunition magazines designed for these purposes, or in areas designated specifically for the storage of explosives, ammunition, or loaded components. These areas are usually not wired for electricity and generally are not heated. The packaged item must be adequately preserved to protect it from deteriora-tion. The outer package must be labeled to identify the contents as explosive. The package should be designed to facilitate inspection required by periodic monitoring and surveillance without cover removal.

5.16.4.2 Care of Supplies in Storage (COSIS). The package must be designed for easy inspection either through unpacking and repacking or through the use of windows, ports, access hatches, or removable container sections. The package must be adequately labeled so that regardless of how the package is positioned, the identification labels are readily accessible. To aid in inventory control, the same number of units should be packed in any one container so that a count can be taken without referring to the identification label on each container. The need for care and preservation of packaged items during storage can be reduced to a minimum by proper design. In packaging design, only the best and most durable materials should be used consistent with economy. Some of the trouble spots that have been uncovered during the inspection, care, and representation phase of storage are:

a. Excessive runoff of preservatives on critical interior operating surfaces, requiring frequent renewing.

b. Electrical components not readily accessible for preservation without disassembly and unsoldering of components.

c. Frequent need for sealing of exterior openings opened during inspection.

d. Requirements for packing large voids such as grilles, louvers, and openings with waterproof barrier materials.

e. Nameplate treatment to maintain legibility and transparency and to prevent corrosion.

f. Packing material that cannot be used to repack an item after it is unpacked, requiring extensive new material for repacking.

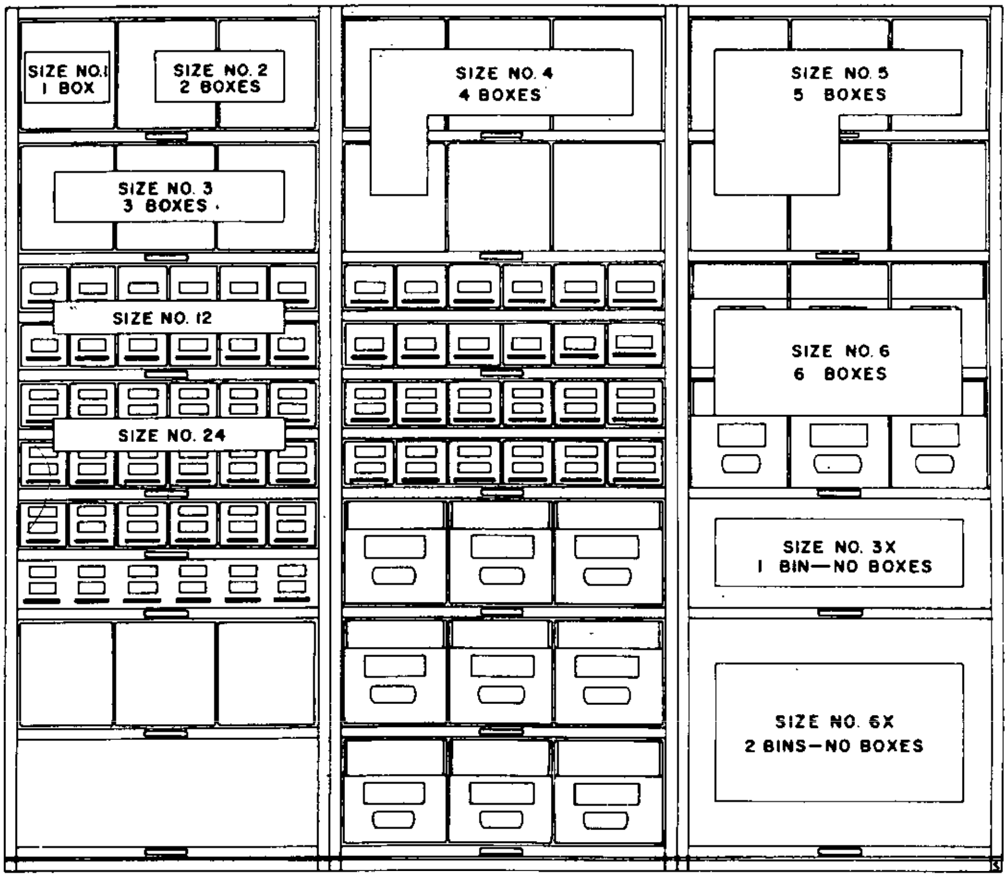
g. Unit packs and packs that must be repackaged or strengthened to meet the minimum packaging requirements for oversea shipment.

5.16.4.3 Time in storage and shelf life. The packaging engineer usually must design the package so that it is capable of protecting the packaged item throughout the whole storage time without the need for repackaging. The length of time the item remains in storage is based on many factors, principally the demand and the shelf life. For food, rubber products, chemicals, certain drugs, and many other items that deteriorate rapidly, the shelf life is the governing factor. The package design for those items should be based on the expected shelf life of the materiel in order to effect maximum economy of packaging materials.

5.16.4.4 Standard layout and dimensions for stored materiel. Storage space limitations depend on the dimensions of the building, elevators, entrance ways, stairwells, support columns, locker rooms, and materials handling equipment (MHE). However, regardless of the size and configuration of the storage area, definite head space and aisle widths are required. Aisle widths in storage depots are usually between 10 and 12 feet, where standard forklift trucks are used, but may be reduced to only 30 to 36 inches in width for stock selector trucks within bin and shelving areas. Dimensions and weight limitations are also placed on packages by the load limits of the MHE (see 5.16.5). Storage space limitations also invlove bin and shelf box sizes for small packages. Standard Department of Defense bin sizes are shown in figure 76. The dimensions of the metal shelf boxes that fit in these standard bins are also shown. Whenever practical, the packaging engineer should strive to fit the packaged item in an outside package that can be placed in these bins.

5.16.4.5 Stacking requirements for bulky or heavy items. To conserve space and reduce costs in shipping, storing, and handling, packages are usually stacked two or more tiers high, depending on their size and weight. Requirements for stacking must be considered during package design. The package must be designed to be stable with no tendency to tip. This is usually done through the use of a rectangular end profile and wide skid spacing. Additional stability and easier stacking can be obtained by using positive design features (see 5.8.2.6) to prevent the slipping and sliding of one container stacked on another.

5.16.5 Handling limitations. Throughout all phases of transportation and storage, the packaged item is continually in the process of being handled. In order that the package may be easily handled, the packaging engineer must observe the limitations placed on the package by the handling equipment. The size and weight of the package should be such that it can be handled efficiently by standard military equipment. The packaging engineer



Note. The shelf box arrangements shown above are examples of only some of the layouts that can be used. The number of small or large or whole shelves to be used depends upon the physical characteristics and volume of bin stocks to be stored. The main principles to be followed are:

1. Use shelf boxes extensively for ease of inventory and stock relocation.

2. Place small lot in the center so that the majority of items are in chest high position for easy picking.

3. Place heavy, large items toward the bottom with most inactive on lower shelves.

4. Place light, large items toward the top with most inactive on highest shelves.

FIGURE 76. Bin sizes.

must avoid the requirement for special vehicles or new handling equipment. The limitations imposed on the package by the type of handling equipment, terminal and port facilities, amphibious operations, and human factor considerations are covered separately in 5.16.5.1 and 5.16.5.4.

5.16.5.1 Handling equipment. The standard types of MHE that may be used with a package at the various cargo handling installations are:

a. Self-propelled equipment consisting of forklift trucks, tiering trucks (narrow aisle), wheeled warehouse tractors, warehouse truck cranes, hand-lift pallet trucks, fixed platform trucks, straddle-carry trucks, overhead and gantry cranes, and hoists.

b. Nonpowered mobile equipment consisting of platform warehouse trailers, hand trucks, and dolly trucks.

c. Conveyors, including portable belt-types, roller gravity and wheel gravity types.

d. Pallets made of wood, plastic or metal.

The packaging engineer must be certain the container can be handled by a combination of these common pieces of handling equipment. If necessary, two or three ~~pieces~~ of equipment can be used together to lift extremely long or heavy containers. The containers should be clearly marked showing the handling locations such as lifting eyes, handles, rings, brackets, and center of balance. Lifting eyes should be permanently attached and large enough to accept rigging cable hooks. They should also be far enough above the center of gravity of the package to stabilize it. Handles should be so positioned that they will not catch on other units, cables, lines, structural members, etc. If the container is too awkward or heavy for manual lifting, some method of mechanical handling must be provided. To permit handling by forklift trucks, the bottom of the container should be raised 3 inches above the floor. This is usually accomplished through the use of skids spaced to allow for entry of forklift tines. Reinforced channels should be constructed at the bottom of the container to prevent the fork tines from damaging the container wall. Two fittings should be located at the end adjacent to the skids for use in moving the container.

5.16.5.2 Terminal and port facilities. The capabilities of handling equipment available to terminals and ports located in the United States are almost unlimited. Forklift trucks ranging from 2,000- to 50,000-lb capacity are usually standard equipment at most terminals and ports. Overhead transverse cranes for loading and unloading trucks and rail cars are available at many of the terminals and ports, and will usually range from 1- to 10-ton capacity, although there are larger ones in use. Portable cranes for both land and water are available which have capacities over 150 tons. For moving and stacking the heavier containers and palletized loads on-board ship, forklift trucks are used along with the ship's gear. Due to the limitations of hatch sizes and available space in compartments and holds for maneuvering, forklift trucks are usually limited to 4,000-lb capacity. Heavier loads may be handled by using two forklift trucks. The size of forklift trucks used for loading and unloading railroad box cars is usually limited by the door sizes of the box cars. These door sizes vary among cars (5.13.1). Facilities of oversea terminals and ports are usually more limited than those for the United States except for the larger and busier ones. Some of the smaller and less used terminals and ports may not be equipped with any mechanized equipment system.

5.16.5.3 Amphibious operations. In some instances, landing craft and amphibious vehicles may be used for the transportation of packaged items. This type of transportation is commonly used in time of war for beachhead landings, but may also be used in peacetime. It may be used for the transfer of cargo between ships and port facilities where, due to the location and physical aspects of the port, ships cannot dock. The ship's facilities will usually be used for loading and unloading the ship, while the available shore facilities will be used for loading and unloading the landing craft and amphibious vehicles on shore. The shore facilies may consist of anything from manual labor to the equipment listed under handling equipment.

5.16.5.4 Human factor considerations. The human factor consideration should be recognized by the packaging engineer and provided for in the preparation of the package when these requirements do not conflict with the packaging requirements and the design of the packaged item. The packaging engineer is severely limited in the changes he/she can make to the weight, size, and movability of the package and packaged item. However, through the use of mechanical aids, such as handholds, hook eyes, and skids on the package, the handling qualities of the packaged item can be much improved.

5.17 Relationship of US military packaging to mutual security organizations. Agreements between the United States and members of the mutual security organizations (e.g., NATO, OAS) include support with military supplies and equipment.

Adequate preservation and packing procedures must be followed to insure delivery of serviceable goods to a specific recipient. Marking and shipment must be in accordance with the applicable International Standardization Agreements. Bilingual markings are considered as special markings and will be treated as such.

Custodians:
Army - SM
Navy - AS
Air Force - 69
Defense Logistics Agency - DH

Preparing activity:
Army - SM

Project: PACK 0594

Review activities:
Army - AT, ME, AV, AR, EA, MT, MR
Navy - YD
DLA - PS, CS, IS, CT, GS, DP

User activities:
Army - AL, CR, TE

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