

GUIDELINES FOR
**SAFE WAREHOUSING
OF CHEMICALS**

**This is a publication of the
CENTER FOR CHEMICAL PROCESS SAFETY
of the
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GUIDELINES FOR
**SAFE WAREHOUSING
OF CHEMICALS**

CENTER FOR CHEMICAL PROCESS SAFETY
of the
American Institute of Chemical Engineers
345 East 47th Street, New York, NY 10017

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Contents

<i>Preface</i>	<i>xi</i>
<i>Acknowledgment</i>	<i>xiii</i>
<i>Acronyms</i>	<i>xv</i>

1

Introduction

1.1. Background	1
1.2. Scope	1
1.3. Purpose	2

2

Commodity Hazards

2.1. Synopsis	3
2.2. Identification of Chemicals	3
2.3. Properties and Hazard Identification of Chemicals	5
2.4. Systems for Commodity Classification	5
2.4.1. Environmental Protection Agency	11
2.4.2. National Fire Protection Association	12
2.4.3. National Paint and Coatings Association's Hazardous Materials Identification System	16
2.4.4. United Nations (UN) and Department of Transportation (DOT) Hazardous Materials Classes	17
2.5. Container and Packaging Systems	17
2.6. Commodity Compatibility and Separation	18
References	20
Additional Reading	23



3

Administrative Controls

3.1. Synopsis	25
3.2. Safety and Risk Management Policies	25
3.3. Hazard and Risk Management	26
3.4. Control of Ignition Sources	26
3.5. Regulatory Compliance	26
3.6. Risk Management Organization	28
3.7. Employee Hiring, Training and Operations	28
3.7.1. <i>Employee Hiring</i>	28
3.7.2. <i>Training</i>	
3.7.3. <i>Operations</i>	29
3.8. Housekeeping	29
3.9. Inventory Management	29
3.10. Management of Change	31
References	32
Additional Reading	33

4

Employee Safety and Health

4.1. Synopsis	35
4.2. Policy	35
4.3. Administrative and Engineering Controls	36
4.3.1. <i>Administrative Controls</i>	36
4.3.2. <i>Engineering Controls</i>	37
4.4. Hazard Communication	37
4.4.1. <i>Labels</i>	38
4.4.2. <i>Material Safety Data Sheets</i>	38
4.4.3. <i>Employee Information and Training</i>	39
4.5. Personal Protective Equipment	40
4.5.1. <i>Implementing a PPE Program</i>	40
4.5.2. <i>Selecting PPE</i>	40
4.5.3. <i>Chemical Protective Clothing</i>	41
4.5.4. <i>Foot Protection</i>	43
4.5.5. <i>Head Protection</i>	43
4.5.6. <i>Eye and Face Protection</i>	43
4.5.7. <i>Hand Protection</i>	43
4.5.8. <i>Respirators</i>	44

4.5.9. Respirator Selection	46
4.5.10. Respirator Usage	46
4.5.11. Training	46
4.5.12. Maintenance and Inspection	48
4.6. Safety Equipment	48
4.7. Emergency Response Training	49
4.7.1. Emergency Spill Response	49
4.7.2. Manual Fire Fighting	52
4.7.3. First Aid	52
References	52
Additional Reading	53

5

Site Considerations

5.1. Synopsis	55
5.2. Health and Environmental Exposure	55
5.2.1. Baseline Environmental Assessment	56
5.2.2. Population Proximity, Density, and Sensitivity	56
5.2.3. Warehouse Truck Traffic	56
5.2.4. Highly Sensitive Environments	57
5.2.5. Surface Water, Ground Water, and Soil Permeability	57
5.3. Natural Peril Exposures	57
5.3.1. Earthquake	58
5.3.2. Flood	59
5.3.3. Hurricanes	59
5.3.4. Tornadoes	60
5.3.5. Lightning	62
5.3.6. Arctic Freeze	62
5.4. Exposures from Surrounding Activities	63
5.4.1. Adjacent Facilities, Airports, Highways, and Railroads	63
5.4.2. High Pressure Flammable Gas and Liquid Transmission Lines	63
5.4.3. Riot and Civil Commotion	63
5.5. Emergency Responders	64
5.6. Adequacy and Reliability of Public Utilities	64
References	64
Additional Reading	65

6**Design and Construction**

6.1. Synopsis	67
6.2. Construction Documents—Approvals and Permits	67
6.3. Means of Egress	70
6.3.1. <i>Travel Distance</i>	72
6.4. Environmental Protection	73
6.4.1. <i>Containment and Drainage Capacity Considerations</i>	73
6.4.2. <i>Warehouse Floor System</i>	82
6.4.3. <i>Concrete Criteria</i>	82
6.4.4. <i>Surface Preparation</i>	83
6.4.5. <i>Coatings and Sealers</i>	84
6.4.6. <i>Maintenance and Repair of the Floor</i>	85
6.4.7. <i>Airborne Effluent</i>	86
6.5. Fire Mitigation Construction Features	86
6.5.1. <i>Fire-Rated Separations</i>	89
6.5.2. <i>Protection of Openings and Penetrations</i>	93
6.5.3. <i>Through-Penetrations</i>	94
6.5.4. <i>Heat and Smoke Venting</i>	97
6.5.5. <i>Powered Ventilation Systems</i>	99
6.5.6. <i>Emergency and Standby Power Systems</i>	99
6.6. Deflagration Prevention and Mitigation	99
6.6.1. <i>Temperature Control</i>	100
6.6.2. <i>Gas and Vapor Control</i>	101
6.6.3. <i>Sources of Ignition</i>	102
6.6.4. <i>Spatial Separation</i>	103
6.6.5. <i>Damage Limiting Construction</i>	103
6.7. Natural Peril Mitigation	104
6.7.1. <i>Earthquake</i>	105
6.7.2. <i>Flood</i>	106
6.7.3. <i>Lightning</i>	107
6.7.4. <i>Windstorm, Hurricane and Tornado</i>	107
6.8. Security Features	107
6.9. Outdoor Storage	108
References	109
Additional Reading	111

7

Fire Protection Systems

7.1. Synopsis	113
7.2. Storage Considerations	114
7.3. Fire Control, Suppression, and Extinguishing Systems	115
7.3.1. <i>Fire Control</i>	116
7.3.2. <i>Fire Suppression</i>	117
7.3.3. <i>Fire Extinguishment</i>	119
7.3.4. <i>Fire Extinguishers</i>	121
7.4. Fire Detection and Alarm Systems	121
References	126
Additional Reading	127

8

Inspection, Testing, and Maintenance Programs

8.1. Synopsis	129
8.2. Inspection and Test Programs	129
8.2.1. <i>Program Objectives</i>	129
8.2.2. <i>Critical Equipment and Construction Features</i>	129
8.2.3. <i>Inspection and Test Program Elements</i>	130
8.2.4. <i>Maintenance</i>	131
8.2.5. <i>Maintenance Procedures</i>	132
References	132
Additional Reading	134

9

Emergency Planning

9.1. Synopsis	135
9.2. Loss Scenarios	135
9.3. Plan Objectives	135
9.3.1. <i>Employees</i>	136
9.3.2. <i>Surrounding Population</i>	136
9.3.3. <i>Environment</i>	136
9.3.4. <i>Property Protection and Business Interruption</i>	136
9.4. Plan Development	136
9.5. Plan Elements	137

9.5.1. <i>Policy Statement</i>	137
9.5.2. <i>Scope and Objectives</i>	137
9.5.3. <i>Pre-Incident Planning</i>	137
9.5.4. <i>Incident Response</i>	140
9.6. Emergency Spill Response	141
9.6.1. <i>Planning</i>	
9.6.2. <i>Responding to a Hazardous Material Spill</i>	143
9.6.3. <i>Cleanup</i>	143
9.6.4. <i>Reporting</i>	144
9.6.5. <i>Public Response</i>	146
9.7. Regulations and Resources	146
9.7.1. <i>U.S. Regulations</i>	146
9.7.2. <i>CMA Responsible Care Program</i>	148
References	149
Additional Reading.	149
10	
Selected Research and Discussion Topics	
10.1. Synopsis	151
10.2. Commodity Hazards and Fire Protection Systems	151
10.3. Design and Construction	152
Appendix A	
Summary of NFPA 704 Marking System	153
Appendix B	
Summary of HMIS	155
Appendix C	
United Nations and U.S. Department of Transportation Hazardous Materials Classes	157
Appendix D	
Additional Resources	160
<i>Glossary of Terms</i>	161
<i>Index</i>	169

Preface

The American Institute of Chemical Engineers (AIChE) has more than a 30-year history of involvement with process safety for chemical processing plants. Through its strong ties with process designers, builders, operators, safety professionals and academia, the AIChE has enhanced communication and fostered improvement in the high safety standards of the industry. AIChE publications and symposia have become an information resource for the chemical engineering profession on the causes of accidents and means of prevention.

The Center for Chemical Process Safety (CCPS) was established in 1985 by the AIChE to develop and disseminate technical information for use in the prevention of major chemical accidents. The CCPS is supported by a diverse group of industrial sponsors in the chemical process industry and related industries who provide the necessary funding and professional guidance for its project. The CCPS Technical Steering Committee and the individual technical subcommittees overseeing individual projects are staffed by representatives of sponsoring companies. The first CCPS/AIChE project was the preparation of *Guidelines for Hazard Evaluation Procedures*. Since that time a number of Guidelines and shorter Concept Books, have been produced.

Chemicals are ubiquitous in commerce and industry, and warehousing of chemicals and chemical products is an essential part of those activities. While many of the practices and standards applied to safe warehousing of chemicals are similar to those followed for safe warehousing of a wide range of other materials and commodities, chemicals may present unique safety, environmental or property protection challenges. The purpose of these Guidelines is to identify and address those issues unique to chemical warehousing while recognizing the large areas of commonality with other types of warehousing operations. These



This book, *Guidelines for Safe Warehousing of Chemicals*, is the result of a project begun in 1993 with the formation of the Subcommittee on Safe Warehousing of Chemicals. The Subcommittee, representing several major chemical companies, selected and worked with a contractor, Schirmer Engineering Corporation, to produce these Guidelines.

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Acronyms

ACGIH	American Conference of Governmental Industrial Hygienists
AFFF	Aqueous Film Forming Foam
AIChE	American Institute of Chemical Engineers
ANSI	American National Standards Institute
ASTM	American Society for Testing and Materials
BFE	Base Flood Elevation
BOCA	Building Official and Code Administrators, International
BOD	Biological Oxygen Demand or Biochemical Oxygen Demand
Btu	British Thermal Units
CAS	Chemical Abstracts Service
CCPA	Canadian Chemical Producers Association
CCPS	Center for Chemical Process Safety
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act of 1980
CFR	Code of Federal Regulations
CHRIS	Chemical Hazards Response Information System
CMA	Chemical Manufacturers Association
DOT	Department of Transportation
EPA	Environmental Protection Agency
EPCRA	Emergency Planning and Community Right to Know Act
FEMA	Federal Emergency Management Agency
FFFP	Film Forming Fluoroprotein
FIRM	Flood Insurance Rate Map
FIS	Flood Insurance Study
FM	Factory Mutual
HAZWOPER	Hazardous Waste Operations and Emergency Response
HMIS	Hazardous Materials Identification System

IDLH	Immediately Dangerous to Life and Health
IRI	Industrial Risk Insurers
IUPAC	International Union of Pure and Applied Chemistry
LFL	Lower Flammable Limit
MSDS	Material Safety Data Sheet
NA	North America
NCP	National Contingency Plan
NFPA	National Fire Protection Association
NIOSH	National Institute for Occupational Safety and Health
NPCA	National Paint and Coatings Association
OSHA	Occupational Safety and Health Administration
PEL	Permissible Exposure Limit
ppm	Parts Per Million
PPE	Personal Protective Equipment
RCRA	Resource Conservation and Recovery Act
RQ	Reportable Quantities
RTECS	Registry of Toxic Effects of Chemical Substances
SADT	Self-Accelerating Decomposition Temperature
SARA	Superfund Amendments and Reauthorization Act
SHFA	Special Hazard Flood Area
TLV	Threshold Limit Value
TCLP	Toxicity Characteristic Leaching Procedure
UBC	Uniform Building Code
UFL	Upper Flammable Limit
UL	Underwriters Laboratories
UN	United Nations
US	United States

Index

- accident scenarios, 29
- Aerosols, 12–13, 90, 151–152
- airborne effluents, 86
- air monitoring/sampling, 49, 51
- arctic freeze, 62
- building codes, 67–70
- building construction
- combustible, 86–88
 - damage limiting, 103–104
 - fire resistive, 86–88
 - noncombustible, 86–88
 - wind resistant, 107
- changes in occupancy, 32
- chemical identity, 3–4
- chemical properties, 6
- chemical protective clothing 41–49
- chemical releases, 144–146
- chemical resistance, 41–42
- cma responsible care, 148
- coatings and sealers, 84–85
- commodity compatibility & 18–20
 - separation
- commodity classification, 5, 151–152,
 - reference list, 11
- commodity hazard, 3
- concrete, 82–85
- container and packaging systems 17
- decontamination procedure 51
- deflagration, 99–104
- dept. of transportation, 17, 157–158
- detection alarms, 37
- earthquakes, 58, 105–106
- egress design, 70–72
- emergency notification procedures 139
- emergency plan, 135–149
- emergency responders, 64, 138
- emergency spill response 49–52, 140–146
- employees, 36–37, 39–40, 136
- engineering controls, 37
- environmental assessments 56
- environmental protection
 - agency 11–12, 147
- evacuation, 70–72, 136, 139
- federal emergency management
 - agency, 59
- fire doors, 93–97
- fire control, 51, 115–119
 - environmental hazards 10
 - fire/explosion hazards 7
 - human health hazards 8
- hazardous use facilities, 69
- hazardous wastes, 12
- high risk materials, 29
- hurricanes, 59–61, 107
- ignition sources, 26–27, 102, 113
- incident response, 140

1 Introduction

1.1. Background

The chemical industry and the chemicals it produces play a major role in advancing the quality of life and improving our standard of living. These improvements, however, have not been without associated risks.

As a society, we have learned to accept and manage the risks to which we are subjected in everyday life. We understand that a completely risk-free environment is unattainable. The chemical warehouse environment is similarly not entirely risk-free. Given the hazards associated with the storage of many chemicals, the potential exists for injuries, illness, environmental damage, property damage, and business interruption.

These occurrences may be initiated by natural disasters, such as earthquake or flood, or by people or equipment. The impact may be felt for many years, and some situations may produce irreversible effects. Therefore, it is paramount that the risks of chemical warehousing be fully understood and appropriate steps taken to prevent or mitigate losses.

1.2. Scope

These Guidelines address the identification of potential hazards associated with the warehouse storage of chemicals in various container and packaging systems. The hazards that are addressed include health effects, environmental pollution, fire and explosion. These guidelines also present means to minimize risk to employees, the surrounding population, the environment, property and business operations. The issues covered in these guidelines are most readily applicable to new warehouses in the planning stage. However, they may also be used by management to assess existing facilities. The types of facilities covered



by this guideline include those that are strictly chemical warehouses and those that store other commodities as well. These warehouses can be located on a manufacturing site or be free-standing facilities. It may be appropriate to apply these guidelines to non-company owned or operated warehouses at which company materials are stored (e.g., third party or public warehouses) as a prudent business practice.

These Guidelines do not cover materials in process, rolling stock and transportation issues, filling, dispensing or repackaging of chemicals, or storage of radioactive or detonable material. It also does not address reactivity issues covered in *Guidelines for Safe Storage of Reactive Materials*, published by CCPS.

1.3. Purpose

Safe warehousing of chemicals requires a multi-faceted approach that integrates a wide spectrum of issues. Consistent with its scope, the purpose of these Guidelines is to act as a resource for warehouse operators, designers and others concerned with safe warehousing of chemicals using a performance based approach.

2

Commodity Hazards

2.1. Synopsis

Chemicals have a wide range of properties and hazards which must be identified and understood if the conditions of “Safe Warehousing” are to be achieved. A complete understanding of the hazards also requires an assessment of the container and packaging systems and storage arrangements, and conditions that might be encountered during the life of the warehouse, such as fire or flood.

This chapter will present the characteristics that determine the overall commodity hazard which is the first step in understanding and limiting the risk. In the chapters that follow, strategies for limiting the risk to employees, the surrounding population, the environment, and property will be presented.

2.2. Identification of Chemicals

Whether the warehouse is in the planning stage or a fully operational facility, chemical identity is usually the first of many considerations in a comprehensive risk assessment.

The hazards of chemicals and commodities can be ranked by various systems of commodity classifications. Chemical identity can be established through the International Union of Pure and Applied Chemistry (IUPAC) name, trade name, common name, United Nations/North America (UN/ NA) number, Chemical Abstract Service (CAS) registry number, Registry of Toxic Effects of Chemical Substances (RTECS) number or chemical formula. As an example, acrylonitrile can be identified as follows:



- IUPAC Name: Cyanoethylene
- Trade and Common Name (Synonyms): Acrylon, Acrylonitrile, AN, Carbacryl, Fumigrain, Propenenitrile, VCN, Ventox, Vinyl Cyanide
- (UN/NA) Number: 1093
- CAS Registry Number: 107-13-1
- RTECS AT5250000
- Chemical Formula: $\text{CH}_2=\text{CHCN}$

Containerized and packaged chemicals should be readily identifiable through the container labels, shipping papers or material safety data sheets (MSDS). In the event that additional information is needed, there

TABLE 2-1
***Chemical Identity, Properties, Hazards, Reactivity,
and Special Handling Reference List***

ACIGIH Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices
Bretherick's Handbook of Reactive Chemical Hazards
29 CFR 1910.1000, Toxic and Hazardous Substances
49 CFR Parts 100-179, Hazardous Materials
Condensed Chemical Dictionary (Lewis, 1997)
Farm Chemicals Handbook
Hazardous Chemicals Desk Reference (Lewis, 1993)
The Merck Index (Windholz)
NFPA 30 Flammable and Combustible Liquids
NFPA 30B Manufacture and Storage of Aerosol Products
NFPA 43B Storage of Organic Peroxide Formulations
NFPA 43D Storage of Pesticides in Portable Containers
NFPA 49 Hazardous Chemicals Data
NFPA 325 Fire Hazard Properties of Flammable Liquids, Gases and Volatile Solids
NFPA 430 Storage of Liquid and Solid Oxidizers
NFPA 490 Storage of Ammonium Nitrate
NFPA 491M Hazardous Chemical Reactions
NIOSH/OSHA Occupational Health Guidelines for Chemical Hazards
NIOSH Pocket Guide to Chemical Hazards
Sax's Dangerous Properties of Industrial Materials
U.S. Dept. of Transportation Emergency Response Guidebook
U.S. Dept. of Transportation/U.S. Coast Guard Chemical Hazard Response Information System (CHRIS)

are a number of useful references, as listed in Table 2-1, where extensive listings of chemicals can be found.

2.3. Properties and Hazard Identification of Chemicals

The physical properties of chemicals determine the type of container and packaging system used and the mode of dispersion if container or package failure occurs. Physical properties also determine the hazards presented. For example, the boiling point of a liquid will affect the rate of vapor evolution if a spill occurs. A low boiling point flammable liquid will increase fire or explosion hazards. Table 2-2 lists some examples of the physical properties of a number of chemicals, including physical state, specific gravity, vapor density, boiling point and water solubility. The fire and explosion hazards of the same chemicals are listed in Table 2-3. The table includes the flash point, auto-ignition temperature, flammable limits, and data on self-reactivity and instability.

Some of the hazards to humans of these example chemicals are listed in Table 2-4. The human health hazards listed include warnings regarding an acute exposure as well as concentrations considered Immediately Dangerous to Life and Health (IDLH), Toxicity by Ingestion (LD_{50}), and Special Hazards of Combustion Products. The OSHA Permissible Exposure Limits (PEL) and ACGIH Threshold Limit Values (TLV) are also listed and are used as an index of chronic health hazard. Additionally, some of the environmental hazards of these chemicals are listed in Table 2-5. The environmental hazards listed include Aquatic Toxicity, Waterfowl Toxicity, Biological Oxygen Demand, and Food Chain Concentration Potential.

2.4. Systems for Commodity Classification

Relative ranking systems have been developed to characterize the degree of hazard associated with a given class of stored commodity. The systems that are pertinent to a chemical warehouse include those that rank aerosol products, compressed and liquefied gases, flammable and combustible liquids, hazardous wastes, ordinary commodities, organic peroxide formulations, pesticides, and liquid and solid oxidizers. In addition to ranking the hazards of the commodities, the rankings are used to establish conditions necessary for prevention and mitigation of unwanted events. Table 2-6 lists some commodity classification references.

TABLE 2-2
Physical Properties

Chemical Name	Physical State @ 70°F (21°C) and 1 atm. (1 Bar)	Specific Gravity (H ₂ O = 1)	Vapor-Air Density (Air = 1)	Boiling Point °F (°C)	Water Soluble
Ammonia	Gas	N/A	.6	−28 (−33)	Yes
Chlorine	Gas	N/A	2.44	−29 (−34)	No
Propane	Gas	N/A	1.6	−44 (−42)	No
Acetone	Liquid	.8	2.0	133 (56)	Yes
Acrylonitrile	Liquid	.8	1.8	171 (77)	Yes
Corn Oil	Liquid	.9	Not Reported	Not Reported	No
Diazinon	Liquid	1.117	Not Reported	Very High; Decomposes	Slight
Ethyl Ether	Liquid	.7	2.6	95 (35)	Slight
Mineral Spirits	Liquid	.8	3.9	300 (149)	No
Motor Oil	Liquid	.84–.96	Not Reported	Very High	No
Ammonium Nitrate	Solid	1.72	N/A	N/A	Yes
Calcium Hypochlorite (Hydrated & Unhydrated)	Solid	2.35	N/A	N/A	Yes (Reacts with water releasing chlorine gas.)
Carbaryl	Solid	1.23	N/A	N/A	No
Sources: NFPA 49, NFPA 325, U.S. Coast Guard CHRIS Manual, and Condensed Chemical Dictionary N/A = Not Applicable					

TABLE 2-3
Fire and Explosion Hazard Data

Chemical Name	Flash Point °F (°C)	Auto-Ignition Temperature °F (°C)	Lower Flammable Limit	Upper Flammable Limit	Self-Reactivity and Instability
Ammonia	N/A	1,204 (651)	15	28	N/A
Chlorine	N/A	N/A	N/A	N/A	N/A
Propane	N/A	842 (450)	2.1	9.5	N/A
Acetone	-4 (-20)	869 (465)	2.5	12.8	N/A
Acrylonitrile	32 (0)	898 (481)	3	17	Hazardous polymerization may be caused by elevated temperature.
Corn Oil	490 (254)	740 (393)	Not Reported	Not Reported	N/A
Diazinon	82–105 (28–41) (solutions only; pure liquid difficult to burn)	N/A	N/A	N/A	N/A
Ethyl Ether	-49 (-45)	356 (180)	1.9	36	May form explosive peroxides.
Mineral Spirits	104 (40)	473 (245)	.8 @ 212°F (100°C)	Not Reported	N/A
Motor Oil	275–600 (135–316)	325–625 (163–329)	Not Reported	Not Reported	N/A
Ammonium Nitrate	N/A	N/A	N/A	N/A	Decomposes above 410°F (210°C) releasing nitrous oxide.
Calcium Hypochlorite (Hydrated & Unhydrated)	N/A	N/A	N/A	N/A	Decomposes above 350°F (177°C) releasing oxygen and chlorine.
Carbaryl	N/A	N/A	N/A	N/A	N/A
Sources: NFPA 49 and NFPA 325			N/A—Not Applicable		

TABLE 2-4
Human Health Hazards

Chemical Name	Acute Health Hazards	IDLH and Toxicity by Ingestion	Special Hazards of Combustion Products	Chronic Health Hazards
Ammonia	VAPOR Poisonous if inhaled. Irritating to eyes, nose and throat. LIQUID Will burn skin and eyes. Harmful if swallowed. Will cause frostbite.	500 ppm Not Pertinent	Not Reported	OSHA PEL: 50 ppm ACGIH TLV: 25 ppm
Chlorine	VAPOR Poisonous if inhaled. Will burn eyes. LIQUID Will burn skin and eyes. Will cause frostbite.	25 ppm Not Pertinent	Toxic products are generated when combustibles burn in chlorine.	OSHA PEL: 1 ppm ACGIH TLV: 1 ppm
Propane	VAPOR Not irritating to eyes, nose or throat. If inhaled, will cause dizziness, difficult breathing, or loss of consciousness. LIQUID May cause frostbite.	20,000 ppm Not Pertinent	Not Reported	OSHA PEL: 1,000 ppm ACGIH TLV: Asphyxiant
Acetone	VAPOR Irritating to eyes, nose and throat. If inhaled, may cause difficult breathing or loss of consciousness. LIQUID Irritating to eyes, not irritating to skin.	20,000 ppm $LD_{50} = 5 \text{ to } 15 \text{ g/kg (dog)}$	Not Reported	OSHA PEL: 1,000 ppm ACGIH TLV: 750 ppm
Acrylonitrile	VAPOR Poisonous if inhaled. Irritating to eyes. LIQUID Poisonous if swallowed. Irritating to skin and eyes.	4 ppm $LD_{50} = 50 \text{ to } 500 \text{ mg/kg (rat, guinea pig)}$	When heated or burned, Acrylonitrile may evolve toxic hydrogen cyanide gas and oxides of nitrogen.	OSHA PEL: 2 ppm ACGIH TLV: 2 ppm
Sources: U.S. Coast Guard CHRIS Manual, 29 CFR 1910.1000 and 29 CFR 1910.1045, and ACGIH TLV Indices				

Chemical Name	Acute Health Hazards	IDLH and Toxicity by Ingestion	Special Hazards of Combustion Products	Chronic Health Hazards
Corn Oil	Not harmful.	Data not available. None	Not Reported	OSHA PEL: Not Reported ACGIH TLV: Not Reported
Ethyl Ether	VAPOR Irritating to eyes, nose and throat. If inhaled, will cause nausea, vomiting, headache, or loss of consciousness. LIQUID Irritating to skin. Harmful if swallowed.	19,000 ppm $LD_{50} = 0.5$ to 5 g/kg	Not Reported	OSHA PEL: 400 ppm ACGIH TLV: 400 ppm
Mineral Spirits	LIQUID Irritating to skin and eyes. Harmful if swallowed.	Data not available. $LD_{50} = 0.5$ to 5 g/kg	Not Reported	OSHA PEL: 500 ppm ACGIH TLV: Data not available.
Motor Oil	LIQUID Irritating to skin and eyes. Harmful if swallowed.	Data not available. $LD_{50} = 5$ to 15 g/kg	Not Reported	OSHA PEL: Not Reported ACGIH TLV: Data not available.
Diazinon	LIQUID Poisonous if swallowed. Irritating to skin and eyes.	Data not available. Grade 3; oral $LD_{50} = 76$ mg/kg (rat)	Oxides of sulfur and of phosphorus are generated in fires.	OSHA PEL: Not Reported ACGIH TLV: 0.1 mg/m ³
Ammonium Nitrate	DUST Irritating to eyes, nose and throat. If inhaled, may cause coughing or difficult breathing.	Not Pertinent Data not available.	Decomposes, giving off extremely toxic oxides of nitrogen.	OSHA PEL: Not Reported ACGIH TLV: Not pertinent.
Calcium Hypochlorite	SOLID Irritating to skin and eyes. If swallowed, will cause nausea, vomiting or loss of consciousness.	Data not available. LD_{50} above 15 g/kg	Poisonous gases may be produced when heated.	OSHA PEL: Not Reported ACGIH TLV: Not Pertinent.
Carbaryl	SOLID or SOLUTION Irritating to skin and eyes. Harmful if swallowed.	625 mg/m ³ Grade 2; $LD_{50} = 0.5$ to 5 g/kg (rat LD_{50} 0.51 g/kg)	Not Reported	OSHA PEL: Not Reported ACGIH TLV: 5 mg/m ³
Sources: U.S. Coast Guard CHRIS Manual, 29 CFR 1910.1000 and 29 CFR 1910.1045, and ACGIH TLV Indices				

TABLE 2-5 *Environmental Hazards*

Chemical Name	Aquatic Toxicity					Waterfowl Toxicity	Biological Oxygen Demand	Food Chain Concentration Potential
	Concentration	Time of Exposure	Aquatic Species	Effects	Water Type			
Ammonia	2.0–2.5 ppm	1–4 days	Goldfish and yellow perch	not stated	not stated	120 ppm	Not Pertinent	None
	60–80 ppm	3 days	Crayfish	LC ₁₀₀				
	8.2 ppm	96 hr.	Fathead minnow	TL _M				
Chlorine	0.08 ppm 10 ppm	168 hr. 1 hr.	Trout Tunicates	TL _M killed	fresh salt	DNA*	None	None
Propane	None	None	None	None	None	None	None	None
Acetone	14,250 ppm 13,000 ppm	24 hr. 48 hr.	Sunfish Mosquito fish	killed TL _M	tap turbid	Not Pertinent	(Theor) 122%, 5 days	None noted
Acrylonitrile	100 ppm 0.05–1 ppm	24 hr. 24 hr.	All fish Bluegill	100% killed lethal	fresh salt	Not Pertinent	70%, 5 days	None noted
Corn Oil	DNA*	DNA*	DNA*	DNA*	DNA*	DNA	DNA*	None
Diazinon	0.025 ppm	96 hr.	Stonefly nymph	TL _M	fresh	LD ₅₀ =3.54 mg/kg LD ₅₀ =5 days, 90 ppm mallard LD ₅₀ =7 days, 68 ppm quail	DNA	DNA*
Ethyl Ether	DNA	DNA	DNA	DNA	DNA	DNA	3%, 5 days	None
Mineral Spirits	DNA	DNA	DNA	DNA	DNA	DNA	8%, 5 days	None
Motor Oil	DNA	DNA	DNA	DNA	DNA	DNA	DNA	None
Ammonium Nitrate	DNA	DNA	DNA	DNA	DNA	DNA	DNA	None
Calcium Hypochlorite	0.5 ppm	Time not specified	Trout	killed	fresh	DNA	Not Pertinent	Not Pertinent
Carbaryl	5.5 ppm 0.013 ppm	96 hr. 48 hr.	Bluegill White shrimp	TL _M TL _M	fresh salt	LD ₅₀ =2179 mg/kg	DNA	None observed
Source: U. S. Coast Guard CHRIS Manual					*DNA—Data Not Available			

TABLE 2-6

Commodity Classification Reference List

40 CFR Part 152 Pesticide Products
40 CFR Part 261 Hazardous Wastes
NFPA 30B Manufacture and Storage of Aerosol Products
NFPA 30 Flammable and Combustible Liquids Code
NFPA 231 General Storage (Ordinary Commodities)
NFPA 231C Rack Storage of Materials (Ordinary Commodities)
NFPA 43B Storage of Organic Peroxide Formulations
NFPA 430 Storage of Liquid and Solid Oxidizers
NFPA 55 Compressed and Liquefied Gases
NFPA 704 Standard System for the Identification of the Fire Hazards of Materials
NPCA Hazardous Materials Identification System

It should be recognized that definitions for certain hazardous materials, such as “flammable liquids,” may not be the same for different classification systems, such as NFPA and DOT. Therefore, it is important to state which classification system a definition is based upon.

2.4.1. Environmental Protection Agency**2.4.1.1. Pesticides**

Pesticides can be designated as Toxicity Category I, II, III or IV by the classification system of the Environmental Protection Agency (EPA) in 40 Code of Federal Regulations (CFR) Part 152 Pesticide Products. Toxicity Category I pesticides are the most hazardous and Toxicity Category IV the least hazardous. This system accounts for acute short-term toxicity and does not account for chronic long term toxicity.

Additionally, this system does not account for fire hazard, reactivity hazard or environmental hazard. The toxicity category of a pesticide is determined from the oral LD₅₀, LC₅₀, Dermal LD₅₀ as well as local effects to both skin and eyes.

In addition to the toxicity category designation, pesticides can also be labeled with signal words. Toxicity Category I pesticides are labeled “Danger” or “Poison” depending on the effect of an exposure. Toxicity Category II pesticides are labeled “Warning” and both Toxicity Category III and IV are labeled “Caution.” This system has limitations in that the LD₅₀ and LC₅₀ values are based on exposure to laboratory animals and may not correlate directly to humans. Also, the terms used to describe skin and eye effects are subject to interpretation.

2.4.1.2. Hazardous Wastes

Wastes are considered hazardous according to the Resource Conservation and Recovery Act (RCRA) when they meet one or more criteria including ignitability, corrosivity, reactivity or toxicity as per EPA definitions (see Glossary of Terms). Additionally, wastes are also considered hazardous when they are included in one of the following lists:

- F-List (see 40 CFR Part 261.31, Hazardous Wastes from Non-specific Sources)
- K-List (see 40 CFR Part 261.32, Hazardous Wastes from Specific Sources)
- P-List (see 40 CFR Part 261.33(e), Discarded Commercial Chemical Products, Off-specification Species, Container Residues and Spill Residues Thereof)
- U-List (see 40 CFR Part 261.33(f), Discarded Commercial Chemical Products, Off-specification Species, Container Residues and Spill Residues Thereof)

2.4.2. National Fire Protection Association

2.4.2.1. Aerosol Products

Aerosol products are designated as Level 1, 2, or 3 by the classification system of NFPA 30B, "Code for the Manufacture and Storage of Aerosol Products." Level 1 aerosols are considered the least hazardous and Level 3 the most hazardous. This system is based upon the fire hazard of these products. Other hazards such as the acute and chronic health hazards, as well as the environmental hazards of aerosol products are not addressed by the NFPA 30B classification system. The fire hazard associated with aerosol products is determined by either a 12-pallet aerosol classification test or the chemical heat of combustion of all of the constituents within the aerosol can.

The 12-pallet classification test results consider the number of opened sprinklers, maximum steel beam temperature at the ceiling, maximum plume temperature and velocity, maximum heat flux, maximum weight loss rate, and net percentage weight loss. The classification of a given aerosol product is based upon suppression or control of the fire and the number of sprinklers that opened during the fire test. An aerosol product is considered a "Level 1" if the fire was well controlled or suppressed, a "Level 2" if the fire was well to marginally well controlled or a "Level 3" if the fire was not well controlled.

The other method of classifying an aerosol product is by determining the chemical heat of combustion of all of the constituents within the aerosol can. This method provides consistent correlation with the 12-pallet aerosol classification test. The chemical heat of combustion is the product of the theoretical heat of combustion and combustion efficiency. An aerosol product is considered “Level 1” if the chemical heat of combustion is greater than 0 and less than or equal to 8600 Btu/lb (20 KJ/g), “Level 2” if it is greater than 8600 Btu/lb (20 KJ/g) and less than or equal to 13,000 Btu/lb (30 KJ/g), and “Level 3” if it is greater than 13,000 Btu/lb (30 KJ/g). NFPA 30B requires that the classification of an aerosol product be stated on the carton to allow easy identification.

A listing of the theoretical heats of combustion, combustion efficiencies and chemical heats of combustion for a number of chemicals commonly found in aerosol products is shown in Table 2-7.

The NFPA 30B classification system is used to specify or determine the need for certain requirements for building ceiling height, allowable quantities, storage arrangement, automatic sprinkler protection, and building construction features.

2.4.2.2. Flammable and Combustible Liquids

Flammable and combustible liquids can be designated as Class IA, IB, IC, II, IIIA, or IIIB by the classification system of NFPA 30, “Flammable and Combustible Liquids Code.” Class IA liquids are considered the most hazardous and Class IIIB the least hazardous. This classification system is based upon the closed-cup flash point temperature and with Class IA and Class IB liquids also the boiling point temperature of the liquid. Liquids are considered flammable if their flash points are below 100°F (37.8°C) and combustible if their flash points are at or above 100°F (37.8°C).

TABLE 2-7
Heats of Combustion

Material	Theoretical Heat of Combustion	Efficiency	Chemical Heat of Combustion
	BTU/lb (kJ/g)		BTU/lb (kJ/g)
Acetone	12,296 (28.6)	0.97	11,909 (27.7)
Corn Oil	15,821 (36.8)	0.96	15,176 (35.3)
Mineral Spirits	19,260 (44.8)	0.92	17,712 (41.2)
Source: Newman, 1994			

Fire testing used to develop automatic sprinkler system design criteria has shown that other factors are important to determine the overall fire hazard of containerized liquids. These factors include the liquid properties, such as liquid burning rate, fire point, specific gravity, water solubility, and viscosity, as well as the container design and size. These important factors have been incorporated into the sprinkler system design tables in Section 4-8 of the 1996 edition of NFPA 30.

2.4.2.3. *Ordinary Commodities*

Ordinary commodities can be designated as either non-combustible or as combustible Class I, II, III, IV, or as Group A, B, or C plastics by the classification system established by NFPA 231 "Standard for General Storage" and NFPA 231C, "Standard for Rack Storage of Materials." This system is based upon the fire behavior of ordinary commodities stored under automatic sprinklers. Non-combustible commodities are considered the least hazardous and Group A plastics the most hazardous by this system. The relative hazard of a commodity is a function of the combustion properties of the material as well as its configuration in the storage array. There are essentially four methods that are used for classifying ordinary commodities. These include small-scale fire tests, subjective physical comparison, intermediate or full-scale fire tests, and fire tests based upon calorimetry.

The classification system used in NFPA 231 and NFPA 231C is used to specify or determine the need for certain requirements that can prevent or mitigate the effects of fire. These includes automatic sprinkler protection, storage arrangement, and building construction features.

2.4.2.4. *Organic Peroxide Formulations*

Organic Peroxide formulations are designated as Class I, II, III, IV, or V by NFPA 43B, "Code for the Storage of Organic Peroxide Formulations." Class I organic peroxide formulations are considered the most hazardous and Class V organic peroxide formulations are the least hazardous by this system. The fire hazard and self-reactivity behavior of organic peroxide formulations, under storage conditions when subjected to fire exposure, are the basis of this classification system. Specifically, this system applies to certain commercial formulations that are packaged in containers approved by the U.S. Department of Transportation or the Canadian Ministry of Transport. Organic peroxide formulations that can undergo detonation when exposed to a fire are not addressed by this system. The acute and chronic health hazards as well as the environmental hazards of organic peroxides are also not addressed.

The NFPA 43B classification system addresses organic peroxide formulations that will not sustain combustion through those that burn very

rapidly. Additionally, the self-reactivity behavior of organic peroxide formulations includes those that have no self-reactivity through those that can undergo spontaneous decomposition resulting in a deflagration.

The definitions applied to organic peroxide formulation behavior can be subject to interpretation. Therefore, in an effort to better identify commercial organic peroxide formulations by class, a listing of typical formulations and their classes can be found in the Appendix of NFPA 43B. This listing includes the name and concentration of the organic peroxide, type of diluent, maximum individual container size and the NFPA 704 hazard identification rating.

The NFPA 43B classification system is used to specify or determine the need for certain requirements that can prevent or mitigate the effects of fire and explosion. These requirements include allowable quantities, automatic sprinkler protection, the need to store certain organic peroxide formulations in a refrigerator or freezer, storage arrangement, and building construction features.

2.4.2.5. *Liquid and Solid Oxidizers*

Liquid and solid oxidizers are designated as Class 1, 2, 3, or 4 by NFPA 430, "Code for the Storage of Liquid and Solid Oxidizers." Class 1 oxidizers are considered the least hazardous and Class 4 the most hazardous. The behavior of commercially available strengths of liquid and solid oxidizers under storage conditions is the basis for this classification system. This behavior includes fire hazard and reactivity. The acute and chronic health hazards as well as the environmental hazards of liquid and solid oxidizers are not addressed.

The NFPA 430 classification system, the fire hazard behavior of liquid and solid oxidizers that can increase the burning rate or cause spontaneous ignition of a combustible material. Also, the reactivity behavior of liquid and solid oxidizers includes those that can undergo a self-sustained decomposition or an explosive reaction. The definitions used to define liquid and solid oxidizer classes can be subject to interpretation. The NFPA 430 classification system "is based on the Technical Committee's evaluation of available scientific and technical data, actual experience, and it's considered opinion." A listing of typical liquid and solid oxidizers by class can be found in the Appendix of NFPA 430. The oxidizers listed are assumed to be pure materials unless otherwise specified.

The NFPA 430 classification system is used to specify or determine the need for certain requirements that can prevent or mitigate the effects of fire and explosion. These requirements include allowable quantities,

automatic sprinkler protection, storage arrangement features, and building construction type.

2.4.2.6. *Compressed and Liquefied Gases*

Compressed and liquefied gases are classified according to their primary hazard using the definitions in NFPA 55, "Storage, Use, and Handling of Compressed and Liquefied Gases in Portable Cylinders." NFPA 55 classifies compressed and liquefied gases as toxic, pyrophoric, flammable, nonflammable, or oxidizing. The definitions for these materials can be found in the Glossary of Terms.

2.4.2.7 *NFPA 704, "Identification of the Fire Hazards of Materials"*

This system of hazard identification uses a numerical designation of 0 through 4 to provide a relative ranking of health, flammability and reactivity for emergency responders. Additionally, other hazards such as oxidizing potential and water reactivity are also shown. The NFPA 704 markings are diamond shaped and use four color-coded quadrants. Appendix A provides a basic description of the hazard associated with each number. This system provides a general indicator of the type and severity of the hazards associated with a material under fire exposure or spill conditions. The effects of chronic long term health exposure, container and packaging system performance, environmental hazards, and incompatibility with other chemicals are not addressed. **The NFPA 704 fire and reactivity hazard ratings do not correlate with other commodity classification systems such as used in NFPA 430 and 43B.**

2.4.3. *National Paint and Coatings Association's Hazardous Materials Identification System*

This system of hazard identification is very similar to the NFPA 704 system in that it also uses a relative ranking scale from 0 through 4 for health, flammability and reactivity hazards. The system scaling is the same and commonly uses NFPA 704 fire and reactivity ratings. Terminology used to describe each hazard, however, can differ. Additionally, this system also incorporates what is known as a Personal Protective Index. The Personal Protective Index uses an alphabetical designation and symbols that correspond to a specific combination of protective equipment such as gloves and safety glasses. Appendix B provides a summary of the ratings and a listing of the equipment specified under the Personal Protective alphabetical designation. This system of hazard identification is intended to protect employees against occupational exposures under

conditions of “normal handling.” The recommended protective equipment may not be adequate under adverse or upset conditions.

2.4.4. *United Nations (UN) and Department of Transportation (DOT) Hazardous Materials Classes*

United Nations Committee on Transport of Dangerous Goods and the U.S. Department of Transportation use a classification system, outlined in Appendix C that does not completely correlate with the systems previously described. Furthermore, this system applies to the transportation of commodities and was not intended to be applied to the warehouse environment. It is intended to give an at-a-glance identification of the hazards much like the NFPA 704 and the NPCA Hazardous Materials Identification System.

2.5. Container and Packaging Systems

Container and packaging systems utilize various designs and materials of construction (see Table 2-8). Warehoused chemicals can also be stored in loose bulk piles. The overall hazard of a given commodity is derived from the inherent physical properties, fire and explosion hazards and health

TABLE 2-8
Typical Container and Packaging Systems

Type		Material
NON-BULK	Bags	Cloth, paper, plastic and paper/foil/plastic composites
	Bag-in-a-box	Plastic bag in corrugated cardboard and polyvinyl alcohol film (water soluble) in corrugated cardboard.
	Bottles	Glass, plastic and polyvinyl alcohol (water soluble).
	Pails	Steel, plastic and fiber.
	Drums	Steel, plastic and fiber.
BULK	Intermediate Bulk Container (rigid, semi-rigid, or flexible)	Steel, aluminum, plastic, wood, fiber, textile and paper.
	Portable Tank	Steel and aluminum

hazards of a particular chemical and the performance of the container or packaging system, if used. Ideally, container and packaging systems should maintain their integrity and not release their contents. In order to fully assess the risk associated with the storage of a particular chemical, all of the conditions or possible scenarios that might occur in a warehouse should be considered. This includes the potential for material handling accidents, water exposure and fire exposure.

The United Nations (UN) has developed criteria for the testing of chemical container and packaging systems. This criteria is “performance-based” and is covered in their publication entitled “Recommendations on the Transport of Dangerous Goods.” The U.S. Department of Transportation adopted United Nations recommendations in 1990 and amended them in 1996.

Depending on the container type, UN/DOT “performance-based” testing includes drop, leakproof, hydrostatic pressure, stacking, vibration, top and bottom lift, tear, topple, and righting tests.

Based upon the UN or DOT Hazardous Materials Class, discussed in Section 2.4, a given chemical is also assigned to a “packing group.”

There are three “packing groups” as follows:

- Packing Group I—assigned to materials presenting great danger
- Packing Group II—assigned to materials presenting medium danger
- Packing Group III—assigned to materials presenting minor danger

Each “Packing Group” requires that a container or package meet and be maintained to certain performance criteria for the tests previously mentioned. None of these tests evaluates fire performance of containers and packaging systems and therefore will not provide a complete assessment of all of the hazards associated with warehouse storage.

As discussed in Section 2.4, there are four basic methods for assessing the fire hazard of commodities for warehouse storage. This includes small-scale fire tests, subjective physical comparison, intermediate or full-scale fire tests, and fire tests based upon calorimetry. The most accurate assessment of the fire hazard of a commodity will be obtained with intermediate or full-scale fire tests and with some commodities, fire tests based upon calorimetry.

2.6. Commodity Compatibility and Separation

Chemicals are normally packaged in containers that are physically and chemically compatible with them. The release of and accidental contact

between incompatible chemicals can result in a hazardous situation. Incompatible combinations can also occur between the released chemical and containers, packaging materials, air, fire-fighting water, other fire-extinguishing agents, spill clean-up materials, and building components. The accidental contact can be the result of improper material handling, faulty containers or an event such as a fire or earthquake. Chemicals are considered incompatible when their contact can produce a hazardous chemical reaction. This includes exothermic reaction and production of toxic or flammable products. An exothermic chemical reaction can release energy at a rate or quantity that results in a fire or explosion. Additionally, the reaction between incompatible materials might not occur immediately. Some combinations can result in products that are heat, shock, or friction sensitive and subject to reacting later, such as during a clean-up operation.

Table 2-9 lists a number of binary chemical combinations that are chemically incompatible and indicates the results of their coming in contact with each other. Additional information can be obtained by consulting the material safety data sheet (MSDS), the manufacturer or supplier, Bretherick's Handbook of Reactive Chemical Hazards, NFPA 49, NFPA 491M and U.S. Coast Guard CHRIS (Chemical Hazards Response Information System) Manual. Although the cited literature contains an exten-

TABLE 2-9
Examples of Incompatible Binary Combinations

Combinations of A and B		
A	B	Produce
Hydrochloric Acid	Calcium Hypochlorite	Chlorine Gas Release (Toxic)
Primary Amines	Calcium Hypochlorite	<i>n</i> -Chloroamines (Explosive)
Organic Liquids	Calcium Hypochlorite	Violent Reaction
Sodium Cyanide	Sulfuric Acid	Hydrogen Cyanide (Highly Toxic)
Acrylonitrile	Sulfuric Acid	Vigorous Exothermic Reaction
Acetyl Chloride	Water	Violent Reaction
Acetic Anhydride	Water	Violent Reaction
Aluminum Phosphide	Water	Phosphine Gas Release (Pyrophoric and Toxic)
Source: NFPA 491M and NFPA 49		

sive amount of information, the absence of published reactivity data should not infer that no hazard exists.

Incompatible chemicals should be separated by arranging them in segregated, cut-off, or detached storage areas. "Segregated storage" separates the incompatible materials spatially, intervening inert or mutually compatible materials, constructing line of sight barriers, or storing the incompatible material in a fire-resistive cabinet. This approach may be appropriate for materials that are mildly incompatible such as ordinary combustibles and oxidizers that cause an increase in burning rate. Curbing, ramps, or depressed floors can be utilized to restrict the flow of liquids across the floor or to adjacent building areas.

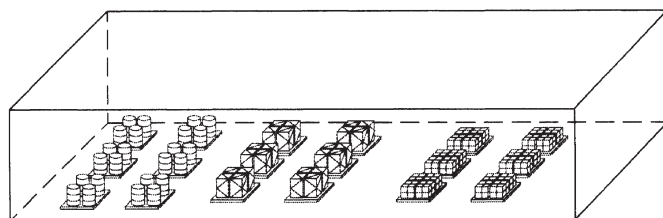
"Cut-off storage" involves partitioning the building into separate compartments. Organic peroxides that present a severe burning rate and reactivity hazard are candidates for cut-off storage. In addition to fire resistance, these walls might also need to be blast resistant.

"Detached storage" involves storage in separate buildings. This storage arrangement is usually reserved for materials that present severe fire, reactivity or health risk. For example, the storage of aluminum phosphide, which reacts with water to produce toxic and pyrophoric phosphine gas, in an unsprinklered detached building will reduce the risk of exposure to the facility and employees, and possibly the surrounding community.

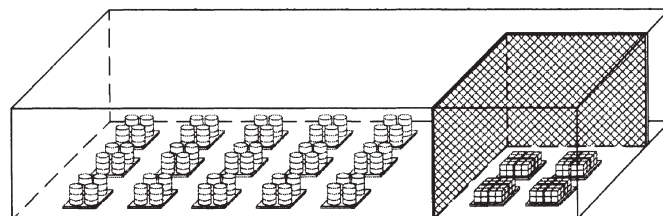
Figure 2-1 illustrates warehouse arrangements incorporating segregated, cut-off, and detached storage.

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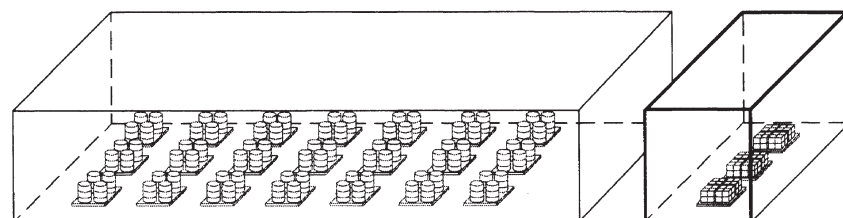
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SEGREGATED STORAGE
STORAGE SEPARATED BY DISTANCE
OR INERT MATERIAL



CUT-OFF STORAGE
STORAGE SEPARATED BY A WALL



DETACHED STORAGE
STORAGE IN SEPARATE BUILDINGS

LEGEND

-  – MATERIAL "A"
-  – MATERIAL "B"
-  – MATERIAL "C"

NOTE: Materials "A" and "B" are incompatible with each other. Material "C" is inert.

FIGURE 2-1 Warehouse arrangements incorporating segregated, cut-off, and detached storage.

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3 Administrative Controls

3.1 Synopsis

Safe warehousing of chemicals begins with an explicit management commitment to employees, community and other stakeholders, and includes efforts to protect against the hazards posed by the materials stored and transported to and from the facility. This chapter outlines some of the specific actions management should take to fulfill this responsibility.

3.2. Safety and Risk Management Policies

Operating procedures, safety rules, employee training, emergency preparedness and other management initiatives should be based on a management philosophy which make safety and risk management a primary management responsibility and concern. Policies which derive from this philosophy should address:

- The importance of employee and community safety, environmental protection, and property conservation as core management values,
- The responsibility of each employee to follow all safety practices, and to inform management of unsafe conditions, and,
- The commitment of management to be in compliance with all applicable safety, health, and environmental protection regulations.

It should be noted that the word “safety” has been used in this book to refer to the overall safe operation of the warehouse, as it relates to people, the environment, property and business opportunity.

Employee safety and health policy issues are outlined in Chapter 4.

3.3. Hazard and Risk Management

Identification of hazards which might threaten employee or public safety, the environment or property is the first step. Later chapters in this Guideline discuss the major types of hazards which chemical warehousing might present, and which should be evaluated.

After identifying existing or anticipated hazards, the next step is risk assessment, that is, evaluating and interpreting the hazards. Several widely used hazard identification and risk assessment techniques are described in the literature, including AIChE/CCPS's *Guidelines for Hazard Evaluation Procedures*. Emergency planning is also covered in Chapter 9.

3.4. Control of Ignition Sources

Control of ignition sources is an essential strategy for minimizing the potential for fires and explosions in chemical warehouses. There are several types of ignition sources that could potentially cause a fire in a chemical warehouse; some examples, preventive measures and useful references can be found in Table 3.1. Operations, such as, filling, dispensing, and repackaging of chemicals are sometimes performed in conjunction with chemical warehousing. These operations can also create an ignition potential through static electricity buildup. However, this issue is beyond the scope of this guideline.

3.5. Regulatory Compliance

Companies which handle hazardous chemicals operate in a complex regulatory environment, often subject to many regulations, standards, rules, and procedures from government, standards organizations, and insurers. These requirements can be confusing, redundant or even mutually inconsistent. Moreover, even complete regulatory compliance will not assure a safe warehouse operation. The unique operation of every company therefore requires that management should look beyond the letter of the law to the specific needs of that operation to establish an effective safety policy that is based on the nature of the hazards involved.

Management is best able to identify and respond to risks most effectively when there is a definite commitment to understanding the risks associated with the business, to adequately defining and carrying out a comprehensive safety program, and to funding and otherwise supporting that program.

TABLE 3-1
Typical Ignition Sources

Type	Examples	Preventive Measures	References
Open flames/Sparks	Cutting and welding	Hot work policy	NFPA 51B NFPA Fire Protection Handbook IRInformation
	Metal grinding		
	Concrete chipping		
	Smoking	No smoking policy	
Electrical	Direct-fired heaters	Isolate or use other type of heater	NFPA 70 NFPA 505 NFPA 780
	Arcing and sparking from electrical equipment, including industrial trucks	Install appropriate electrical equipment and appropriate industrial trucks	
	Lightning	Install lightning protection system	
Hot surfaces	Ducts, pipes, radiant heaters, or industrial trucks exposing heat sensitive material	Provide appropriate space separation and appropriate industrial trucks	MSDS NFPA 505
	Slipping conveyor belt on a roller	Provide inspection and maintenance	Manufacturer's recommendation
Chemical decomposition	Heating of organic peroxide formulations requiring refrigeration	Provide adequate temperature controls	MSDS
Spontaneous ignition	Rags soaked with unsaturated oils such as linseed	Adequate house-keeping practices	MSDS

3.6. Risk Management Organization

Effective risk management involves virtually all functions within a warehousing organization, including personnel, materials handling, maintenance, marketing and finance. Because many issues cross functional lines, a safety and risk management team should be formed with all functions represented. Because of their first-hand knowledge of problems and practical solutions, non-supervisory employees (operators, mechanics, etc.) should be included in the process.

3.7. Employee Hiring, Training and Operations

Most safety policy is carried out at the operations level. Effective screening, training and oversight of employees will result in increased awareness of safety issues and fewer accidents. See also Chapter 4, Employee Safety and Health..

3.7.1. Employee Hiring

Safety related criteria for use in choosing candidates for typical chemical warehouse operations (e.g., including shipping/receiving, put and pick, material handling, etc.) might include:

- a literacy level adequate to be able to read and understand instructions and Material Safety Data Sheets (MSDS)
- lifting strength, as necessary
- warehousing/industrial truck operations experience
- chemical handling experience
- computer use experience, as needed when dealing with inventory tracking systems

Safety and personnel policies of the warehouse should state clearly that the safety of workers in the warehouse depends upon maintaining a drug and alcohol-free workplace.

3.7.2 Training

Hazard communication and personal protective equipment and emergency procedures training are addressed in Chapter 4. As with conventional warehouse operations, employees should be trained in safe lift truck operations, lifting and other procedures which are not specific to chemical warehouse operations. However, in a chemical warehouse, instructions on these routine functions should be tailored to address the unique hazards present in the chemical warehouse environment.

3.7.3. Operations

Operations should be analyzed to identify possible accident scenarios, and measures taken to limit those exposures. Such measures include but are not limited to:

- eliminating or controlling filling, dispensing and sampling operations, particularly of flammable or toxic materials in the warehouse area.
- setting a policy whereby employees work in pairs with high risk materials where exposure can result in a situation immediately dangerous to life and health or that may impact the surrounding community.
- employees working in pairs with high risk materials should be physically separated by enough distance so that a single event will not result in exposure to both employees.
- rotating tasks and employees. Under certain circumstances, long hours of repetition can lead to reduced attention and thus to accidents. Repetitive motion may also lead to cumulative trauma disorders such as carpal tunnel syndrome.
- scheduling regular and routine maintenance of building and equipment, particularly safety equipment. Properly maintained equipment is safer and more efficient to operate.

3.8. Housekeeping

As simple and basic as good housekeeping practices may seem, a commitment to maintaining good order will limit the chance or severity of accidental spills, releases or fires. Good housekeeping practices will also increase employee efficiency and safety.

3.9. Inventory Management

Maintaining tight inventory controls in chemical warehousing is essential to assure compliance with storage arrangement restrictions, such as separation of incompatible materials, storage height, and quantity limits. An up-to-date inventory is also critical information in case of a fire.

Automated inventory identification and management (automated ID) systems have been developed which greatly facilitate inventory control. Automated ID systems have created dramatic changes in the manage-

ment of chemical warehouses, improving productivity, efficiency, quality control, inventory management, warehouse space utilization, retrieval systems, and safety. The primary reason, from a safety perspective, for an automated ID system in a chemical warehouse is that it makes the task of material handling easier and more efficient, reduces potential for incompatible storage, and avoids exceeding safe storage heights and quantity limitations. While there are clear benefits to safety from the use of Automated ID systems, it should be noted that, like all such systems, they are not infallible. Common sense should not be ignored.

Central to the development of an automated inventory management system is the database of inventory which can contain the following information:

- commodity type and hazard classification;
- assignment of warehouse location information to assist “put and pick” operations;
- MSDS sheets; and
- inventory accounting.

Where bar code labels are generated and applied on site, a unique inventory number can be generated and applied to the specific carton, pallet load, or packaging system. The system should be engineered so that bar code labels correspond with storage standards. The inventory number can then be assigned specific warehouse location information.

Information regarding the volume of inventory at each specific warehouse bin location can be included in the parameters programmed into the database as shipments arrive. Total facility limits on quantity of specific materials or material classes should be considered in accepting materials for storage. Information regarding specific storage requirements related to properties and hazards can be considered by the database in assigning location. Materials to be stored should be evaluated against warehouse design specifications to assure that they are within the facility limitations. For example, the system can be used to direct certain commodities to sections of the warehouse where special fire protection schemes have been installed. Additionally, parameters dealing with compatibility, storage height, and quantity limits can also be addressed. Material to be stored should be evaluated against warehouse specifications to assure that it is within the facility specifications or limitations.

As shipments move through the warehouse, terminals at the various picking stations carry the information which was entered at the receiving dock. Real time interface between existing inventory and the database helps maintain efficiency and quality control.

As items are pulled from the shelves, the bar code is scanned, and the retrieval is downloaded into the database. The inventory accounting and warehouse space allocation are adjusted accordingly. MSDS sheets, customer invoices, and bills of lading can be automatically generated.

In the case of a fire, the inventory management system can inform emergency responders on the amount of each chemical involved. Thus, access to inventory information off-site and in a timely manner should be made available.

3.10. Management of Change

Change is pervasive, a part of our lives. But change in the chemical warehouse creates potential risks which must be evaluated. Change may be gradual and slow, and thus go unnoticed; planned and scheduled; or abrupt and demanding. It may originate outside of the warehouse and affect the entire community where the warehouse is located, or it may be limited to the warehouse or even a single employee, product, or piece of equipment in the warehouse. Management of change involves a process from recognition of change, preferably before it occurs, assessment of the impact of the change on safety, to action to control the impact when appropriate.

Communication at all levels, including management and employees, will cultivate this awareness. Communication with local fire department officials, insurance carriers, cartage companies, suppliers, customers, or the community may also be required.

By maintaining a commitment to loss prevention, management can assess the real risks in any change and develop strategies to deal with them. Loss control professionals can assist management in determining loss potential and identifying solutions.

Documented procedures and parameters for the safe operation of the warehouse are important tools in managing change. Even minor changes in maintenance procedures such as the temperature in the warehouse may have serious consequences.

Staff changes require an awareness of the potential impact on operations. Temporary leave, such as vacation, labor disputes, or illness, may involve employee shortages or untrained temporary laborers. Increased supervision or establishing training requirements for employees temporarily assigned to different duties may be necessary in such cases. Management should assure through documentation of procedures and

training that no voids are left in institutional knowledge or assigned roles when employees leave.

Changes in occupancy, such as the types of chemicals and associated hazards, repackaging and transfer activities, product packaging, or method of storage can create new risks.

Such changes in occupancy may necessitate:

- upgrading the warehouse sprinkler system;
- installation of a treatment system or cylinder containment vessel when storing toxic compressed or liquified gases;
- new storage arrangements;
- separation of incompatible chemicals;
- additional staff training;
- fire department notification;
- neighboring occupancy notification;
- changes in the inventory database;
- additional MSDS;
- changes in the emergency plan (see Chapter 9);
- expansion or modification of the facility.

When designing a fire protection system, management should consider not only the company's current operations, but also plans for the facility and future operational needs. If changes in occupancy or storage arrangements are likely, it is usually less costly to anticipate these changes in the original design, rather than retrofit later.

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