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ERRATUM

On page 15, the definition of EVC *in C.1 should read as follows:*

EVC = equilibrium vapor concentration at 20°C, defined as the substance vapor pressure at 20°C, in millimeters of mercury, multiplied by 10^6 and then divided by 760. Multiplying by 10^6 and dividing by 760 conforms to legislation adopted by the State of New Jersey.

The attached page is included for the convenience of those who wish to replace the current page 15 in their copy of Recommended Practice 750.

APPENDIX C—SUBSTANCE HAZARD INDEX

C.1 Substance Hazard Index (SHI) Calculation

The SHI is defined in 1.4.8 and is represented by the following expression:

$$\text{SHI} = \frac{\quad}{\text{ATC}}$$

Where:

EVC = equilibrium vapor concentration at 20°C, defined as the substance vapor pressure at 20°C, in millimeters of mercury, multiplied by 10^6 and then divided by 760. Multiplying by 10^6 and dividing by 760 conforms to legislation adopted by the State of New Jersey.

ATC = acute toxicity concentration, in parts per million, defined as the lowest reported concentration, based on recognized scientific test protocols, that will cause death or permanent injury to humans after a single exposure of 1 hour or less. Use of the American Industrial Hygiene Association's *Emergency Response Planning Guidelines* [19], where developed, would be equivalent to *ATC*.

C.2 Illustrative List of Substances

Table C-1 lists substances and corresponding SHIs and is from a publication of Organization Resources Counselors, Inc. [20] The table is for illustrative purposes only. The *ATC* values used in the evaluation are also shown. Note that the *ATC* values may change as new information is obtained, thus changing the SHI.

Table C-1—Illustrative List of Substances and Corresponding SHIs

CAS Number	Substance	Acute Toxicity Concentration	Substance Hazard Index
107-02-8	Acrolein	3.00	97807
814-68-6	Acrylyl chloride	2.40	164474
107-05-1	Allyl chloride	29.00	13793
107-11-9	Allylamine	13.80	18402
7664-41-7	Anhydrous ammonia	1000.00	8447
7784-42-1	Arsine	6.00	2500000
542-88-1	Bis (chloromethyl) ether	0.50	57895
10294-34-5	Boron trichloride	20.90	62453
7637-07-2	Boron trifluoride[a]	100.00	14618
7726-95-6	Bromine	10.00	22368
13863-41-7	Bromine chloride	10.00	263158
7789-30-2	Bromine pentafluoride	10.00	45132
353-50-4	Carbonyl fluoride	36.00	1428911
7782-50-5	Chlorine	20.00	335395
10049-04-4	Chlorine dioxide	10.00	139474
13637-63-3	Chlorine pentafluoride	5.70	530933
7790-91-2	Chlorine trifluoride	9.60	143914
542-88-1	Chloromethyl ether	0.53	74479
107-30-2	Chloromethyl methyl ether	5.40	46784
76-06-2	Chloropicrin	3.00	8772
460-19-5	Cyanogen	35.00	138158
506-77-4	Cyanogen chloride	4.80	278235
675-14-9	Cyanuric fluoride	0.30	526316
334-88-3	Diazomethane[a]	10.00	146184
19287-45-7	Diborane[a]	40.00	36546
7572-29-4	Dichloroacetylene	1.90	346260
4109-96-0	Dichlorosilane	27.20	55244
75-18-3	Dimethyl sulfide	1.20	442982
124-40-3	Dimethylamine	201.00	7855
75-78-5	Dimethyldichlorosilane	5.70	32087
75-04-7	Ethylamine	123.00	9253
371-62-0	Ethylene fluorohydrin	0.30	219298
151-56-4	Ethyleneimine	22.80	9580
7782-41-4	Fluorine[a]	25.00	58474
50-00-0	Formaldehyde	25.00	174737
110-00-9	Furan	4.30	150857
684-16-2	Hexafluoroacetone	27.50	209713

Management of Process Hazards

API RECOMMENDED PRACTICE 750
FIRST EDITION, JANUARY 1990

American Petroleum Institute
1220 L Street, Northwest
Washington, D.C. 20005

Management of Process Hazards

Production and Refining Departments

API RECOMMENDED PRACTICE 750
FIRST EDITION, JANUARY 1990

American Petroleum Institute

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FOREWORD

This recommended practice is intended to assist in the management of process hazards. The objective of this publication is to help prevent the occurrence of, or minimize the consequences of, catastrophic releases of toxic or explosive materials. This recommended practice addresses the management of process hazards in design, construction, start-up, operation, inspection, maintenance, and modification of facilities with the potential for catastrophic release.

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Suggested revisions are invited and should be submitted to the director of the Refining Department, American Petroleum Institute, 1220 L Street, N.W., Washington, D.C. 20005.

CONTENTS

Management of Process Hazards

SECTION 1—GENERAL

1.1 Purpose

This recommended practice is intended to assist in the management of process hazards. It is intended to help prevent the occurrence of, or minimize the consequences of, catastrophic releases of toxic or explosive materials. This recommended practice addresses the management of process hazards in design, construction, start-up, operation, inspection, maintenance, and modification of facilities. It applies specifically to processes and facilities with a potential for catastrophic release, as defined herein.

1.2 Objective, Management Systems, and Principles

1.2.1 OBJECTIVE AND MANAGEMENT SYSTEMS

The objective of process hazards management is prevention of catastrophic releases. This can be realized through management systems addressing the following 11 areas:

a. Process safety information.
b. Process hazards analysis.
c. Management of change.
d. Operating procedures.
e. Safe work practices.
f. Training.
g. Assurance of the quality and mechanical integrity of critical equipment
h. Pre-start-up safety review.
i. Emergency response and control.
j. Investigation of process-related incidents.
k. Audit of process hazards management systems.

1.2.2 PRINCIPLES

This recommended practice is based on the following principles:

a. Facilities with a potential for catastrophic release are designed, built, and maintained in a manner compatible with applicable industry codes and consensus standards.
b. Management of process hazards is an integral part of the design, construction, maintenance, and operation of a facility.
c. Support from executive management is essential to the overall success of process hazards management. Local management ensures that the management systems set forth in this recommended practice are in place, with clear accountability for implementation.
d. Process hazards management systems are maintained and kept up to date by means of periodic audits to ensure effective performance.
e. Management of process hazards minimizes business interruptions.

1.3 Scope

1.3.1 APPLICATIONS

1.3.1.1 This recommended practice is intended for facilities that use, produce, process, or store the following substances:

a. Flammable or explosive substances that are present in such quantity and condition that a sudden, catastrophic release of more than 5 tons of gas or vapor can occur over a matter of minutes, based on credible failure scenarios and the properties of the materials involved (see Appendixes A and B).
b. Toxic substances that have a substance hazard index (SHI) greater than 5000 (see Appendix C) and that are present in amounts above a threshold quantity.

1.3.1.2 Toxic substances commonly handled by the petroleum industry that meet the SHI criteria include hydrogen sulfide (H_2S), chlorine (Cl_2), hydrogen fluoride (HF), and ammonia (NH_3). The following facilities are examples of those to which this recommended practice may be applicable, based on the criteria of 1.3.1.1, Item b:

a. Hydrogen sulfide and sulfur recovery facilities.
b. Chlorine handling and storage facilities.
c. Hydrogen fluoride alkylation and storage facilities.
d. Ammonia storage and refrigeration facilities.

An illustrative list of substances, along with calculated SHI values, is included in Appendix C as Table C-1.

1.3.2 APPLICABILITY OF RECOMMENDED PRACTICE

This recommended practice was developed for refineries, petrochemical operations, and major processing facilities. The following operations are not within the scope of this recommended practice:

a. Distribution, retail, and jobber operations.
b. Liquefied natural gas (LNG) facilities and pipeline and

transportation operations regulated by the U.S. Department of Transportation (DOT).
c. Oil and gas well drilling, service, and production facilities and operations covered by the U.S. Minerals Management Service (MMS).
d. Natural gas processing facilities excluded by Appendix B.
e. Storage of hydrocarbon fuels solely for on-site consumption.
f. Storage of flammable or combustible nonreactive, bulk liquid materials at atmospheric pressure without benefit of chilling or refrigeration, and the transfer of those materials.

Storage facilities for liquefied petroleum gases, including surface facilities for underground storage caverns, are within the scope of this recommended practice, unless specifically excluded by Item d above.

When measures are taken in accordance with this recommended practice, such measures should conform to the most current provisions of any applicable, federal, state, or local regulations.

1.4 Definitions

1.4.1 A *catastrophic release* is a major release involving one or more dangerous substances that leads to serious danger to persons both within and outside the workplace and results from uncontrolled developments.

1.4.2 *Critical equipment* refers to vessels, machinery, piping, alarms, interlocks, and controls determined by the management to be vital to preventing the occurrence of a catastrophic release.

1.4.3 A *dangerous substance* is a material possessing flammable or explosive properties as addressed in 1.3.1.1, Item a, or a toxic material as described in 1.3.1.1, Item b.

1.4.4 A *facility* comprises the buildings, containers, and equipment that could reasonably be expected to participate in a catastrophic release as a result of their being physically interconnected or of their proximity and in which dangerous substances are used, stored, manufactured, handled, or moved.

1.4.5 *Process* refers to the activities that constitute use, storage, manufacture, handling, or movement in all facilities that contain dangerous substances.

1.4.6 *Process hazards analysis (PHA)* is the application of one or more analytical techniques that aid in identifying and evaluating process hazards.

1.4.7 *Serious danger* refers to the potential for serious injury to persons within and outside the workplace, including permanent injury to health, whether resulting immediately from the catastrophic release or as a delayed effect.

1.4.8 The *substance hazard index (SHI)* is an index developed to identify objectively the toxic chemicals or substances that could be involved in a catastrophic release. The index is a simple function of vapor pressure and toxicity; the higher a substance's vapor pressure, the more readily it will enter the atmosphere in the event of a release. The greater a substance's toxicity, the lower the concentration required to present a hazard, and the higher its SHI. A more detailed definition, along with an illustrative list of substances and their SHIs, is presented in Appendix C.

1.4.9 *Threshold quantity* refers to the amount of a toxic substance that, if released, could cause serious danger as a result of exposures of 1 hour or less. Threshold quantities should be estimated for the facility using engineering judgment and available dispersion modeling techniques.

1.4.10 *Uncontrolled developments* are occurrences that are likely to develop quickly, to be outside the normally expected range of operating problems, to present only limited opportunity for preventive action, and to require any such action to be in the nature of an emergency response.

1.5 Referenced Publications

The most recent editions of the following publications are cited in this recommended practice:

API

RP 14C	*Recommended Practice for Analysis, Design, Installation and Testing of Basic Surface Safety Systems on Offshore Production Platforms*
RP 55	*Oil and Gas Production and Gas Processing Plant Operations Involving Hydrogen Sulfide*
Publ 510	*Pressure Vessel Inspection Code—Maintenance Inspection, Rating, Repair, and Alteration*
Publ 2007	*Safe Maintenance Practices in Refineries*
Std 2510	*Design and Construction of Liquefied Petroleum Gas (LPG) Installations*
Publ 2510A	*Fire-Protection Considerations for the Design and Operation of Liquified Petroleum Gas (LPG) Storage Facilities*

OSHA[1]

"Employee Emergency Plans and Fire Prevention Plans" [29 *Code of Federal Regulations* Section 1910.38(a)]

"Fire Brigades" (29 *Code of Federal Regulations* Section 1910.156)

"Hazardous Waste Operations and Emergency Response" (29 *Code of Federal Regulations* Section 1910.120)

[1]Occupational Safety and Health Administration, U.S. Department of Labor. The *Code of Federal Regulations* is available from the U.S. Government Printing Office, Washington, D.C. 20402.

SECTION 2—PROCESS SAFETY INFORMATION

2.1 General

A documented compilation of process safety information should be developed and maintained for any facility subject to this recommended practice. This information will provide the foundation for identifying and understanding the hazards involved in the process. It should include an assessment of the hazards presented by all materials, including toxicity information, permissible exposure limits, physical data, thermal and chemical stability data, reactivity data, corrosivity data, and the hazardous effects of inadvertent mixing of materials. The process safety information should also include information on process and mechanical design. The individual elements of the process safety information may exist in various forms and locations and may be referenced in the compilation.

2.2 Process Design Information

2.2.1 The process design information should include a block flow diagram or simplified process flow diagram; the process chemistry; the maximum intended inventory; acceptable upper and lower limits, where applicable, for items such as temperatures, pressures, flows and compositions; and the safety-related consequences of deviations. Where process design material and energy balances are available, these should be included.

2.2.2 When the process design is changed, the process design information should be updated in accordance with Section 4.

2.2.3 Where the original process design information no longer exists, information may be developed in conjunction with a process hazards analysis in sufficient detail to support the analysis.

2.3 Mechanical Design Information

2.3.1 The mechanical design information should include the materials of construction, piping and instrument diagrams [process and instrument diagram (P&ID)], the electrical area classification, the design and basis of the relief system, the design of the ventilation system, equipment and piping specifications, a description of shutdown and interlock systems, and the design codes employed. When changes are made, this information should be updated in accordance with Section 4.

2.3.2 The mechanical design should be consistent with the applicable consensus codes and standards in effect at the time the design is prepared or, in the absence of such codes and standards, recognized and generally accepted engineering practices. When the mechanical design is not consistent with applicable consensus codes and standards, the deviation and its design basis should be documented. When a process hazards analysis or other review reveals that existing equipment is designed and constructed in accordance with consensus codes, standards, or practices that are no longer in general use, procedures should be implemented to ensure that the equipment is fit for its intended use.

2.3.3 Where the original mechanical design information no longer exists, information may be developed from available equipment and inspection records.

2.4 Working Knowledge

Procedures should be in place to ensure that each individual with responsibility for managing the process has a working knowledge of the process safety information appropriate to his or her responsibilities.

SECTION 3—PROCESS HAZARDS ANALYSIS

3.1 Application

A process hazards analysis (PHA) should be performed for any facility subject to this recommended practice. The purpose of this analysis is to minimize the likelihood of the occurrence and the consequences of a dangerous substance release by identifying, evaluating, and controlling the events that could lead to releases.

3.2 Methodology

3.2.1 GENERAL

The PHA should take an orderly, systematic approach, following one or more methodologies such as those recommended in Reference 1 or 2 or API Recommended Practice 14C. The PHA should include the basic steps described in 3.2.2 through 3.2.4.

3.2.2 IDENTIFICATION

Based on the process safety information, expertise, and experience with similar facilities, failure scenarios that could result in a catastrophic release should be identified.

3.2.3 ASSESSMENT

The likelihood and consequences of the failure scenarios should be assessed using qualitative or quantitative techniques judged to be appropriate.

3.2.4 ALTERNATIVES

Feasible changes to reduce the risk of occurrence and the consequences of the failure scenarios should be identified.

3.3 Initial Analysis

3.3.1 The PHAs for existing facilities should be performed in order of priority. The following factors should be considered when establishing priority:

a. High SHI value or large quantities of toxic, flammable, or explosive substances.
b. Proximity to a populous area or a plant location where large numbers of workers are present.
c. Process complexity, including strongly exothermic reactions or secondary reactions.
d. Severe operating conditions, such as high temperatures or pressures, or conditions that cause severe corrosion or erosion.

3.3.2 The PHA for a new process or facility and recommendations resulting from the PHA should be completed before start-up. In performing the PHA for a new process or facility, special consideration should be given to the following:

a. Previous experience with the process.
b. Design circumstances, such as shorter-than-normal design periods or changes in the design team or the design itself after the project is under way.

3.4 Periodic Analyses

PHAs should be reviewed and updated periodically, with typical review intervals ranging between 3 and 10 years. The priority factors listed in 3.3 and changes in technology or in the facility (see Section 4) should be considered in establishing review frequency. Management should establish a program to accomplish this.

3.5 Analysis Team

The initial and periodic PHAs should be performed by a team of persons knowledgeable in engineering, operations, design, process, and other specialities deemed appropriate. At least one member of the team should be intimately familiar with the PHA techniques being employed, and at least one should not have participated in the original design of the facility. Participants should have detailed knowledge specific to the process being evaluated or should have access to that knowledge.

3.6 Analysis Report

A written PHA report that presents the analysis team's findings and recommendations should be prepared. Management should establish a system to address the report's findings and recommendations, to document the actions taken, and to communicate the findings and recommendations to appropriate personnel.

SECTION 4—MANAGEMENT OF CHANGE

4.1 General

A facility is subject to continual change to increase efficiency, improve operability and safety, accommodate technical innovation, and implement mechanical improvements. On occasion, temporary repairs, connections, bypasses, or other modifications may be made out of operating necessity. Any of these changes can introduce new hazards or compromise the safeguards built into the original design. Because of the inherent complexity of processing facilities, care must be taken to understand the process safety implications of any changes made. Appropriate process hazards management systems should be put in place to help ensure that hazards associated with a change are identified and controlled.

4.2 Types of Changes

4.2.1 GENERAL

There are two types of change in processing facilities: change in technology and change in facilities. Although some changes may be minor, with little likelihood of compromising process safety, all changes have the potential for disruption.

4.2.2 CHANGE IN TECHNOLOGY

Change in technology arises whenever the process or mechanical design is altered. Change in technology may also occur as a result of changes in feedstocks, catalysts, product specifications, by-products or waste products, design inventories, instrumentation and control systems, or materials of construction. Typical instances in which change in technology would likely occur include the following:

a. New facility projects that involve tie-ins or equipment modifications on existing units.
b. Projects to increase facility throughput or accommodate different feedstocks or products.
c. Significant changes in operating conditions, including pressures, temperatures, flow rates, or process conditions different from those in the original process or mechanical design.

d. Equipment changes, including the addition of new equipment and modifications of existing equipment. These can include changes in alarms, instrumentation, and control schemes.
e. Modifications of the process or equipment that cause changes in the facility's relief requirements. These can include increased process throughput, operation at higher temperatures or pressures, increased size of equipment, or the addition of equipment that might contribute to greater relief requirements.
f. Bypass connections around equipment that is normally in service.
g. Changes in operating procedures, including procedures for start-up, normal shutdown, and emergency shutdown.
h. Changes made in the process or mechanical design or in operating procedures that result from a PHA performed as described in Section 3.
i. Introduction of new or different process additives (for example, corrosion control agents, antifoulants, antifoam agents).

4.2.3 CHANGE IN FACILITIES

Change in facilities occurs whenever mechanical changes are made that would not necessarily appear on a process and instrument diagram. Temporary connections or replaced components that are "not in kind" represent change in facilities. Specifically, these can include the following:

a. Replacement equipment or machinery that differs from the original equipment.
b. Temporary piping, connections, or hoses.
c. Pipe clamps.
d. Temporary utility connections.
e. An alternative supply of process materials, catalysts, or reactants, such as through temporary drums or tanks located within the facility.
f. Temporary electrical equipment or connections.

4.3 Managing the Changes

Management should establish and implement written procedures to manage change in technology and change in facilities. These procedures should be flexible enough to accommodate both major and minor changes and should be understood and used. These procedures should consider the following factors:

a. The process and mechanical design basis for the proposed change.
b. An analysis of the safety, health, and environmental considerations involved in the proposed change, including, as appropriate, a PHA. The effects of the proposed change on separate but interrelated upstream or downstream facilities should also be reviewed.
c. The necessary modifications of the operating procedures.
d. Communication of the proposed change and of the consequences of that change to appropriate personnel.
e. The necessary documentation for the proposed change.
f. The duration of the change.
g. Required authorizations.

SECTION 5—OPERATING PROCEDURES

5.1 Content of Operating Procedures

Written operating procedures, which specify the following information, should be provided for any facility subject to this recommended practice:

a. The position of the person or persons responsible for each of the facility's operating areas.
b. Clear instructions for the safe operation of each facility that are consistent with the process safety information.
c. Operating conditions and steps for the following phases of operation:
   1. Initial start-up.
   2. Normal operation.
   3. Temporary operations as the need arises.
   4. Emergency operations, including emergency shutdowns, and the position of the person or persons who may initiate these procedures.
   5. Normal shutdown.
   6. Start-up following a turnaround.
d. The operating limits resulting from the information specified in 2.2.1 and, where safety considerations are present, a description of the following:
   1. The consequences of deviation.
   2. The steps required to correct or avoid deviation.
   3. Safety systems and their functions.
e. Occupational safety and health considerations, including the following:
   1. The properties of and hazards presented by the materials used in the process.
   2. The special precautions required to prevent exposure, including engineering controls and personal protective equipment.
   3. The control measures to be taken if physical contact or airborne exposure occurs.
   4. Any special or unique hazards.

5.2 Completion of Operating Procedures

For new and modified facilities, the operating procedures described in 5.1 should be in place before start-up.

5.3 Periodic Review

When changes are made in technology or facilities, operating procedures should be reviewed as described in Section 4. In addition, operating procedures should be reviewed periodically to ensure that they reflect current operating practice. The frequency of the review should correspond to the degree of hazard presented; typical review intervals range between 3 and 5 years. Review or changes of the procedures should be documented.

SECTION 6—SAFE WORK PRACTICES

6.1 General

Safe work practices should be established to ensure the safe conduct of operating, maintenance, and modification activities and the control of materials and substances that could affect process safety. These safe work practices will usually apply throughout the entire location and will normally be in written form. For new and modified facilities, these practices should be in effect before start-up.

6.2 Safe Conduct of Work Activities

Safe work practices should provide for the safe conduct of operating, maintenance, and modification activities, specifically including the opening of process equipment or piping, lockout and tagout of electrical and mechanical energy sources, work that involves ignition sources, entry into confined spaces, and use of cranes and similar heavy equipment. A work authorization system should be an element of the safe work practices.

Work practices should conform to the most current provisions of any applicable federal, state, or local regulations.

6.3 Control of Materials

Raw materials, catalysts, and other process materials that could affect process safety should be identified. Specifications and inventories critical to process safety should be determined and documented. Quality control procedures should be established to ensure that all identified materials received and used meet the specifications.

SECTION 7—TRAINING

7.1 General

Training should be provided for all personnel responsible for operating the facility, in accordance with their duties and responsibilities. Training should address the operating procedures recommended in Section 5, including any change in technology or facilities.

7.2 Initial Training

Qualification criteria should be developed for operating personnel. Procedures should be developed to ensure that persons assigned to operate the facility possess the required knowledge and skills to carry out their duties and responsibilities, including start-up and shutdown.

7.3 Periodic Training

Refresher training should be provided to ensure that facility personnel understand and adhere to the facility's current operating procedures. This training should be provided at least every 3 years. Alternatively, procedures should be established to ensure adequate retention of the required knowledge and skills.

7.4 Communication of Change

Whenever a change is made in the operating procedures recommended in Section 5, all operating personnel should be trained in or otherwise informed of the change before they are expected to operate the facility.

7.5 Instructor Qualifications

Written criteria and procedures should be developed to ensure that instructors are qualified.

7.6 Documentation

Training should be documented.

SECTION 8—ASSURING THE QUALITY AND MECHANICAL INTEGRITY OF CRITICAL EQUIPMENT

8.1 General

Critical equipment for any facility subject to this recommended practice should be designed, fabricated, installed, and maintained in a manner consistent with the service requirements.

8.2 Fabrication

Written quality control procedures that track critical equipment during the fabrication stage should be established and implemented to ensure that materials and construction are in accordance with the design specifications.

8.3 Installation

Appropriate checks and inspection procedures should be established and implemented before start-up to ensure that the installation of equipment is consistent with design specifications and the manufacturer's instructions.

8.4 Maintenance Systems

Maintenance systems that include appropriate inspection and testing should be established and implemented for critical equipment to ensure ongoing mechanical integrity. The maintenance systems should include the following provisions:

a. Maintenance procedures and work practices that ensure the mechanical integrity of equipment (see API Publication 2007).
b. Training of maintenance employees in the application of the procedures.
c. Quality control procedures to ensure that maintenance materials and spare equipment and parts meet design specifications.
d. Procedures to ensure that maintenance employees and contractors are qualified.
e. Procedures to ensure that all changes in technology and facilities are appropriately reviewed and implemented in accordance with Section 4.

8.5 Testing and Inspection

Inspection and testing programs for critical equipment should be established. Such programs should include the following items:

a. A list of critical equipment and systems that are subject to testing and inspection. This list should include pressure vessels and storage tanks; critical piping; relief systems and devices; emergency shutdown systems; and critical controls, alarms, and interlocks. The list should specify the method and frequency of testing and inspection, acceptable limits, and criteria for passing the test or inspection.
b. Testing and inspection procedures that follow commonly accepted standards and codes, such as API 510 or the API *Guide for Inspection of Refinery Equipment* [3].
c. Documentation of completed testing and inspection. In general, to assist in determining any needed changes in the frequency of testing, inspection, and preventive maintenance, documentation should be retained for the life of the equipment.
d. Procedures to correct equipment deficiencies or operations that are outside acceptable limits.
e. A system for reviewing and authorizing changes in tests and inspections.

SECTION 9—PRE-START-UP SAFETY REVIEW

Pre-start-up safety reviews should be performed for new and modified facilities that are subject to this recommended practice to confirm that the following criteria are met:

a. Construction is in accordance with specifications.
b. Safety, operating, maintenance, and emergency procedures are in place and are adequate.
c. PHA recommendations have been considered and completed, as appropriate.
d. Training of operating personnel has been completed.

SECTION 10—EMERGENCY RESPONSE AND CONTROL

10.1 Emergency Action Plan

An emergency action plan should be established in accordance with the most current provisions of the following OSHA regulations:

a. "Employee Emergency Plans and Fire Prevention Plans" [29 *Code of Federal Regulations* Section 1910.38(a)].
b. "Hazardous Waste Operations and Emergency Response" (29 *Code of Federal Regulations* Section 1910.120).

If fire brigades are established, they must comply with the current OSHA requirements under "Fire Brigades" (29 *Code of Federal Regulations* Section 1910.156).

10.2 Emergency Control Center

A designated emergency control center should be established and equipped with the following:

a. Plant layout and community maps.
b. Utility drawings, including the fire-water system.
c. Emergency lighting.
d. Emergency communications.
e. Appropriate reference materials, such as the following:
   1. Emergency plans.
   2. A list of government agencies to be notified.
   3. A list of the telephone numbers of company personnel.
   4. Technical materials (for example, Material Safety Data Sheets, procedures, and manuals).
f. A list of emergency response equipment (including locations) and mutual aid information.
g. Access to meteorological data.

10.3 Emergency Notifications

Where applicable, a plan should be established to comply with the emergency reporting and response requirements of federal and state environmental regulations.

SECTION 11—INVESTIGATION OF PROCESS-RELATED INCIDENTS

11.1 General

11.1.1 Incidents that result in, or could reasonably have caused, a catastrophic release should be investigated. Incident investigations should be initiated as promptly as possible, considering the necessity of securing the incident scene and protecting people and the environment, as well as the need to maintain and recover important evidence and testimony. The investigation should begin at the earliest possible time and should be formalized within a matter of days. The intent of the investigation is to learn from the incident, prevent a recurrence, and help prevent similar incidents.

11.1.2 An incident investigation team should be established and should consist of personnel knowledgeable in the process involved, investigation techniques, and other specialties that are viewed as relevant or necessary.

11.1.3 In appropriate circumstances, consideration should be given to establishing a "work-in-progress privilege" covering any documents generated during the course of an incident investigation or to conducting the entire investigation under attorney–client privilege.

11.2 Investigation

The investigation of an incident should address the following:

a. The nature of the incident.
b. The factors that contributed to the incident.
c. Recommended changes identified as a result of the investigation.

11.3 Follow–up

11.3.1 The findings of the investigation should be kept by the facility for possible use in the next PHA update.

11.3.2 Management should establish a system to determine and document the response to each finding to ensure that agreed-upon actions are completed.

11.3.3 Consideration should be given to providing the conclusions of the investigation to similar facilities within the company and, in some cases, to sharing the information with the industry.

SECTION 12—AUDIT OF PROCESS HAZARDS MANAGEMENT SYSTEMS

12.1 General

The ten areas of process hazards management presented in Sections 2 through 11 should be audited periodically to ensure effective performance. The audit team should be composed of one or more persons knowledgeable in the process involved and other specialties deemed necessary. An audit interval of 3 to 5 years is suggested.

12.2 Audit Reporting

The findings of the audit should be provided to the management personnel responsible for the facility. Management should establish a system to determine and document the appropriate response to the findings and to ensure satisfactory resolution. The audit report should be retained at least until the completion of the next audit.

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APPENDIX A—APPLICATION OF API RECOMMENDED PRACTICE 750 FOR FIVE TONS OF EXPLOSIVE VAPOR

A.1 Summary

API Recommended Practice 750 applies to any facility with the potential to release 5 tons of gas or vapor in a period of a few minutes. The 5-ton quantity was chosen because of its increased probability of igniting and developing explosive overpressures. Alternative concepts, such as an explosion equivalent to a given quantity of TNT, are more difficult to understand and require computations that may be unfamiliar to operating personnel.

A.2 Discussion

A.2.1 PROBABILITY OF IGNITION AND EXPLOSION

When a hydrocarbon vapor cloud forms, the cloud may dissipate harmlessly, be consumed by a flash fire without causing significant blast overpressures, or explode. Small leaks are much more likely to dissipate harmlessly than to ignite. For example, Kletz [4] has stated that in polyethylene plants, only 1 leak in 10,000 ignites. If the cloud ignites, blast effects will not develop unless the cloud is sufficiently large, the material is particularly reactive (as is hydrogen or ethylene), or the degree of confinement is unusually high.

Although vapor cloud explosions have occurred after releases as small as 1 ton, most of these explosions have occurred as a result of releases of more than 5 tons, according to Davenport's survey [5]. Prugh [6] has used information from Kletz [4] and Davenport [5] to develop a curve that relates the probability of explosion to the amounts of flammable vapor in the cloud. The curve indicates that the probability of an explosion after formation of a vapor cloud that contains 5 tons of hydrocarbon is about 5 percent, whereas releases of 1 ton or less have an explosion probability of less than 1 percent. The potential damage caused by a vapor cloud explosion is related to the size of the flammable cloud, and a 5-ton cloud can cause significantly greater damage than can a 1-ton cloud. Thus, 5 tons seems to be a reasonable threshold, based on catastrophic potential and probability of explosion.

A.2.2 POTENTIAL FOR LEAKS PRODUCING FIVE–TON HYDROCARBON CLOUDS

The rate and amount of material that can leak depends on the process conditions, the process inventory, and the process equipment. Leakage of 5 tons or more in a few minutes does not necessarily require a catastrophic vessel failure. Processes at modest pressures can leak at these rates as a result of, for example, rupture of a moderate-diameter pipe, failure of a significant portion of a gasket, or failure of a pump seal.

The amount of leaked material that vaporizes or is entrained as mist into a vapor cloud will vary with process and atmospheric conditions. For example, in a process in which liquid propane is handled at elevated temperatures and pressures, most of the material that leaks will immediately enter the vapor cloud by flash vaporization or entrainment. In this scenario, any combination of vessels and piping that has a total volume greater than about 300 cubic feet and that has a credible way of leaking 300 cubic feet of liquid propane in a few minutes has the potential to form a vapor cloud containing 5 tons of flammables.

APPENDIX B—NATURAL GAS PROCESSING AND ASSOCIATED LPG STORAGE

Many processes that involve sweet natural gas, such as dehydration and compression, present a low risk to public safety and health or to property outside the boundaries of the facility. Most natural gas has a density less than that of air, which aids in dispersion rather than formation of a drifting vapor cloud. Natural gas also has low reactivity and burning velocity. Extensive large-scale field tests have demonstrated that flame speeds in natural gas clouds are far below those that would produce dangerous overpressures [7, 8, 9].

Bull and Martin [10] noted, "It seems that by all mechanisms detonation of unconfined natural gas clouds is extremely unlikely." Confinement, such as in enclosed compressor buildings, can increase the risk of localized destruction; however, flame speeds decelerate very rapidly beyond the boundaries of the confinement and overpressure decreases markedly, even if well-mixed vapor clouds exist outside [11].

Thus, the major hazard presented by an accidental release of natural gas is from flame radiation if the cloud ignites [12, 13]. The risk to the general public is small, since facility boundaries are normally located well beyond the point at which dangerous heat radiation levels would exist. Since radiation intensity is inversely proportional to the square of the distance from the flame, spacing is a strong ally.

Extraction of natural gas liquids in a gas processing plant may constitute a process hazard, since products such as propane and butanes are among those recovered. Propane and butanes (commonly referred to as liquefied petroleum gases, or LPGs) have a vapor density greater than that of air and, if accidentally released under certain conditions, can form vapor clouds that may drift outside the facility boundary. These denser-than-air clouds (sometimes called heavy gas clouds) have been known to result in vapor cloud explosions with damaging overpressures [14, 15, 16]. Another major process hazard presented by a natural gas liquid recovery plant involves exposure of storage tanks to fire, possibly resulting in boiling-liquid/expanding-vapor explosions (BLEVEs). BLEVEs have expelled metal fragments as far as 1200 meters [17]. Offsetting these concerns, many natural gas liquid recovery plants are located in remote, sparsely populated areas and do not pose significant risk to the general public.

In view of the above, this recommended practice applies to natural gas processing and associated LPG storage as follows:

a. Processes involving natural gas without extraction of LPGs should be included in the scope if dangerous heat radiation levels (above 1600 British thermal units per hour per square foot) from a worst-case release would be imposed on the general public.

b. Processes with extraction of LPGs from natural gas, and associated storage or terminaling of LPG products, should be included in the scope unless either of the following criteria is met:

1. The facility is located more than 4000 feet from the general public.
2. No significant risk to the general public is demonstrated by credible case estimates of blast effects, radiant heat calculations, and dispersion modeling of all toxic or flammable materials.

For guidance on the design and operation of LPG storage facilities, refer to API Standard 2510 and API Publication 2510A. For general guidance on fire protection, see Reference 18.

c. All natural gas processes in which the hydrogen sulfide (H_2S) content of any stream is above 100 parts per million (by volume) should be included in the scope, unless dispersion modeling indicates there will be no impact on the general public (see also API Recommended Practice 55).

d. Except as specifically identified in this recommended practice, application of process hazards management and subsequent remedial action should be based on the identification of a significant risk to the general public, as demonstrated by credible case modeling (see Item b, Subitem 2, above.

APPENDIX C—SUBSTANCE HAZARD INDEX

C.1 Substance Hazard Index (SHI) Calculation

The SHI is defined in 1.4.8 and is represented by the following expression:

$$SHI = \frac{EVC}{ATC}$$

Where:

EVC = equilibrium vapor concentration at 20°C, defined as the substance vapor pressure at 20°C, in millimeters of mercury, multiplied by 10^6 and then divided by 760. Multiplying by 10^6 and dividing by 760 conforms to legislation adopted by the State of New Jersey.

ATC = acute toxicity concentration, in parts per million, defined as the lowest reported concentration, based on recognized scientific test protocols, that will cause death or permanent injury to humans after a single exposure of 1 hour or less. Use of the American Industrial Hygiene Association's *Emergency Response Planning Guidelines* [19], where developed, would be equivalent to *ATC*.

C.2 Illustrative List of Substances

Table C-1 lists substances and corresponding SHIs and is from a publication of Organization Resources Counselors, Inc. [20] The table is for illustrative purposes only. The *ATC* values used in the evaluation are also shown. Note that the *ATC* values may change as new information is obtained, thus changing the SHI.

Table C-1—Illustrative List of Substances and Corresponding SHIs

CAS Number	Substance	Acute Toxicity Concentration	Substance Hazard Index
107-02-8	Acrolein	3.00	97807
814-68-6	Acrylyl chloride	2.40	164474
107-05-1	Allyl chloride	29.00	13793
107-11-9	Allylamine	13.80	18402
7664-41-7	Anhydrous ammonia	1000.00	8447
7784-42-1	Arsine	6.00	2500000
542-88-1	Bis (chloromethyl) ether	0.50	57895
10294-34-5	Boron trichloride	20.90	62453
7637-07-2	Boron trifluoride[a]	100.00	14618
7726-95-6	Bromine	10.00	22368
13863-41-7	Bromine chloride	10.00	263158
7789-30-2	Bromine pentafluoride	10.00	45132
353-50-4	Carbonyl fluoride	36.00	1428911
7782-50-5	Chlorine	20.00	335395
10049-04-4	Chlorine dioxide	10.00	139474
13637-63-3	Chlorine pentafluoride	5.70	530933
7790-91-2	Chlorine trifluoride	9.60	143914
542-88-1	Chloromethyl ether	0.53	74479
107-30-2	Chloromethyl methyl ether	5.40	46784
76-06-2	Chloropicrin	3.00	8772
460-19-5	Cyanogen	35.00	138158
506-77-4	Cyanogen chloride	4.80	278235
675-14-9	Cyanuric fluoride	0.30	526316
334-88-3	Diazomethane[a]	10.00	146184
19287-45-7	Diborane[a]	40.00	36546
7572-29-4	Dichloroacetylene	1.90	346260
4109-96-0	Dichlorosilane	27.20	55244
75-18-3	Dimethyl sulfide	1.20	442982
124-40-3	Dimethylamine	201.00	7855
75-78-5	Dimethyldichlorosilane	5.70	32087
75-04-7	Ethylamine	123.00	9253
371-62-0	Ethylene fluorohydrin	0.30	219298
151-56-4	Ethyleneimine	22.80	9580
7782-41-4	Fluorine[a]	25.00	58474
50-00-0	Formaldehyde	25.00	174737
110-00-9	Furan	4.30	150857
684-16-2	Hexafluoroacetone	27.50	209713

Table C-1—Continued

CAS Number	Substance	Acute Toxicity Concentration	Substance Hazard Index
10035-10-6	Hydrogen bromide (anhydrous)	50.00	430316
7647-01-0	Hydrogen chloride (anhydrous)	100.00	414829
74-90-8	Hydrogen cyanide	50.00	16132
7664-39-3	Hydrogen fluoride (anhydrous)	50.00	20263
7783-07-5	Hydrogen selenide	2.00	4473684
7783-06-4	Hydrogen sulfide	300.00	60575
13463-40-6	Iron pentacarbonyl	1.00	52632
625-55-8	Isopropyl formate	3.90	33738
75-31-0	Isopropylamine	74.70	8103
463-51-4	Ketene	1.70	7090557
126-98-7	Methacrylonitrile	10.00	7500
920-46-7	Methacryloyl chloride	1.40	37594
30674-80-7	Methacryloyloxyethyl isocyanate	0.43	244798
78-85-3	Methacrylaldehyde	25.00	6316
74-87-3	Methyl chloride	314.60	15550
79-22-1	Methyl chloroformate	4.64	28358
624-92-0	Methyl disulfide	0.30	96491
453-18-9	Methyl fluoroacetate	0.67	39277
421-20-5	Methyl fluorosulfate	0.50	92105
60-34-4	Methyl hydrazine	5.00	10000
74-88-4	Methyl iodide	23.20	18886
624-83-9	Methyl isocyanate	20.00	24803
74-93-1	Methyl mercaptan	100.00	16671
78-94-4	Methyl vinyl ketone	0.20	493421
74-89-5	Methylamine	500.00	5789
75-79-6	Methyltrichlorosilane	3.00	122807
3463-39-3	Nickel carbonyl	0.50	844737
10102-43-9	Nitric oxide[a]	250.00	5847
10102-44-0	Nitrogen oxides (NO_2, N_2O_4, N_2O_3)	50.00	18974
7783-54-2	Nitrogen trifluoride[a]	200.00	7309
8014-95-7	Oleum[b]	9.80	7309
20816-12-0	Osmium tetroxide	0.10	92105
7783-41-7	Oxygen difluoride[a]	0.15	9745614
10028-15-6	Ozone[a]	10.00	146184
19624-22-7	Pentaborane	3.00	75000
79-21-0	Peracetic acid	14.51	5442
594-42-3	Perchloromethyl mercaptan	10.00	8553
7616-94-6	Perchloryl fluoride	38.50	271770
75-44-5	Phosgene	1.00	1572368
7803-51-2	Phosphine	200.00	173579
10025-87-3	Phosphorus oxychloride	4.80	7675
106-96-7	Propargyl bromide	0.06	3947368
107-44-8	Sarin	0.10	22368
7783-79-1	Selenium hexafluoride[a]	5.00	292368
7803-52-3	Stibine	3.00	1315789
7446-11-9	Sulfur dioxide (liquid)	15.00	221140
5714-22-7	Sulfur pentafluoride	1.00	738158
7783-60-0	Sulfur tetrafluoride	20.90	368232
10086-47-2	Sulfur trioxide	9.80	25913
7783-80-4	Tellurium hexafluoride	1.00	7006579
10086-47-2	Tetrafluorohydrazine[a]	50.00	29237
75-74-1	Tetramethyl lead	3.70	7824
7719-09-7	Thionyl chloride	1.75	72180
10025-78-2	Trichlorosilane	27.20	23800
1558-25-4	Trichloro (chloromethyl) silane	0.40	98694
27137-85-5	Trichloro (dichloromethyl) silane	7.00	13158
79-38-9	Trifluorochloroethylene	86.60	62234
2487-90-3	Trimethoxysilane	7.50	15789

[a]Substance for which no vapor pressure data are available or that is a gas above its critical point at 20°C so that there is no vapor pressure in the traditional sense; a vapor pressure of 1111 millimeters of mercury was arbitrarily used.
[b]65 percent or more SO_3 by weight.

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1-1300—1/90— 1M (5D)
1-1300—2/90—2.5M (5D) C
1-1300—6/90—7.5M (9C) U

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