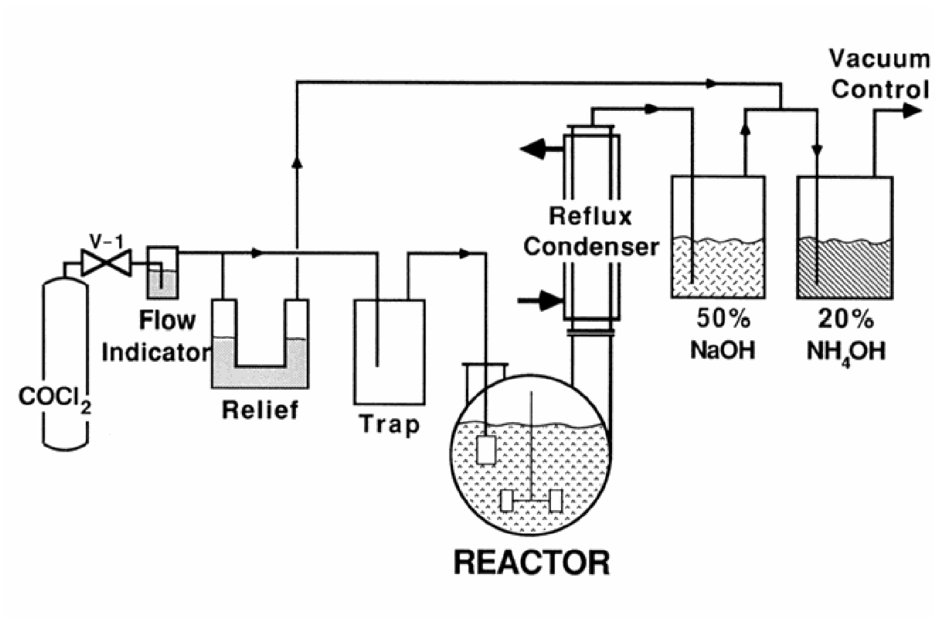
SAFETY IN THE CHEMICAL PROCESS INDUSTRIES

STUDY GUIDE

D. A. Crowl, C. DeFrain, A. Edelson

DVD Edition
2005



Wayne State University
Michigan Technological University

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WAYNE STATE UNIVERSITY
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VIDEOS

1. INTRODUCTION

Safety is becoming an increasingly important activity in the chemical industry. This is due to several recent significant chemical accidents, increasing public awareness and skyrocketing liability and accident costs.

This Study Guide is intended to accompany the video series *Safety in the Chemical Process Industries.* This video series presents a strong introduction on the application of chemical process safety technology in an actual chemical facility. All video material was taped at the Chemical Engineering Research Department at BASF Corporation in Wyandotte, Michigan. Most of the demonstrations are given using actual process equipment in the BASF Process Development (PD) facility.

This series is designed as instructional material for 1) undergraduate students in chemical or mechanical engineering, and 2) industrial engineers or chemists who are being introduced to industrial safety for the first time. This series provides significant supplementary material for an existing undergraduate chemical engineering course on chemical process safety.

This series was funded by the National Science Foundation and by BASF Corporation. Special thanks are given to 1) the contributing BASF presenters, 2) John Davenport and Stanley K. Stynes for introducing the segments, and 3) Robert J. Whitney for directing and managing the video production of this series. All of these individuals committed significant time and effort to the project.

We hope that the material presented in this series will be valuable for improving your awareness and practice of safety in your industrial experiences.

2. HOW TO USE THIS STUDY GUIDE

This Study Guide is designed to supplement, but not replace the video material. It can be effectively used for 1) taking notes during the viewing of the videos, 2) studying and reviewing the material after the initial showing, and 3) as a future reference. Almost all of the figures and diagrams shown in the videos are included in the Guide to assist the viewer.

The organization of the Study Guide is as follows. Each video segment has a well identified section within the Study Guide. The first page of each section introduces the segment. This includes a brief Overview, a list of Objectives, identification of the segment introducers and BASF Presenters, a list of Key Terms, and a list of Supporting Materials and References. The Key Terms listed are defined in the Glossary in Appendix I.

The succeeding pages present a detailed Outline of the material presented. This includes a blank section on the right hand side of the page for taking notes during the viewing. The video segments present the viewer with a number of lists of important concepts. These lists are given in the Outline section, enabling the viewer to concentrate on the material rather than excessive note taking. Important figures used in the series are also provided in the Outline.

3. BIOGRAPHIES OF THE PRESENTERS AND INTRODUCERS

(Note: These biographies are written in the present tense and reflect the status of the individuals at the time this study guide was originally produced in 1988).

Gerry Boicourt is a superviser in Chemical Engineering Research at BASF Corporation. He is responsible for scale-up activities and experiments for safety. These experiments include the Vent Sizing Package (VSP), explosive limit device and the dust bomb apparatus.

Mike Capraro is a manager in Chemical Engineering Research at BASF Corporation. Mike has several years experience in production and is more recently working on scale-up of processes. He is a member of the DIERS Users Group.

John Davenport is Director of Research at Industrial Risk Insurers, a major insurer of petroleum and chemical plants. He has extensive experience with fires and explosions, accident investigations, and safety inspections. He is particularly interested in accident case histories. He is a member of the AICHE Loss Prevention Committee and the AICHE/CCPS Undergraduate Education Committee.

Mark LaRue is a technician in quality control in Chemical Engineering Research at BASF Corporation in Wyandotte, MI.

Joe Louvar is Director of Chemical Engineering Research at BASF Corporation. He is also an Adjunct Faculty member in the Department of Chemical Engineering at Wayne State University. He is a member of the AICHE Loss Prevention Committee and the AICHE/CCPS Undergraduate Education Committee.

Rick Malechuk is a maintenance supervisor in Chemical Engineering Research at BASF Corporation in Wyandotte, MI.

Jim Strickland is a Manager of Construction and Operations at BASF Corporation. He is responsible for facilities operations, construction and the design of new pilot plant processes. He is also responsible for safety and environmental regulations adherence.

Stan Stynes is Professor of Chemical Engineering at Wayne State University. While he admits to being a recent newcomer in the area of chemical process safety, he understands its importance to the undergraduate educational experience and has taken steps to integrate concepts of safety, health and loss prevention into his courses.

4. ACKNOWLEDGEMENTS

The following individuals contributed to the production of this video series:

Executive Producer:	Daniel A. Crowl
Director:	Robert J. Whitney
Introducers:	John Davenport and Stanley K. Stynes
BASF Participants:	Gerry Boicourt, Mike Capraro, Mark LaRue, Joe Louvar, Rick Malechuk, Jim Strickland
Technical Reviewers:	Robert M. Bethea, John C. Friedly, Stanley S. Grossel, Joseph J. Levitsky, Robert W. Powitz, Robert M. Rosen, Richard F. Schwab, Leonard Wenzel
Study Guide Development:	Caron DeFrain, Daniel A. Crowl, Alvin L. Edelson
Lighting:	Rick DeGroot
Production Crew:	Peter I. Hendrix, Lisa A. Kret, Cathyrn C. McDowell, Thomas P. Schmidt. John C. Byrd

Segments of these tapes were produced as a special project of WTVS/56, Detroit, MI.

Project Coordinator:	Donald Sandberg

and were produced through the facilities of Continental Cablevision, Southfield, MI.

Unit Manager:	Shannon Kish
Technical Director:	Bob Davis
Production Crew:	David Cavanaugh, Reggie Smith

These videos were funded by The National Science Foundation and BASF Corporation.

DVD 1: INTRODUCTION AND LABORATORY AREAS

PART 1

INTRODUCTION TO SERIES

OVERVIEW

The video series on chemical process safety is introduced. The narrators introduce themselves, give definitions, describe the importance of safety, and describe the setting for the series.

OBJECTIVES

Alter viewing this tape, you should be able to:

- understand the importance of chemical process safety.
- define safety, health and loss prevention.

INTRODUCERS

John Davenport and Stanley K. Stynes

KEY TERMS

Safety

Health

Loss Prevention

SUPPORTING MATERIALS AND REFERENCES

1. D. A. Crowl and J. F. Louvar, *Chemical Process Safety: Fundamentals with Applications, 2nd ed.* (NY: Prentice Hall), 2002, Chapter 1: Introduction.

2. T. A. Kletz, *What Went Wrong? Case Histories of Process Plant Disasters* (Houston, TX: Gulf Publishing Co., 1985).

3. F. P. Lees, *Loss Prevention In the Process Industries,* 2nd ed. (London: Butterworth-Heinemann 1996), Chapter 1: Introduction; Chapter 2: Hazard, Accident and Loss.

4. Roy E. Sanders, *Chemical Process Safety: Learning from Case Histories* (London: Butterworth-Heinemann, 1999).

Introduction to Series

OUTLINE NOTES

I. Accident Statistics

   A. Chemical plants are the safest of all manufacturing facilities

   B. Accident costs are doubling every ten years

   C. Liability and worker disability costs are skyrocketing

   D. Public concern is increasing

   E. Safety is good business

II. Importance of safety in undergraduate chemical engineering instruction

   A. Safety cannot be ignored

   B. Industry is increasing safety instruction demands

   C. Accreditation is requiring safety instruction

III. Definitions

   A. Safety

   B. Health

   C. Loss prevention

IV. The BASF setting

   A. Demonstrations will occur in the Process Development (PD) area

   B. BASF has an outstanding safety program

   C. BASF's program is typical of the effort within the chemical process industry

DVD 1: INTRODUCTION AND LABORATORY AREAS

PART 2

INTRODUCTION TO CORPORATE SAFETY

OVERVEW

This unit introduces corporate safety, while contrasting a "good" safety program with an "outstanding" program. Key points to an outstanding safety program are emphasized.

OBECTIVES

After completing this unit, you should be able to:

- contrast a good safety program with an outstanding one.
- list several ways to achieve an outstanding safety program.
- describe the objectives of a safety program
- describe several ways to follow through on these objectives.

INTRODUCER

John Davenport

BASF PRESENTER

Joe Louvar

KEY TERMS

Safety Audit

Industrial Hygiene

Toxicology

SUPPORTING MATERIALS AND REFERENCES

1. F. P. Lees, *Loss Prevention in the Process Industries*, 2nd ed. (London: Butterworth-Heinemann, 1996). Chapter 6: Management and Management Systems.

2. V. C. Marshall*, Major Chemical Hazards (*New York, NY: John Wiley and Sons, 1987), Chapter 20: The Role of Management in the Control of Major Chemical Hazards.

3. Roy E. Sanders, *Chemical Process Safety: Learning from Case Histories* (London: Butterworth-Heinemann, 1999).

Introduction to Corporate Safety

OUTLINE | NOTES

I. Need for improved safety programs

II. A good safety program identifies and removes existing safety hazards.

III. An outstanding safety program prevents the existence of safety hazards. This is achieved by:

A. Company commitment (most important)

B. Visibility

C. Management support

1. BASF's safety policy objectives:

a. supervisors are responsible

b. everyone is responsible

c. safety is equal to production

d. serious about safety

2. Safety policy follow through

a. meetings

(1) discussion of accidents

(2) training

(3) inspection of facilities

(4) delegation of work

b. performance review - includes safety performance

c. safety audits

(1) audit team

(a) corporate safety

(b) site safety

OUTLINE NOTES

(c) toxicology and industrial hygiene

(2) activities of audit team

(a) review records

(b) make inspections

(c) conduct interviews

(d) rate performance

(e) make recommendations

DVD 1: INTRODUCTION AND LABORATORY AREAS

PART 3

LABORATORY SAFETY AND INSPECTIONS

OVERVEW

Safety In the laboratory is an important part of any corporate safety program. This segment focuses on laboratory safety concepts and gives detailed examples of safe versus unsafe laboratory situations.

OBJECTIVES

After you have completed this unit you should be able to:

- describe proper usage of laboratory hoods.
- identify safety features and equipment used in the laboratory.
- state the important parts of a chemical label.
- identify several hazardous laboratory situations and remedy them.

INTRODUCER

Stan Stynes

BASF PRESENTERS

Mike Capraro, Mark LaRue

KEY TERMS

Material Safety Data Sheet (MSDS)	Relief device
Face velocity	Velometer

SUPPORTING MATERIALS AND REFERENCES

1. D. A. Crowl and J. F. Louvar, *Chemical Process Safety: Fundamentals with Applications, 2nd ed.* (NY: Prentice Hall, 2002) Chapter 3: Industrial Hygiene

2. *Industrial Ventilation: A Manual of Recommended Practice*, 25th ed. (Cincinnati, OH: American Conference of Governmental Industrial Hygienists, 2004).

3. Prudent Practices in the Laboratory, Handling and Disposal of Chemicals (Washington, DC: National Academy Press, 1995).

Laboratory Safety and Inspections

OUTLINE NOTES

I. Laboratory safety

A. Safety glasses: must have side shields and must be ANSI Z87 certified and stamped.

B. Proper usage of laboratory hoods
Design criteria: 100 feet per minute (fpm) face velocity

1. hood must be checked

a. annually using a velometer

b. continuously by using a draft gauge which is mounted on the surface of the hood

2. Sashes must be set in the correct position to maintain an adequate face velocity across the hood

C. Safety features and equipment

1. eye washes: must continue to flow once activated

a. must be near work area.

b. must be used for a minimum of fifteen minutes

c. someone must assist

2. fire extinguishers

a. must be in the proper location, and unobstructed

b. must be in good condition

c. must be inspected monthly for these two features

Laboratory Safety and Inspections

OUTLINE NOTES

3. safety showers: used to extinguish fires and for chemical spills on clothing. Clothing must be removed.

4. buddy system - at least two people should work in an area at a time

5. storage of lab equipment

   a. segregate glassware from heavy metal objects

   b. dispose of broken glassware in a designated, rigid-walled container

6. Proper chemical storage

   a. do not store chemicals alphabetically

   b. store only compatibles together

   c. limit the amount of flammable storage on the benchtops

      (1) no more than two gallons in the open

      (2) safety cans used if you must exceed that amount

   d. properly label all samples and chemicals.

      (1) identity of contents

      (2) date material was acquired

      (3) disposal date

      (4) responsible staff member

      (5) hazardous characteristics

      (6) pertinent safety information

   e. all chemicals must be inventoried

      (1) ensures against expired outdates

OUTLINE NOTES

(2) ensures against reordering duplicate materials

f. order only what you need

g. properly dispose of material in an environmentally acceptable manner

h. Material Safety Data Sheets (MSDS) must be available. MSDS's include:

(1) physical property data

(2) safety information

(3) toxicology information

(4) must be stored in a centralized location for others to use.

II. Recognizing safety hazards

A. Situational remedy: Labeling and storage of laboratory chemicals during lab usage

1. limit the amount of solvent on the bench

2. move containers away from the edges and corners

3. make sure all materials are properly labeled

4. toxic materials should be stored in the hood

5. store bulk solvents in proper safety cans

B. Situational remedy: equipment procedures in hoods

1. provide for spill containment underneath any reaction flasks in the hood

2. use proper relief devices

3. inspect equipment before use for any unsafe conditions such as frayed cords

OUTLINE | NOTES

4. use an alternative method for preventing drafts across the mouth of the flask

5. make sure the sash is at the correct height to maintain adequate face velocity across the hood

C. Situational remedy: segregating and storing equipment in drawers

1. always keep sharp implements and syringes properly guarded

2. segregate glassware from metal objects

3. dispose of broken glassware

4. store mercury thermometers with care elsewhere

5. do not keep damaged fittings
   - discard or repair

D. Situational remedy: Mark in lab

1. always wear safety glasses

2. handle glassware property

3. shield any vacuum glassware

4. never eat, drink, or smoke in the lab

E. Situational remedy: poor housekeeping

1. store mercury thermometers carefully

2. always keep clear access to safety equipment

3. limit use of extension cords - use with care

4. inspect safety equipment on a routine regular basis

5. clean and dispose of all chemical containers properly

Laboratory Safety and Inspections

OUTLINE	NOTES
III. Summary: The laboratory can be a hazardous environment if proper safety procedures are not followed.	

DVD 1: INTRODUCTION AND LABORATORY AREAS

PART 4

PERSONAL PROTECTIVE EQUIPMENT

OVERVIEW

Personal protective equipment is an important aspect of handling chemicals safely. This segment demonstrates several different types of personal protective equipment.

OBJECTIVES

After this unit, you should be able to:

- state the rules for proper chemical handling.
- identify unsafe attitudes toward safety.
- identify various types of personal protective equipment and describe how it is used.

INTRODUCER

Stan Stynes

BASF PRESENTERS

Mike Capraro, Mark LaRue, Rick Malechuk

KEY TERMS

Airline mask

Airline Hood

Cartridge respirator

Canister respirator

Manufacturers technical information

Material Safety Data Sheet (MSDS)

Self contained breathing apparatus (SCBA)

SUPPORTING MATERIAL AND REFERENCES

1. H. H. Fawcett and W. S. Wood, Editors, *Safety and Accident Prevention in Chemical Operations,* 2nd Edition (New York, NY: John Wiley and Sons, 1982) Chapter 25: Respiratory Hazards and Protection, by H. H. Fawcett; Chapter 26: Eye Safety in Chemical Operations, by J. Nichols; Chapter 27: Other Personal Protective Equipment, by H. H. Fawcett.

2. H. H. Fawcett, *Hazardous and Toxic Materials* (New York, NY: John Wiley and Sons, 1984), Chapter 5: Personal Protective Equipment

Personal Protective Equipment

OUTLINE | NOTES

I. Rules for safe chemical handling

  A. Err on the safe side

  B. Review and establish safety properties of chemicals

  C. Take responsibility for safety

II. First line of defense for safety:

  A. Good engineering design

  B. Good operating procedures

  C. Wearing of proper personal protective equipment

III. Avoid these unsafe attitudes:

  A. laziness

  B. “tough guy”

  C. “good guy”

  D. vanity

IV. Sources of safety information

  A. Material Safety Data Sheet (MSDS)

  B. Manufacturer’s technical information

V. Safeguards for safety

  A. Wearing proper protective equipment

  B. Safety procedures

  C. Safety features

VI. Personal protective equipment

  A. Face protection

    1. safety glasses

Personal Protective Equipment

OUTLINE | NOTES

2. safety goggles
3. face shield
4. Hard hat

C. Apron

D. Gloves

1. protects hands and wrists
2. type used depends on situation

E. Special chemical suits

1. rubber
2. disposable

F. Foot protection

1. rubbers
2. steel safety-toe boot
3. high top boot - trousers outside

G. Respirators- require good facial fit

1. dust mask
2. cartridge respirator
3. canister respirator
4. airline mask
5. self-contained breathing apparatus
8. airline hood

DVD 2: PROCESS AREAS

PART I

PROCESS AREA SAFETY FEATURES

OVERVIEW

Safety features are designed to prevent accidents or reduce the impact in the event of an accident. Some of the safety features of the process area are shown and explained in this tape.

OBJECTIVES

After viewing this tape, you should be able to:

- define the term ‘eXplosion Proof’ (XP) and describe XP features.
- state the necessity for grounding and bonding.
- describe two types of ventilation.
- describe vessel overpressure protection systems describe double block and bleed.
- select a correct fail-safe valve given a situation requiring a fail safe action.

INTRODUCER

John Davenport

BASE PRESENTER

Jim Strickland

KEY TERMS

Bonding clamp	Grounding clamp
Colorimetric tubes	Grounding network
Dielectric union	Interlock
Double block and bleed	Normally closed
Elephant trunk	Normally open
Explosion proof (XP)	Relief valve
Fail-safe	Rupture disk
Fusible link	Spill alarm

Process Area Safety Features

SUPPORTING MATERIALS AND REFERENCES

1. H. H. Fawcett and William S. Wood, eds., *Safety and Accident Prevention in Chemical Operations,* 2nd Ed. (New York, NY: John Wiley and Sons, 1982), Chapter 6: Instrumentation for Safe Operation, by Donald Richmond.

2. T. A. Kletz, *Cheaper, Safer, Plants* (Warwickshire, England: The Institution of Chemical Engineers, 1985).

3. F. P. Lees, *Loss Prevention in The Process Industries*, 2nd ed. (London: Butterworth-Heinemann, 1996) Chapter 10: Plant Siting and Layout; Chapter 12: Pressure System Design; Chapter 13: Control System Design.

OUTLINE NOTES

I. explosion Proof (XP) features - eliminates or reduces ignition sources

   A. Design basis for XP fixtures:

      1. must be capable of containing the force of an explosion

      2. hot gases from an internal explosion are quenched and cooled before they are allowed to escape to the external environment

   B. XP electrical fixtures

      1. construction features:

         a. heavy duty cast metal

         b. flat machine-surfaced cover

         c. threaded holes on ends to run wires

      2. wires

         a. run through a special conduit fitting

         b. sealed in fitting with epoxy mixture

II. Ventilation - dilutes and removes flammable vapors

   A. Elephant trunk: provides spot ventilation

   B. Main ventilation system: has a high and low speed

      1. low speed: normal operation

Process Area Safety Features

OUTLINE | NOTES

2. high speed: used for a spill

III. Grounding system

A. grounding network around building: provides common ground for all units

B. grounding and bonding clamps: connects equipment to ground and to each other

IV. Safety features for adjacent control room:

A. Negative air pressure in PD area insures that flammable vapors do not travel to non-XP fixtures

B. Laminated plate safety glass window

1. Purposes

a. allows operator to see PD area without entering it

b. provides protection against projectiles or explosions

2. Fusible link releases metal plates to cover windows in event of a fire

V. Pressure vessel safeguards - every vessel must be protected against overpressure

A. Rupture disk - consists of a calibrated sheet of metal or other material which ruptures at a pre-set pressure

B. Safety relief valve - consists of a spring loaded valve which releases at a pre-set pressure

C. Rupture disks are frequently used to protect the safety relief valve from corrosive process fluid – tattle-tale or tell-tale pressure gauge must be installed to indicate leakage in rupture disk

Process Area Safety Features

OUTLINE | NOTES

VI. Additional safety features:

A. Sprinkler system

B. Fire alarm

C. Safety showers

D. Sewer drain plugs

E. Sewer isolation valve - stops spills from entering main sewer system

F. Panic button - to perform emergency shut-down of process

G. Spill alarm

H. Gas detection tubes

I. Fire extinguishers

J. Eyewash stations

VII. Double block and bleed - insures hazardous materials do not enter process vessel when personnel are inside. Procedure is:

A. Close both block valves

B. Open the bleed valve to ensure cut-off to the reactor

VIII. Corrosion

A. Occurs with dissimilar metals

B. A dielectric union is used to electrically insulate between the dissimilar metals

IX. Fail safe features of processes

A. Control valves

1. Normally closed valve

a. closed when air pressure is low

Process Area Safety Features

OUTLINE | NOTES

b. open when air pressure is high

2. Normally open valve

a. open when air pressure is low

b. closed when air pressure is high

B. Valve selection made according to required fail-safe action

1. Example: cooling an exothermic reaction - cooling water valve fails open to insure maximum cooling to the reactor - see Figure 2

2. Example: heating a volatile liquid - steam supply valve fails closed to terminate steam - see Figure 2/1-2.

X. Interlocks - insures that process events occur in the proper sequence - see Figure 2/1-3.

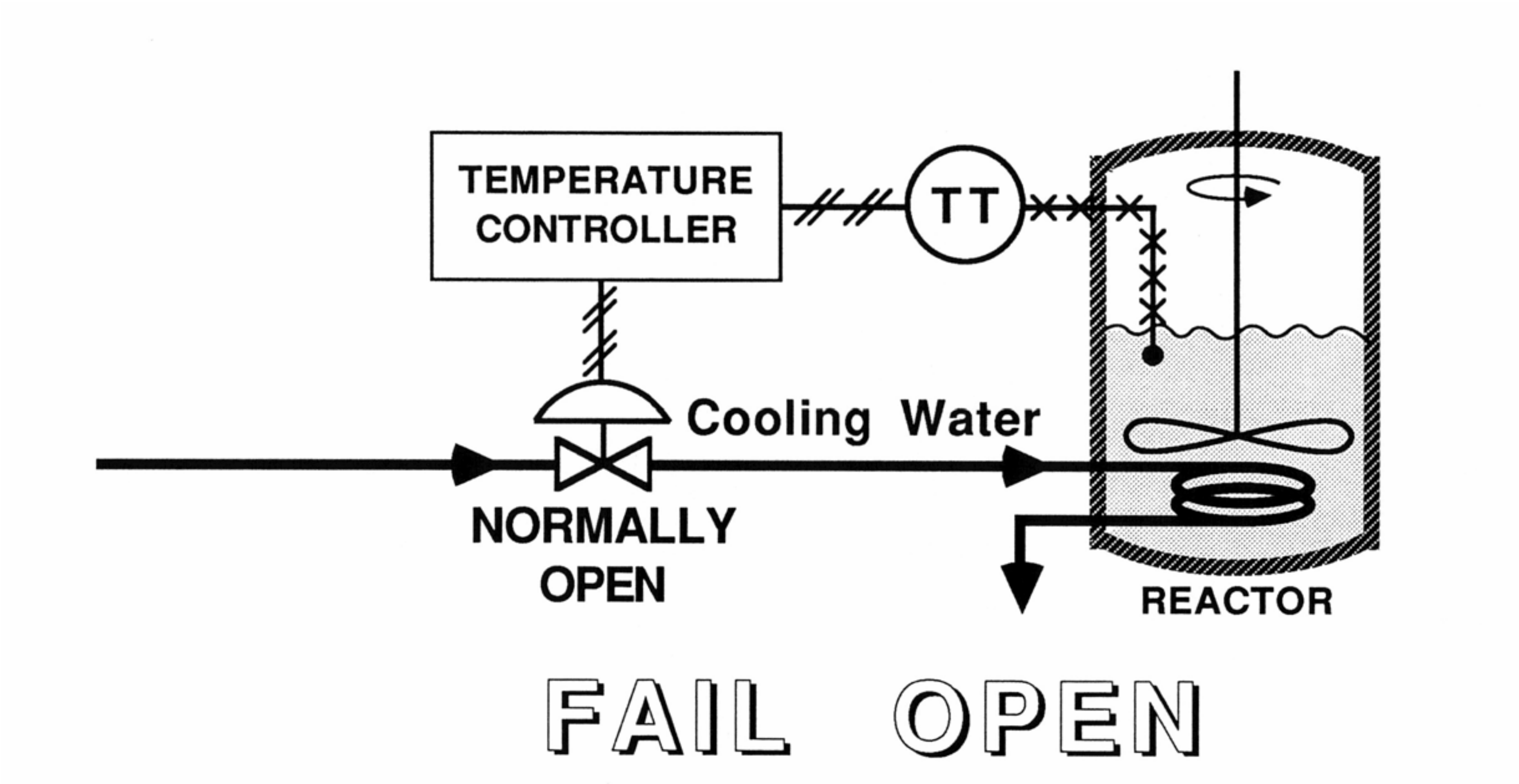

Figure 2/1-1: Control valve on cooling coils configured for fail open.

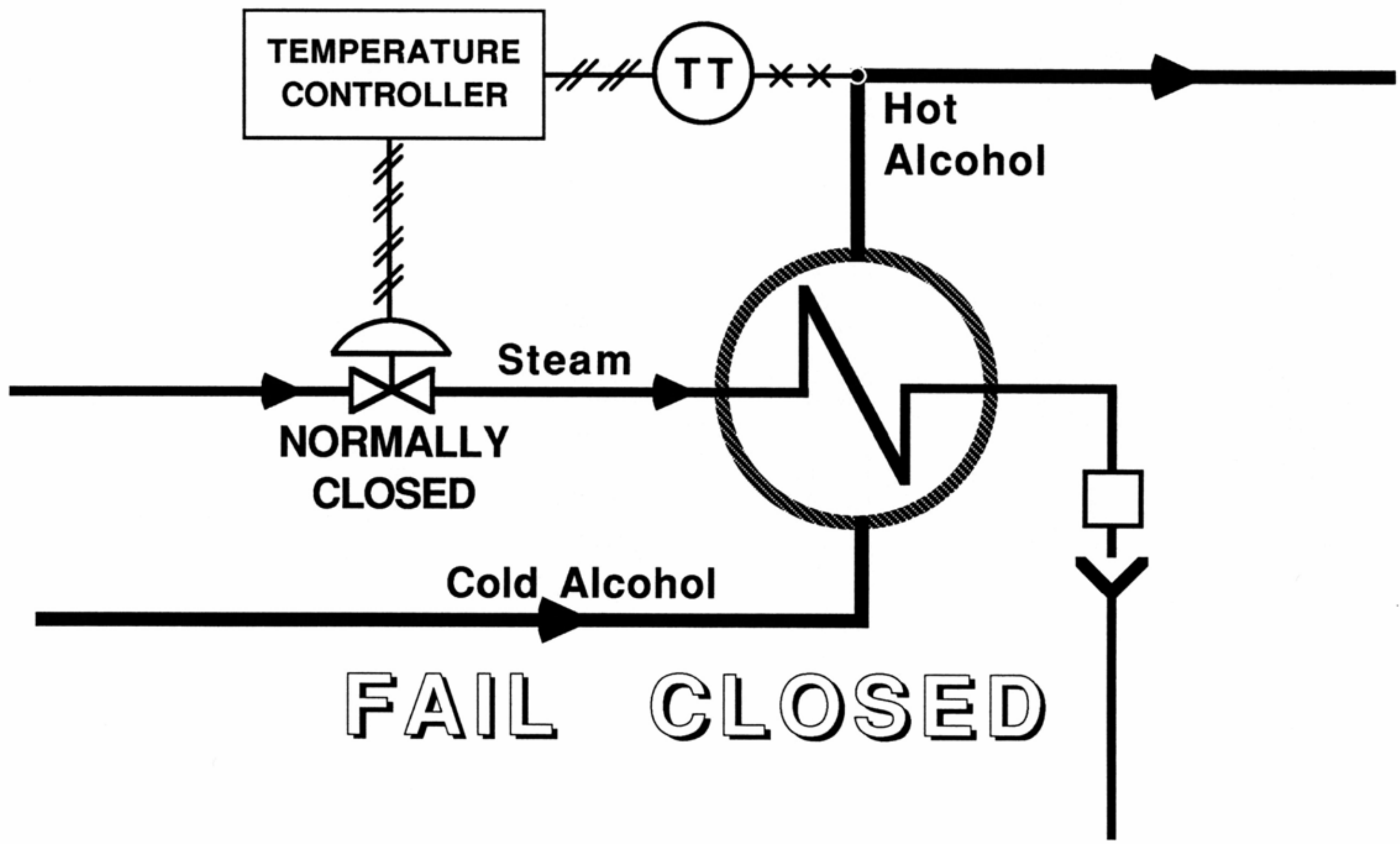

Figure 2/1-2: Control valve in heat exchanger steam line configured to fail closed.

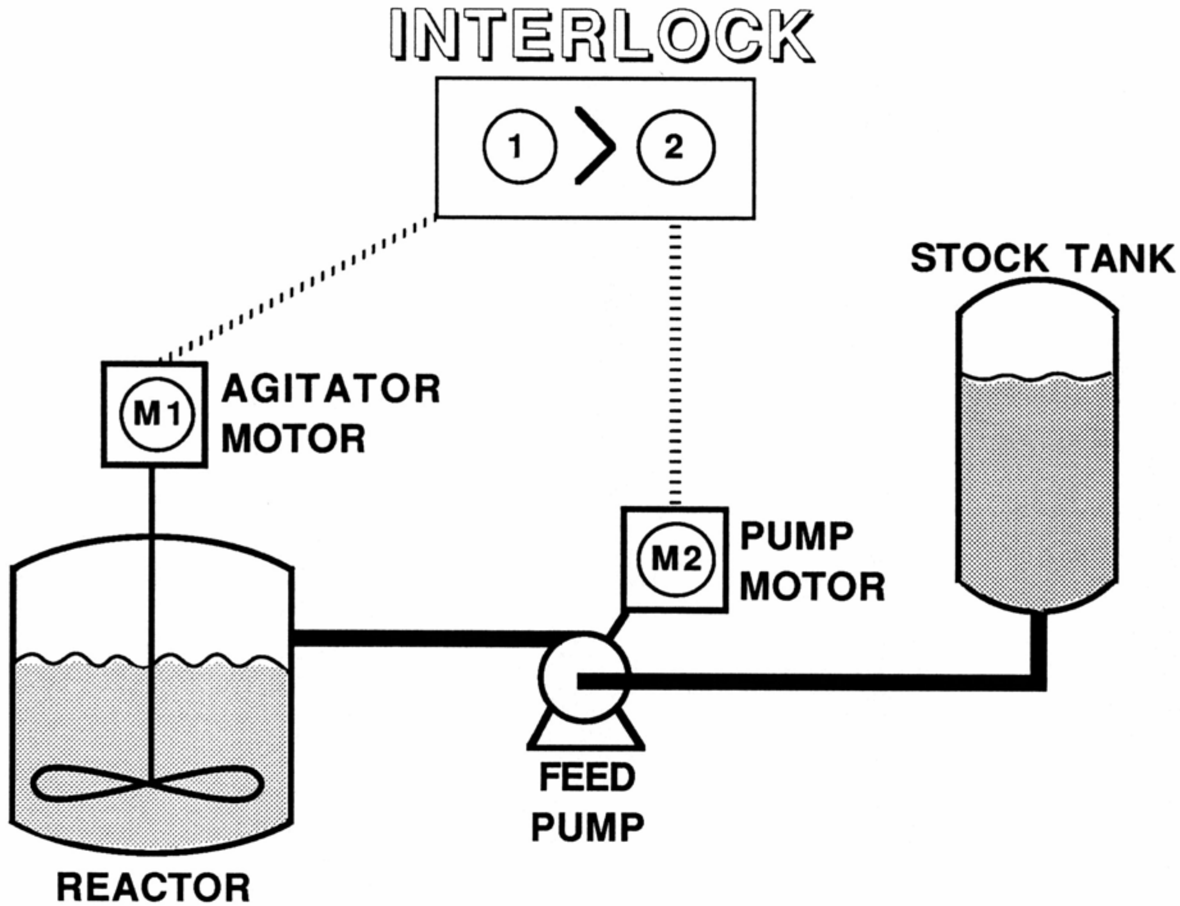

Figure 2/1-3: An interlock system. The feed pump cannot be activated unless the agitator is operating.

DVD 2: PROCESS AREAS

PART 2

PROCESS AREA SAFETY PROCEDURES

OVERVIEW

Hazardous materials are part of the daily operations in chemical plants. Special procedures have been developed to ensure safe handling of these materials. The procedures *are* explained and illustrated in this video.

OBJECTIVES

After you have finished this unit, you should be able to:

- state why and when a hot work permit is needed and describe the procedure.
- explain the Lock-Tag and Try procedure.
- identify the key points in the confined space entry procedure.
- describe a pressure vessel test procedure.
- explain how to transfer flammable liquids using a grounding / bonding procedure.

INTRODUCER

John Davenport

BASF PRESENTERS

Jim Strickland, Rick Malechuk

KEY TERMS

Bonding

Confined space

Dip leg

Elephant trunk

Grounding

Hot work permit

Lock, tag and try

Purging

Vessel pressure test

Process Area Safety Procedures

<u>SUPPLEMENTARY MATERIALS AND REFEFENCES</u>

1. H. H. Fawcett and William S. Wood, ed., *Safety and Accident Prevention in Chemical Operations* (New York, NY: John Wiley and Sons, 1982), Chapter 13: Maintenance of Chemical Equipment, by David T. Smith; Chapter 19: Safe Handling of Flammable and Combustible Materials, by William S. Wood; Chapter 31: Transportation of Hazardous Materials, by William S. Wood; Chapter 33: Tools and Techniques for Chemical Safety Training, by F. Owen Kubias; Chapter 36: Hazards in Chemical System Maintenance: Permits, by Trevor A. Kletz

2. F. P. Lees, *Loss Prevention in the Process Industries*, 2nd ed. (London: Butterworth-Heinemann, 1996), Chapter 20: Plant Operation; Chapter 21: Plant Maintenance and Modification; Chapter 23: Transport.

<u>OUTLINE</u>	<u>NOTES</u>

I. Hot Work Permit

  A. Issuing a hot work permit:

    1. work scheduled before hand

    2. all flammable solvents are removed or isolated

    3. flammable vapor detection meter used throughout the building

    4. flashing red light turned on to warn others

    5. hot work permit is issued

  B. Activities requiring a hot work permit:

    1. burning and welding

    2. using non-explosion proof tools

    3. using non-explosion proof fork truck

    4. sparking and grinding

II. Lock, Tag and Try Procedure - provides protection against electrical shocks, mechanical injury and exposure to chemicals. The procedure is:

  A. De-energize and lock switch

  S. Tag with notification

Process Area Safety Procedures

OUTLINE | NOTES

C. Try the switch to insure device can't be activated

III. Confined space entry procedure

A. Confined space defined as:

1. hole or trench
2. diked areas
3. reactors
4. storage vessels
5. large pipes

B. Key points of 14 point confined space entry procedure

1. area supervisor responsible
   a. insures all points in procedure are performed
   b. signs and issues document
2. isolate and clean space
3. can involve other procedures
   a. lock, tag and try
   b. hot work permit
   c. test for adequate oxygen (minimum of 19.5%)
4. provide a second attendant
5. emergency equipment in vicinity

C. Vessel entry demonstration

1. isolate piping
2. lock, tag and try power equipment

Process Area Safety Procedures

OUTLINE | NOTES

3. vessel must be cleaned and purged (oxygen>19.5%; 0% flammables and acceptable toxics)

4. Equipment:

   a. blower provides fresh air

   b. pressure respiratory equipment

   c. low voltage or GFCI power tools

   d. fire extinguisher (not $C0_2$)

   e. safety cuffs to facility emergency exit

   f. chain fall to help lift individual

   9. continuous air monitor

   h. 2-way radio

   I. ladder, if required

IV. Pressure vessel test procedure

A. Hydraulic test on pressure-rated vessels Done on a frequency dependent on use (normally once every 2 to 5 years)

B. Water is used - never gas

V. Transferring flammables using proper grounding and bonding procedures

A. Transferring a flammable liquid from a drum to a vessel:

1. purge the vessel several times with nitrogen to remove any oxygen, preventing an explosive atmosphere.

2. bond the drum to the vessel (the vessel Is already grounded to the building ground system)

4. remove bung from drum and insert dip leg

OUTLINE NOTES

5. bond dip leg to vessel

6. put elephant trunk over opening to provide ventilation

7. turn nitrogen on to displace liquid being drawn out of the drum – see Figure 2/2-1.

8. draw liquid into reactor using vacuum

B. Transferring of liquid from bucket to bucket

1. bond the two buckets together using bonding clamps

2. ground one bucket to the building ground using grounding clamps

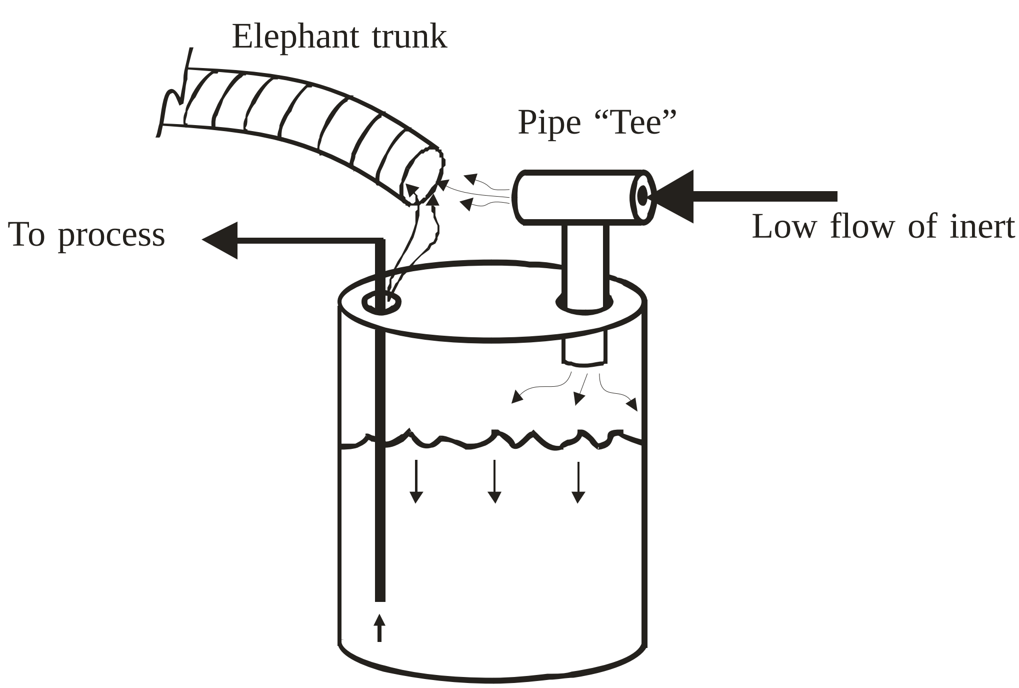

Figure 2/2-1: Inerting system for drum.

DVD 2: PROCESS AREAS

PART 3

PROCESS AREA INSPECTIONS

OVERVIEW

Process area inspections identify hazards before they result in an accident. A proper safety inspection requires experience, attention to detail, and motivation to identify hazards. This segment shows a number of common hazards in the process development (PD) area and how they are corrected.

OBJECTIVES

When you have finished this unit, you should be able to:

- identify the proper components of a safety relief system.
- identify a number of common, unsafe situations and how they are corrected.
- describe the proper procedure for charging hazardous materials to a reactor.

INTRODUCER

John Davenport

BASF PRESENTERS

Jim Strickland, Rick Malechuk

KEY TERMS

Bonding	Inerting
Check valve	Rupture disk
Grounding	Safety relief valve
Flange unions	Telltale gauge

SUPPLEMENTARY MATERIALS AND REFERENCES

1. D. A. Crowl and J. F. Louvar, *Chemical Process Safety: Fundamentals with Applications, 2nd ed.,*(NY: Prentice Hall), 2002, Chapter 6: Fires and Explosions; Chapter 7: Designs to Prevent Fires and Explosions; Chapter 8: Introduction to Reliefs; Chapter 9: Relief Sizing.

2. D. A. Crowl, *Understanding Explosions* (New York: AICHE, 2003).

Process Area Inspections

3. Thomas H. Pratt, *Electrostatic Ignitions of Fires and Explosions* (Marietta, GA: Burgoyne, Inc., 1997).

<u>OUTLINE</u> <u>NOTES</u>

I. Inspections:

   A. Performed on a regular basis: usually monthly

   B. All employees must be involved

   C. Different areas assigned each month

II. Identifying hazards in the process development (PD) area

   A. Ten-gallon reactor system

      1. Relief system must have rupture disk, telltale gauge and relief valve

      2. Belt guards required

      3. Nitrogen must not be vented to worker areas

      4. Process sketch must be posted and current

      5. Nitrogen line must have check valve

   B. Two-foot diameter glass-lined dryer blender

      1. Sketch must be current

      2. Valve handles must be properly selected and positioned

   C. Solvent tank- must be properly labeled

   D. Charging a flammable and toxic material into a reactor. Must use:

      1. Proper personal protective equipment

      2. Proper ventilation

      3. Grounding and bonding

      4. Inerting and purging

Process Area Inspections

<u>OUTLINE</u> <u>NOTES</u>

III. PD Area inspection review

A. Properly installed reliefs - protects against overpressure

B. Nitrogen not vented in work area

C. Belt guards

D. Current process diagrams

E. Care in valve handle selection and placement

F. Use of check valves to prevent backflow of process materials

G. Labeled storage tanks

H. Unobstructed safety equipment

I. Discard damaged equipment

J. Avoid clutter

K. Insulate steam lines - to prevent burns

DVD 3: EXPERIMENTS FOR SAFETY

PART 1

DIERS AND VSP

OVERVIEW

This unit demonstrates concepts regarding reactor relief systems. This includes runaway reactions and two-phase relief. The Vent Size Packaging (VSP) device developed by the Design Institute for Emergency Relief Systems (DIERS) is explained.

OBJECTIVES

After completing this unit you should be able to:

- explain the problems associated with runaway reactions and two-phase relief.
- explain the purpose and results of the DIERS investigation.
- state the purposes of the VSP device.
- describe the VSP device.
- describe the procedure for operating the VSP device.

INTRODUCER

John Davenport

BASF PRESENTER

Gerry Boicourt

KEY TERMS

Adiabatic calorimeter	Runaway reaction
Blowdown experiments	Two-phase flow
Design Institute for Emergency Relief Systems (DIERS)	Vent Sizing Package (VSP)

SUPPLEMENTARY MATERIALS AND FEFERENCES

1. D. A. Crowl and J. F. Louvar, *Chemical Process Safety, Fundamentals with Applications*, 2nd ed. (Upper Saddle River, NJ: Prentice Hall, 2002), Chapter 8: Introduction to Reliefs; Chapter 9: Relief Sizing.

DIERS and VSP

2. H. K. Fauske, "A Quick Approach to Reactor Vent Sizing," *Plant/Operations Progress,* July, 1984, p. 145.

3. H. K. Fauske, "Generalized Vent Sizing Monogram for Runaway Chemical Reactions," *Plant/Operations Progress,* October, 1984, p.213.

4. H. K. Fauske and J. C. Leung, "New Experimental Technique for Characterizing Runaway Chemical Reactions," *Chemical Engineering Progress,* August, 1985, p. 39.

5. H. K Fauske, "Emergency Relief System Design," *Chemical Engineering Progress,* August, 1985, p. 53.

6. H. G. Fisher, DIERS Research Program on Emergency Relief Systems," *Chemical Engineering Progress,* August 1985, p. 33.

7. M. Isaacs, "Pressure Relief Systems," *Chemical Engineering.* February 22, 1971, p. 113.

OUTLINE

NOTES

I. Reactor relief systems

A. Typical system

1. Reactor contents cooled by coils within the reactor

2. Runaway reaction scenario:

a. coolant flow interrupted

b. temperature within reactor increases

c. reaction rate increases

d. higher rate of heat generation

e. runaway reaction

(1) pressure increases with temperature

(2) vessel cannot withstand pressure

(3) vessel ruptures explosively

B. Early relief systems assumed all vapor relief, but reactors were still exploding.

DIERS and VSP

OUTLINE | NOTES

II. Design Institute for Emergency Relief Systems (DIERS)

A. Created to study reactor relief systems

1. confirmed two-phase flow

2. developed relief-sizing methods

B. Developed the Vent Size Packaging (VSP)

1. purposes

a. determines runaway character of reactive chemicals

b. small quantities used safely in lab

c. determines relief device vent areas

2. components of the VSP see Figure 3/1-1

a. thin-walled sample can or cell see Figure 3/1-2

(1) acts as an adiabatic calorimeter

(2) several types of cans are available depending on material tested and application

b. main heater - heats sample to exotherm

c. guard heater - maintains adiabatic conditions

d. insulating mantle

e. containment vessel - withstands high pressure

f. pressure transducers

g. thermocouples

h. computer and remote control module

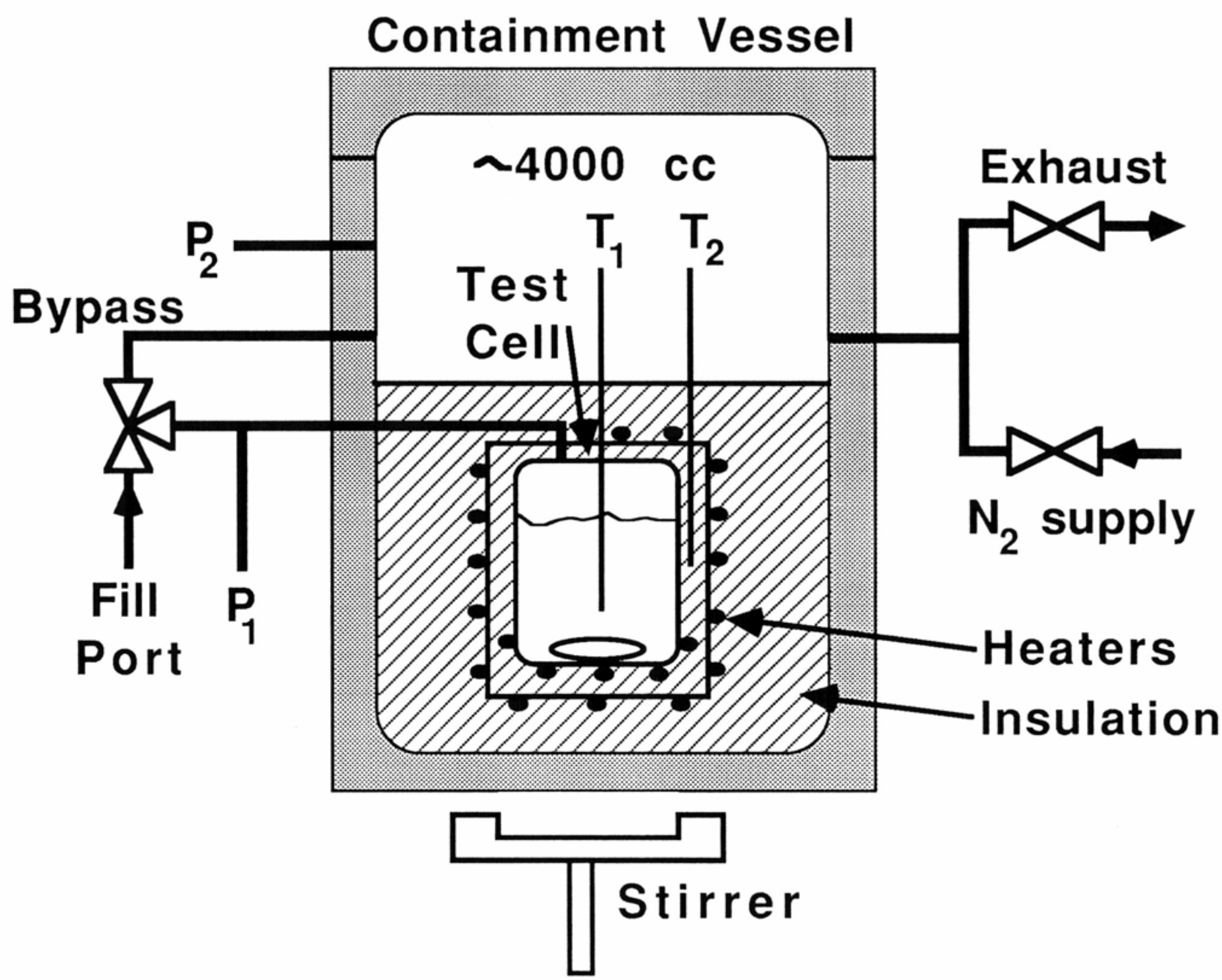

Figure 3/1-1: Schematic of Vent Sizing Package (VSP).

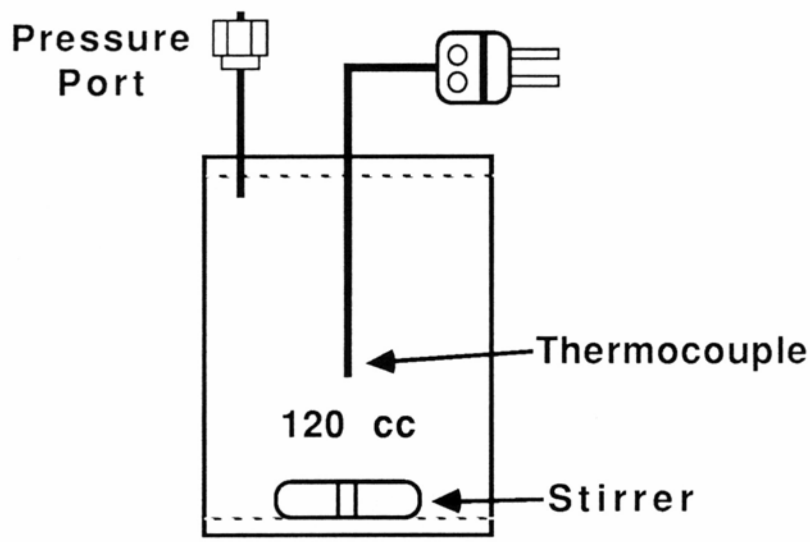

Figure 3/1-2: Sample can for Vent Sizing Package (VSP).

DIERS and VSP

OUTLINE | NOTES

3. procedure for operating the VSP

   a. sample heated to exotherrn detection point

   b. guard heater tracks exotherm

   c. pressure external to can maintained during runaway

      (1) pressure in sample can builds

      (2) computer monitors external pressure in transducer line

      (3) computer regulates nitrogen source valve to containment vessel

      (4) containment vessel and sample are pressurized to same level.

4. VSP data includes:

   a. onset of runaway - see Figure 3/1-4

   b. pressure and temperature as a function of time - see Figure 3/1-3 and Figure 3/1-4

   c. temperature rate - see Figure 3/1-5

   d. pressure rates

5. type of VSP experiment depends on viscosity of reactants. Type of sample can used varies depending on type of experiment
   - see Figure 3/1-6

6. blowdown experiments used for high viscosity systems - see Figure 3/1-7

   a. simulates the opening of a relief valve at a set pressure

   b. results:

      (1) characterizes flow regimes

      (2) determines the viscosity

      (3) determines flow rate through relief

DIERS and VSP

OUTLINE | NOTES

7. VSP results aid in the design of relief valves, but are not absolute.

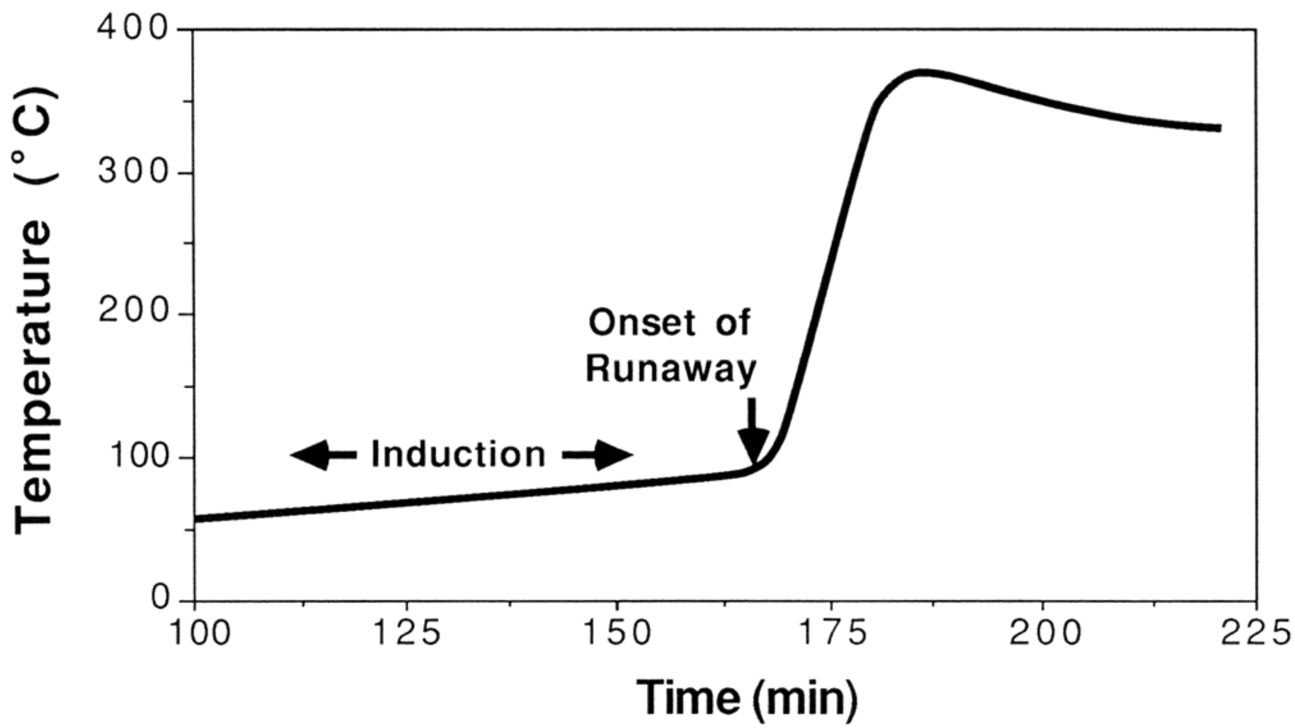

Figure 3/1-4: Temperature data from VSP device.

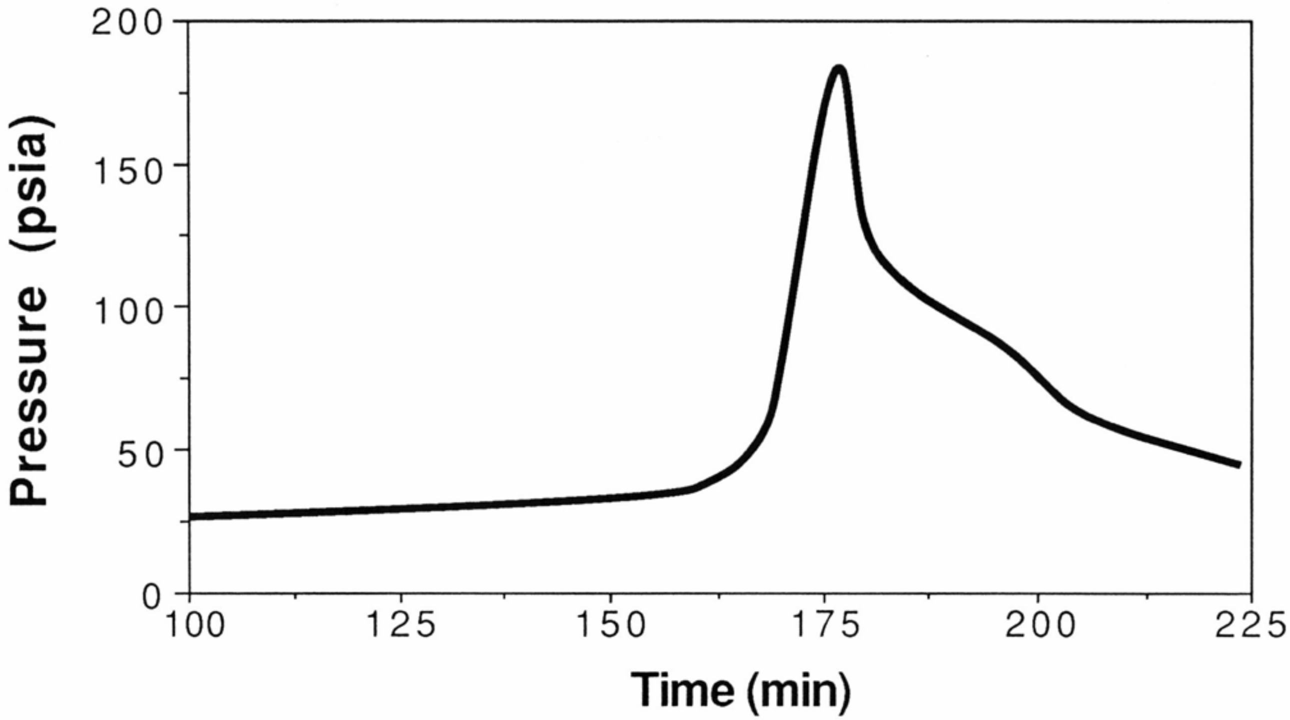

Figure 3/1-4: Pressure data from VSP device.

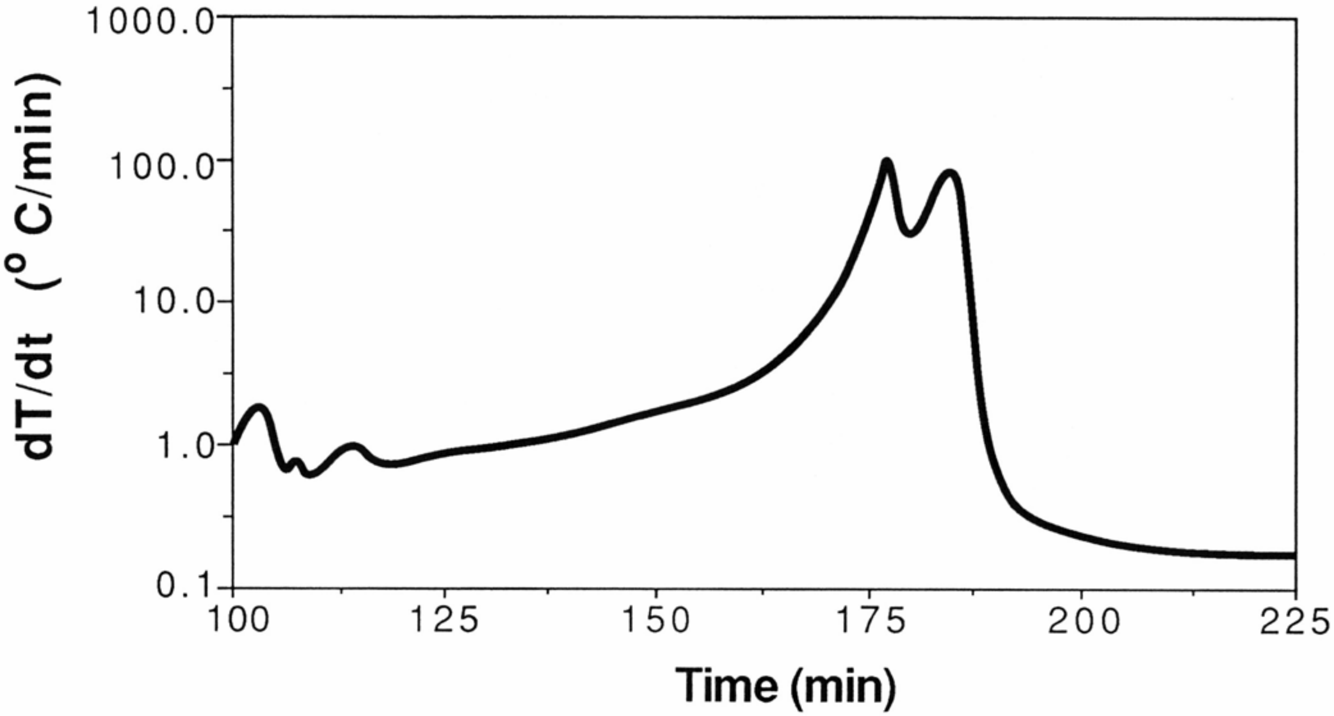

Figure 3/1-5: Temperature rate data from VSP device.

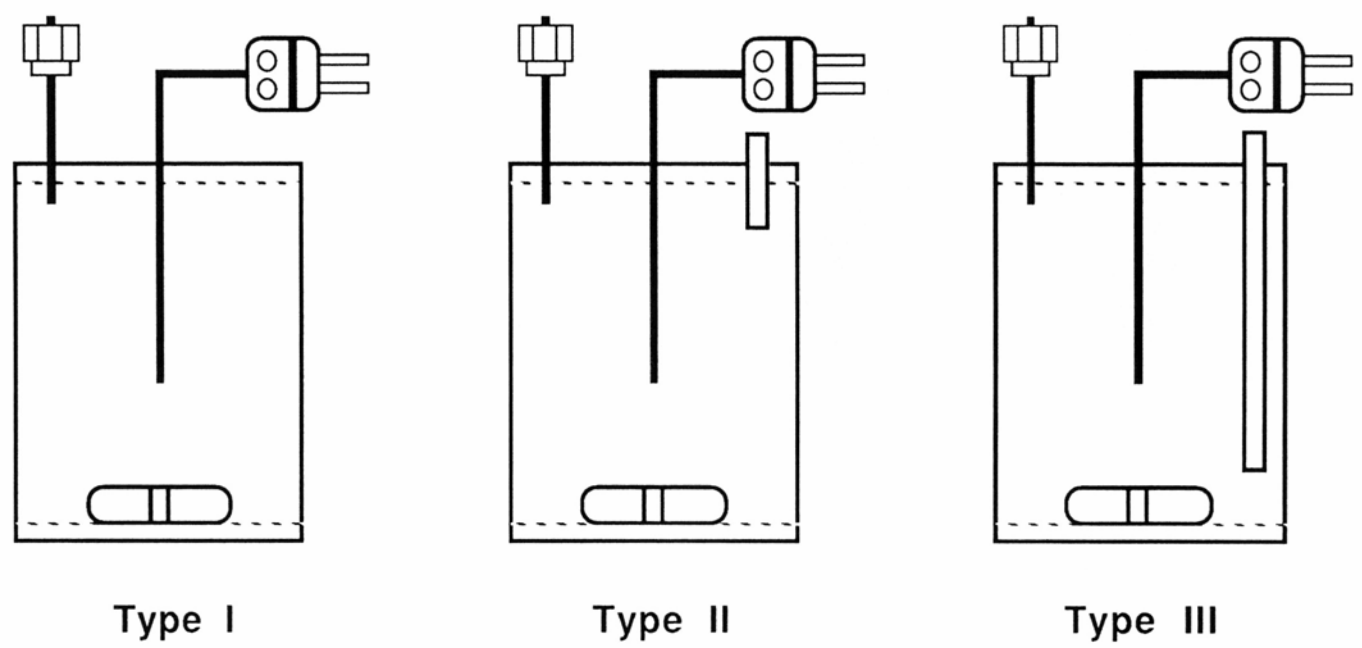

Figure 3/1-6: Three types of sample cans used in the VSP. Note the open tube in the Type II and III cans.

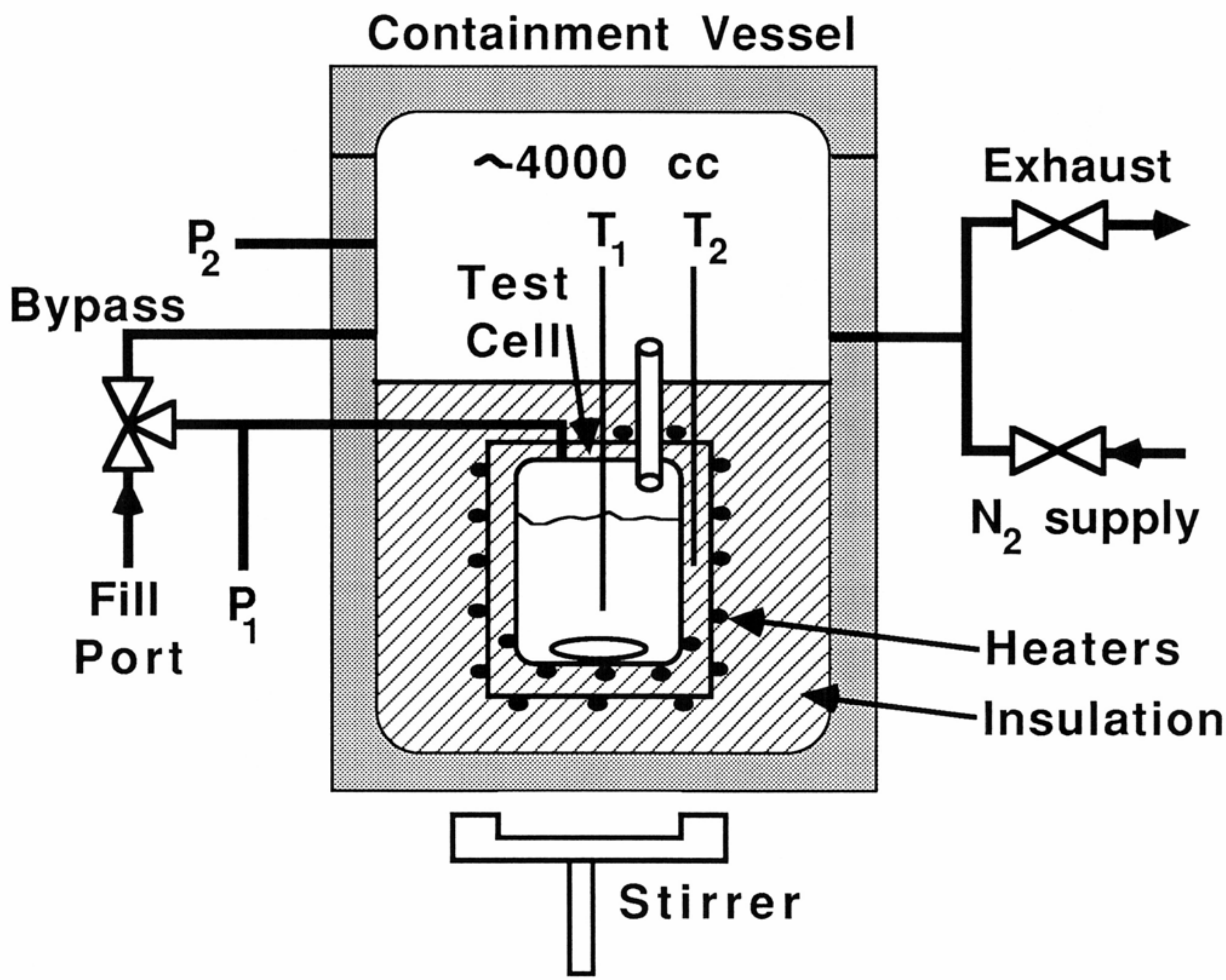

Figure 3/1-7: VSP device configured for blowdown experiments. Note the tubular vent in the sample can.

DVD 3: EXPERIMENTS FOR SAFETY

PART 2

DUST AND VAPOR EXPLOSION APPARATUS

OVERVIEW

Dust and flammable vapors can present serious hazards in chemical plants. Many materials not normally considered dangerous may become flammable and explosive under certain conditions. Because of this, it is necessary to experimentally characterize the material's hazardous properties using small quantities in the laboratory. The deflagration index, which characterizes the materials explosive behavior is discussed. Engineering design methods to reduce the impact of an explosion are introduced.

OBJECTIVES

After completing this unit, you should be able to:

- understand the necessity for determining the hazardous properties of materials.
- explain the characteristics of a dust explosion.
- explain how the 20-liter dust explosion apparatus operates.
- describe the utility of the deflagration index and how it is determined.
- explain how vapors are characterized using the vapor explosion apparatus.
- state the parameters required to design a blowout panel.

INTRODUCER

Stan Stynes

BASF PRESENTERS

Joe Louvar, Gerry Boicourt

KEY TERMS

Blowout panel	Lower explosion limit (LEL)
Deflagration index, K_G or K_{ST}	Upper explosion limit (UEL)

SUPPORTING MATERIALS AND REFERENCES

1. W. Bartknecht, *Explosions* (Berlin: Springer Verlag, 1981).

2. F. T. Bodurtha, *Industrial Explosion Prevention and Protection* (New York. NY: McGraw-Hill, 1980).

Dust and Vapor Explosion Apparatus

3. D. A. Crowl and J. F. Louvar, *Chemical Process Safety, Fundamentals with Applications*, 2nd ed. (Upper Saddle River, NJ: Prentice Hall, 2002), Chapter 6: Fires and Explosions; Chapter 7: Designs to Prevent Fires and Explosions.

4. D. A. Crowl, *Understanding Explosions,* (New York: AICHE, 2003).

5. Rolf K. Eckhoff, *Dust Explosions in the Process Industries,* 2nd ed. (London: Butterworth-Heinemann, 1997).

6. F. P. Lees, *Loss Prevention in the Process Industries*, 2nd ed. (London: Butterworth-Heinemann, 1996). Chapter 17: Explosion.

<u>OUTLINE</u> <u>NOTES</u>

I. Need data about a substance's hazardous properties before it is used. Sources of information are:

   A. Material Safety Data Sheets (MSDS)

   B. Manufacturers technical information

   C. Experimental determination using small quantities in the lab

II. Dusts

   A. Many materials become flammable and explosive in dust form

   B. Dust explosions typically involve two stages:

      1. Primary explosion - stirs up dust

      2. Secondary explosion - develops in stirred up dust

   C. Dust explosion apparatus

      1. Purpose: characterize dust in terms of flammability and explosivity

      2. Dusts are characterized using a deflagration index - see Table 3/2-1

      3. Experimental device - see Figure 3/2-1

Table 3/2-1: Deflagration index classes

Deflagration Index

Class	K_{St} (bar m/s)
St 0	0
St 1	1 - 200
St 2	200 - 300
St 3	> 300

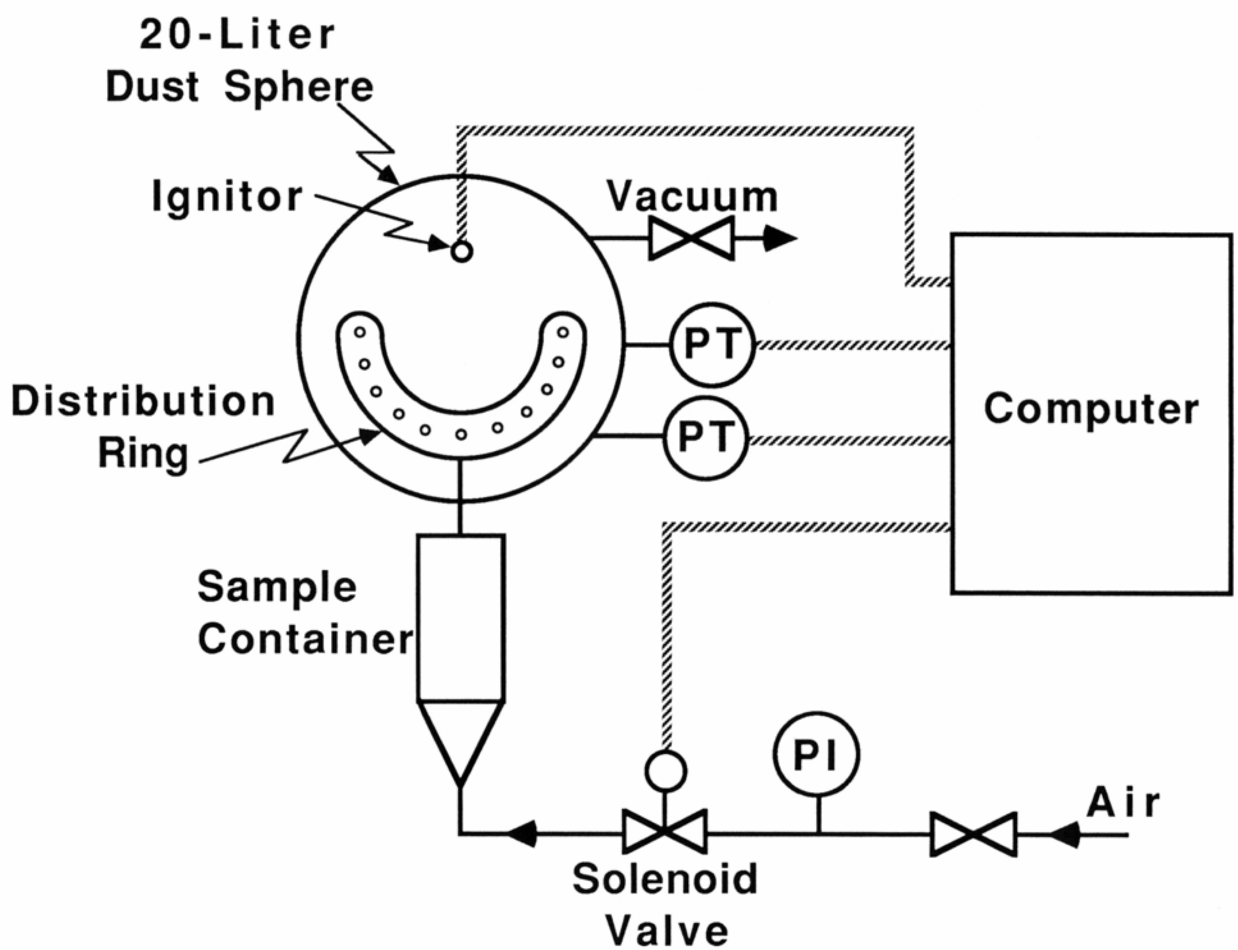

Figure 3/2-1: Experimental device for characterizing dusts.

Dust and Vapor Explosion Apparatus

OUTLINE NOTES

a. components

(1) cylindrical vessel - 20 liters

(2) solenoid valve - opens to inject dusts

(3) dispersion ring - distributes dust in vessel

b. operating procedure:

(1) solenoid valve closed

(2) dust placed in holding container at bottom (amount changed with each run)

(3) solenoid valve opens

(4) air from pressurized cylinder drives dust into vessel

(5) dispersion ring distributes dust in vessel

(6) final pressure is one bar

(7) igniter initiated by computer after suitable delay time for mixing

c. data obtained:

(1) pressure vs. time provides maximum pressure and pressure gradient - see Figure 3/2-2

(2) maximum pressure vs. concentration provides largest maximum pressure and explosion limits - see Figure 3/2-3

(3) deflagration index computed:

$$K_{St} = V^{1/3}\left(dP/dt\right)_{\max}$$

II. Vapor explosion apparatus

A. Purpose: to characterize the explosive behavior of flammable vapors.

Dust and Vapor Explosion Apparatus

OUTLINE | NOTES

B. Types of data obtained:

1. Concentration as a function of initial pressure – shows upper explosion limit (UEL) and lower explosion limit (LEL) - see Figure 3/2-4

2. Pressure vs. time - see Figure 3/2-5

C. Experimental Apparatus - see Figure 3/2-6

1. spherical chamber

2. high speed thermocouple: measures flame temperatures

3. gas manifold line: meters in gases

4. meter line: meters in volatile liquids and enables gas samples to be taken

5. high speed pressure transducer: tracks the pressure of the explosion

6. ignition wand: initializes the actual explosion via command from computer

7. magnetic stir bar - insures gas mixing

8. data acquisition system

D. Data obtained

1. explosion pressure as a function of concentration - see Figure 3/2-7

a. shows explosion pressure for a gas

b. shows upper and lower explosion limits

2. pressure vs. time plot: provides (dP/dt) - see Figure 3/2-8

3. deflagration index: $K_G = V^{1/3}\left(dP/dt\right)_{\max}$

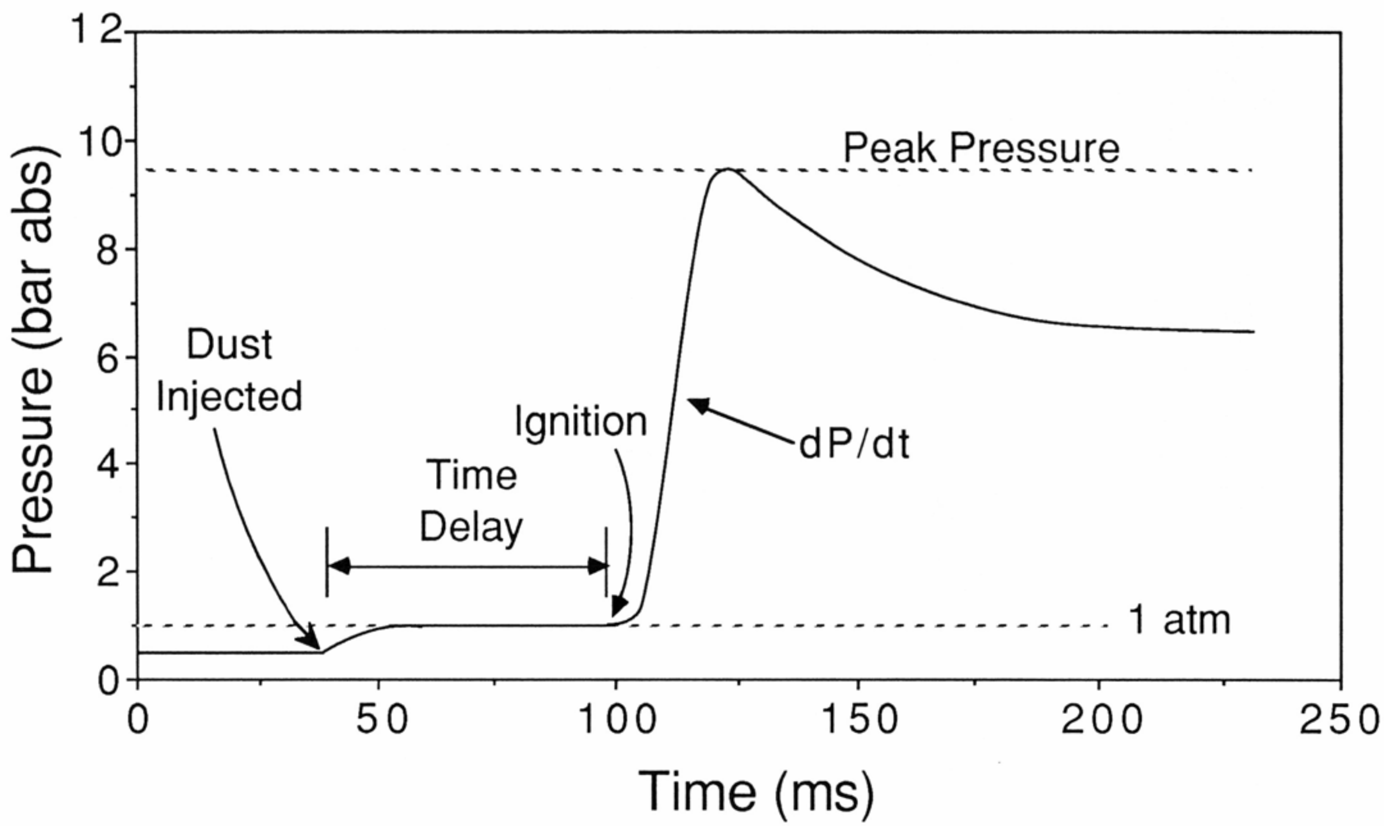

Figure 3/2-2: Pressure data from dust explosion device.

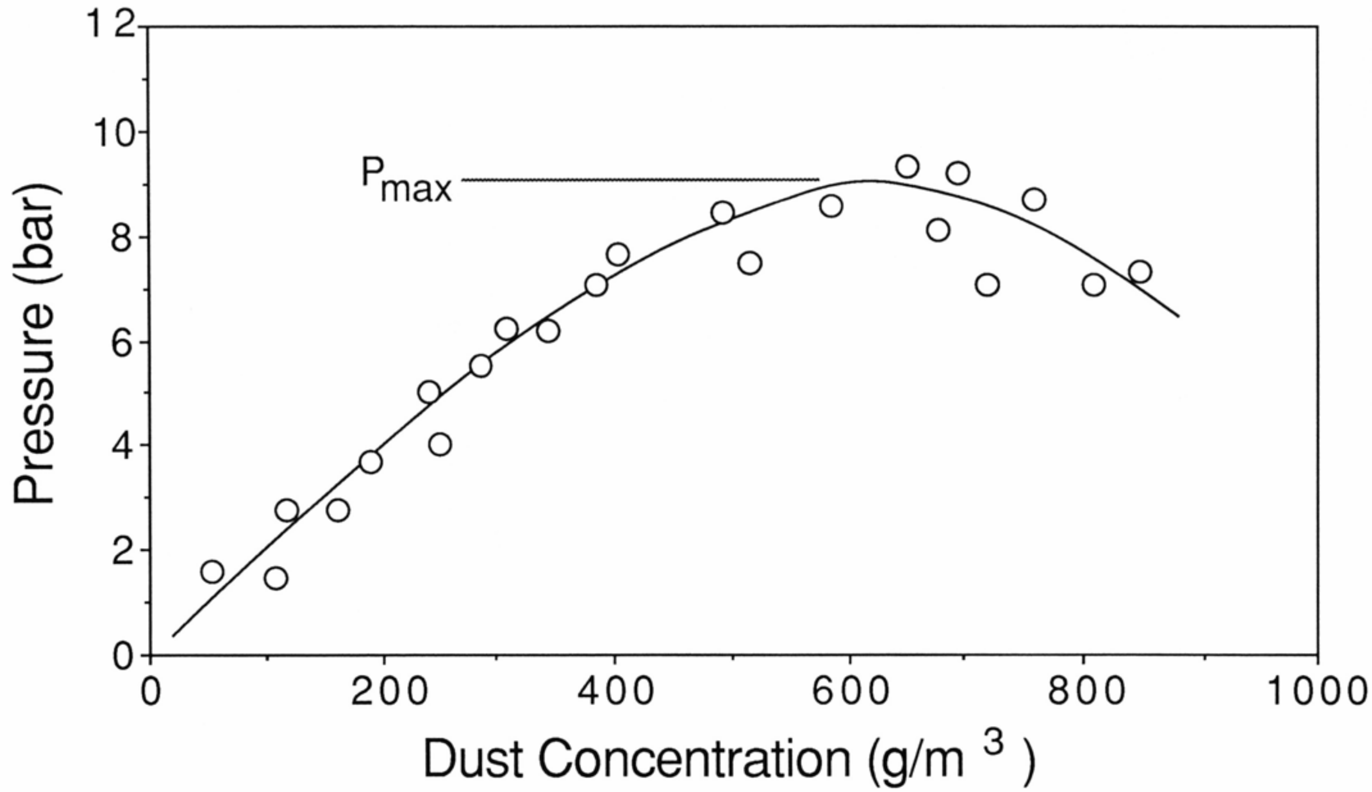

Figure 3/2-3: Maximum pressure as a function of dust concentration.

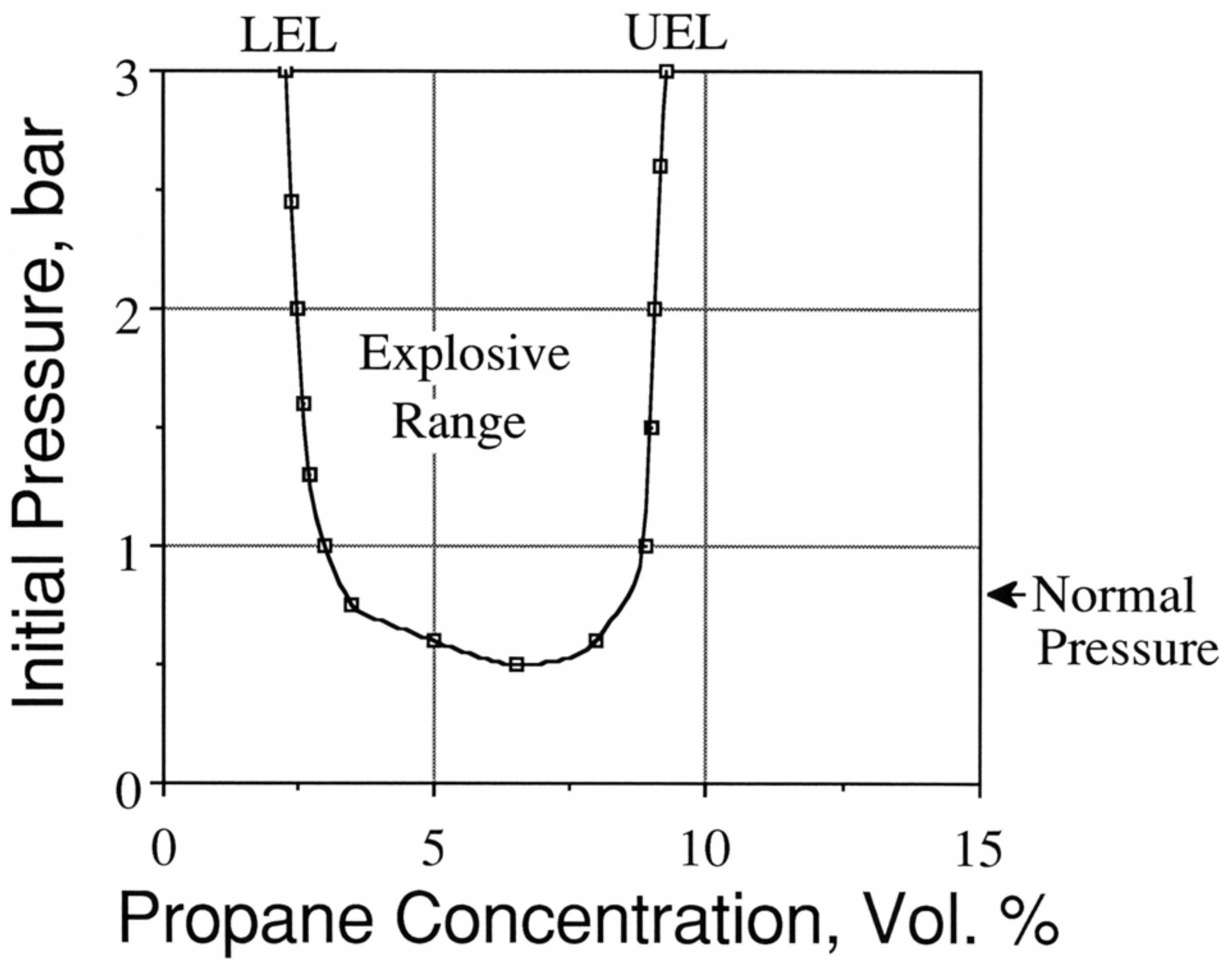

Figure 3/2-4: Concentration vs. initial pressure for the flammable gas propane. The mixture is only flammable in the region indicated.

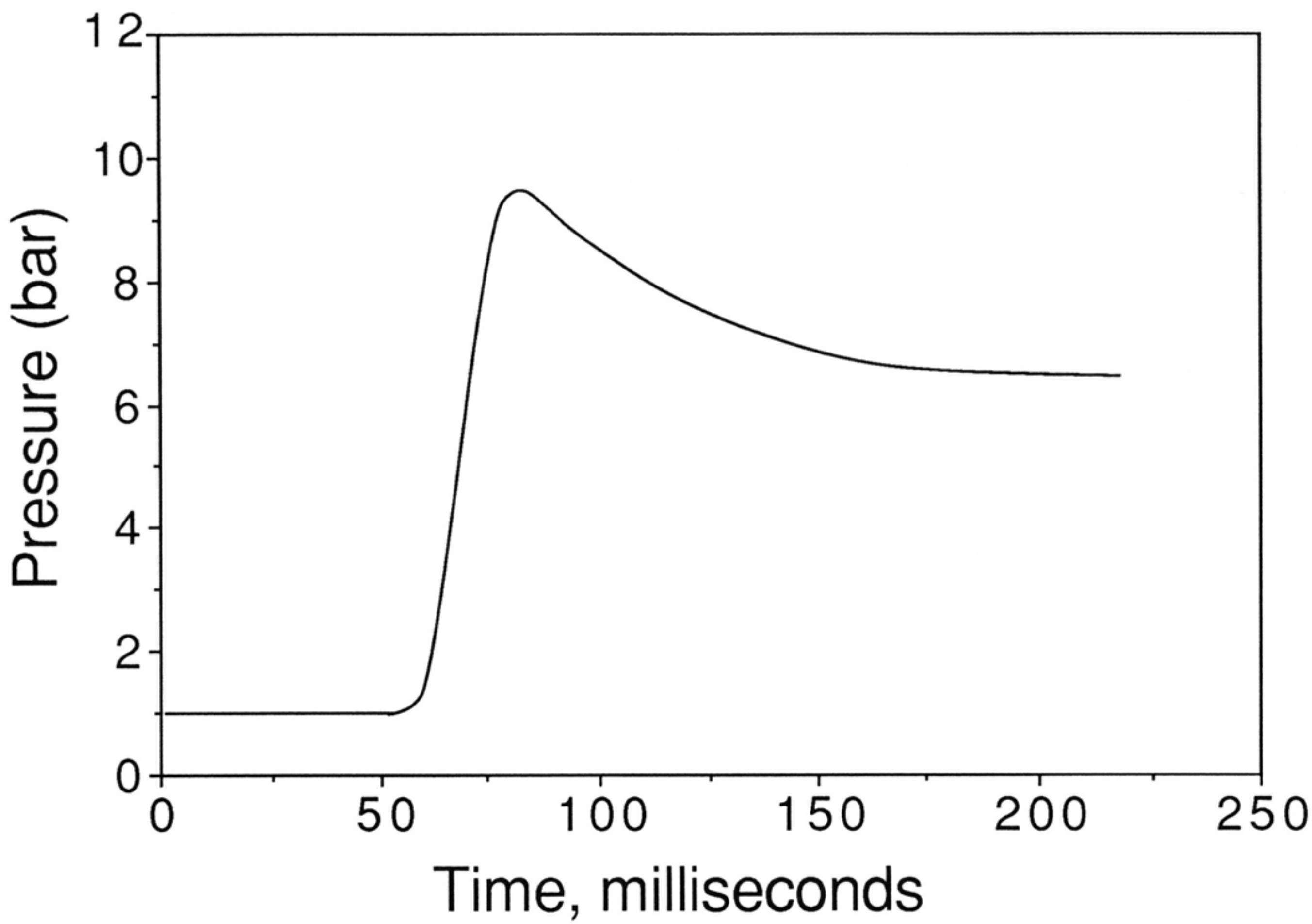

Figure 3/2-5: Pressure vs. time data from vapor explosion apparatus.

Dust and Vapor Explosion Apparatus

OUTLINE

NOTES

III. Handling the material safely using the deflagration index:

A. Determine the course of action

1. small index means little explosion hazard - proceed

2. large index - indicates explosive material

a. change process

b. use alternate material

c. abandon the process

B. Used to design vent devices to reduce the effect of an explosion: blowout panels

1. provides for controlled venting of a possible explosion

2. eliminates or reduces potential injury and damage

3. design determined by
- see Crowl and Louvar (2002)
pp. 404-411:

a. deflagration index

b. enclosure volume

c. maximum explosion pressure

d. allowable relief pressure

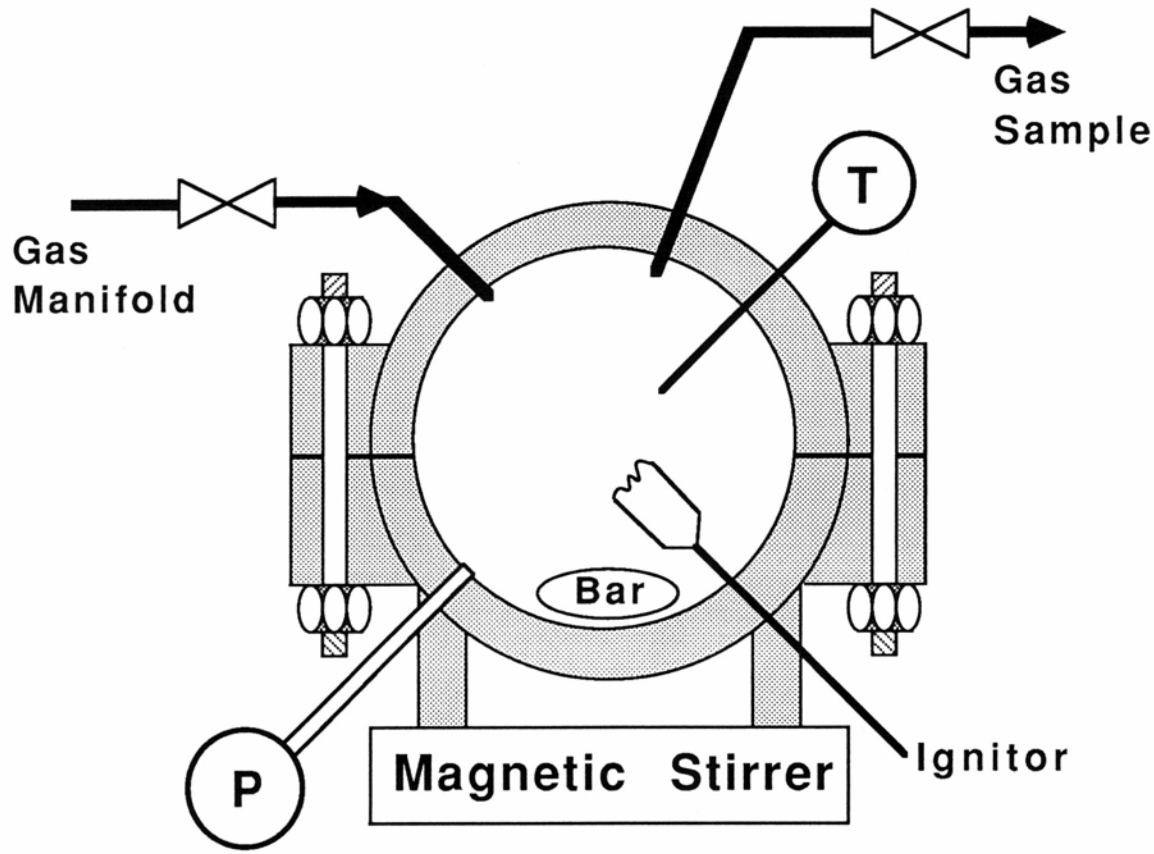

Figure 3/2-6: Vapor explosion apparatus.

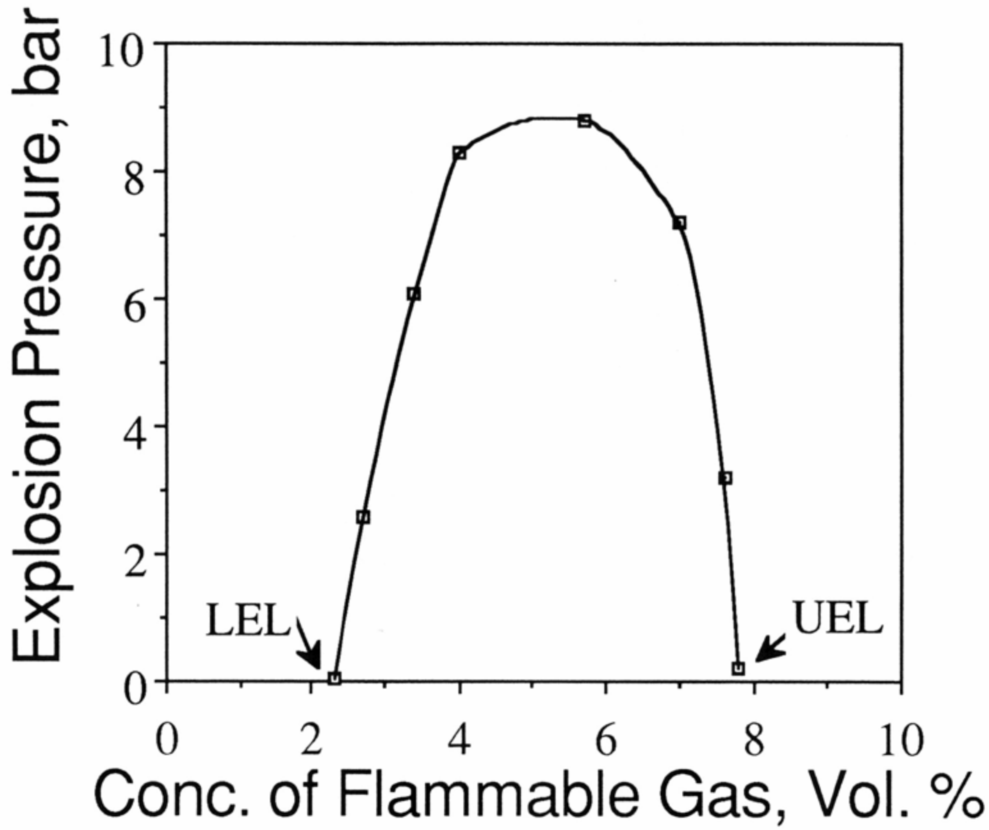

Figure 3/2-7: Explosion pressure as a function of concentration. The region under the dome is the flammable region.

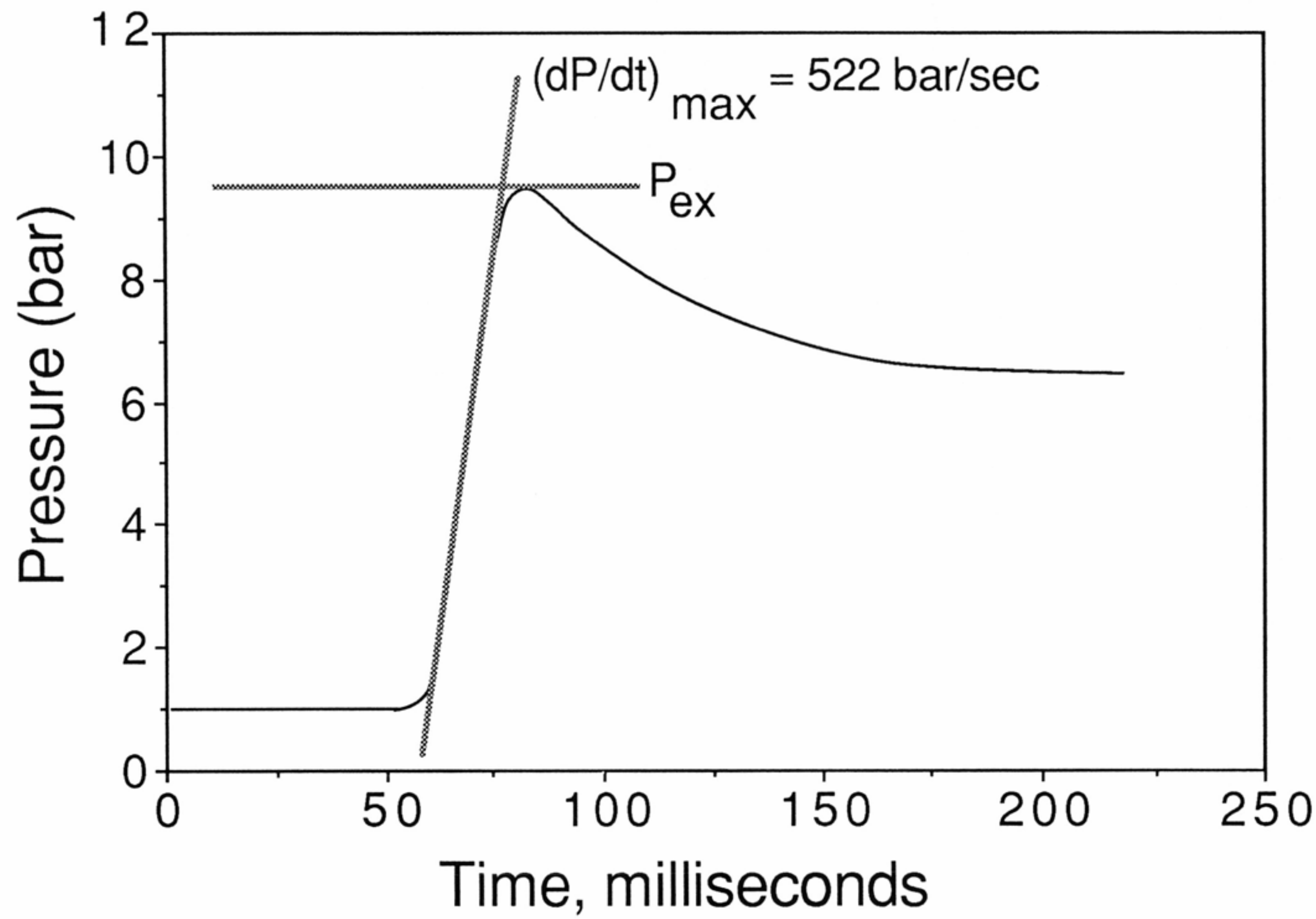

Figure 3/2-8: The maximum explosion pressure and pressure rate determined from pressure vs. time data.

DVD 4: SAFETY REVIEWS

PART 1

INFORMAL SAFETY REVIEWS

OVERVIEW

The informal safety review is a management system used to prevent the existence of safety problems in small processes or for small changes in existing processes. This tape describes its uses, the procedure for using it, and re-enacts an informal safety review.

OBJECTIVES

After you have completed this unit you should be able to:

- explain when and why an informal safety review is used.
- describe the informal safety review procedure.

INTRODUCER

John Davenport

BASF PRESENTERS

Joe Louvar, Jim Strickland

KEY TERMS

Formal safety review	Phosgene paper
Informal safety review	Relief valve
Odor threshold	Threshold limit value

SUPPORTIING MATERIALS AND REFERENCES

1. D. A. Crowl and J. F. Louvar, *Chemical Process Safety: Fundamentals with Applications, 2nd ed.,*(NY: Prentice Hall), 2002, Chapter 10: Hazards Identification.

2. *Guidelines for Hazard Evaluation Procedures* (New York, NY: American Institute of Chemical Engineers, 1985).

3. T. A. Kletz, *HAZOP and HAZAN* (Warwickshire, England: The Institution of Chemical Engineers, 1986).

Informal Safety Reviews

OUTLINE | NOTES

I. Uses of informal safety reviews

   A. Laboratory experiments

   B. Small changes in existing processes

II. Safety review re-enactment

   A. Introduction

      1. Chemistry - see Figure 4/1-1

         a. aniline reacts with phosgene

         b. products are isocyanate and HCI

      2. Original phosgenation process – see Figure 4/1-2

      3. Hazardous properties of chemicals used in the process

         a. Aniline:
            Boiling point: 364°F
            Threshold limit value: 2 PPM
            Absorbant through skin

         b. Phosgene:
            Boiling point: 46.8°F
            Threshold limit value: 0.1 PPM
            Odor threshold: 0.5- 1 PPM
            Colorless vapor with sweet odor

   B. Improvements on the system

      1. vacuum to reduce boiling temperature

      2. relief system with outlet to scrubber – prevents hazard due to plugged fritted glass bubbler

      3. flow indicator- provides visual indication of flow

      4. ammonium hydroxide in scrubber - more absorbant

      5. bubblers used instead of scrubber

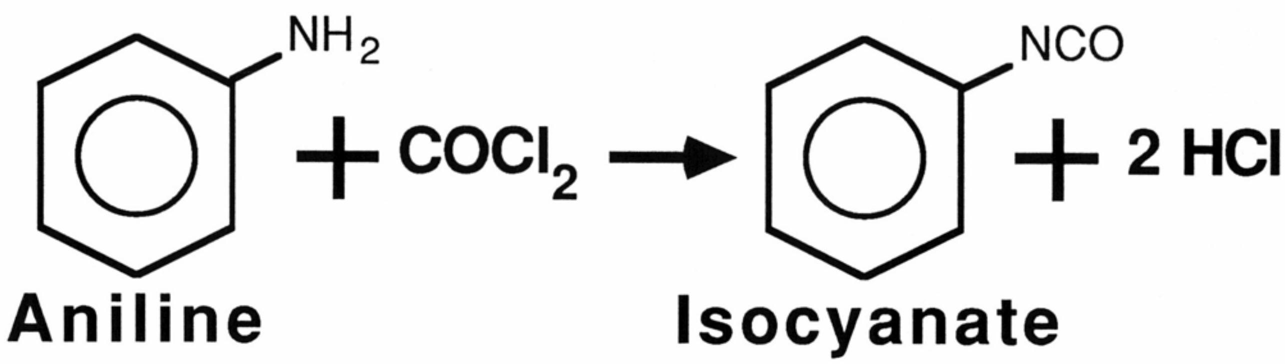

Figure 4/1-1: Reaction stoichiometry for phosgene reaction.

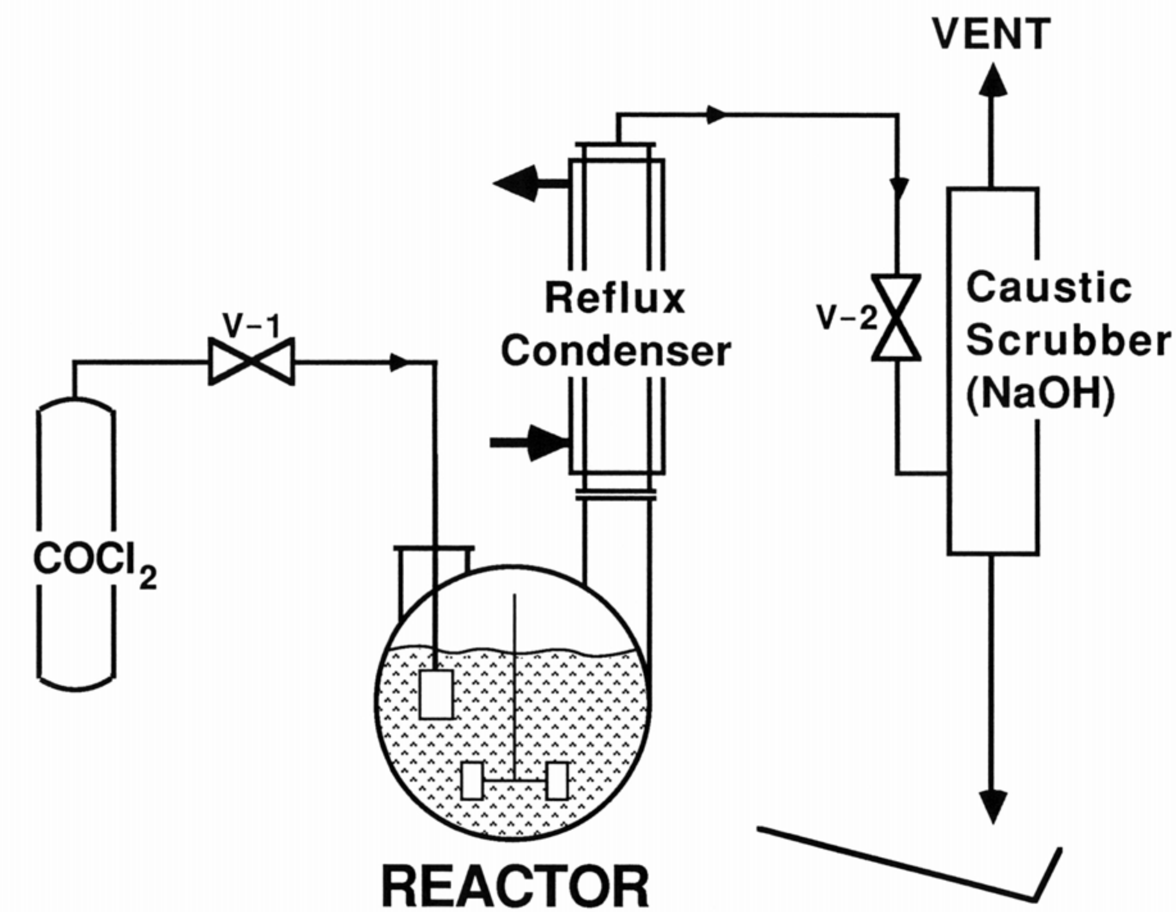

Figure 4/1-2: Original design for phosgene reaction system.

Informal Safety Reviews

OUTLINE | NOTES

6. change relief to dump into ammonium hydroxide bubbler

7. trap to catch liquid phosgene

8. pail of caustic- to reduce hazards of cylinder leak

9. indicator paper- turns brown at 0.1 ppm phosgene

10. checklist - must include

    a. rubber gloves

    b. face shield

    c. airline mask

11. sketch of process- must be up-to-date

C. Final process configuration
- see Figure 4/1-3

III. Informal safety review procedure

A. Two *or* three person procedure

B. Summary memo

C. Recommendations implemented

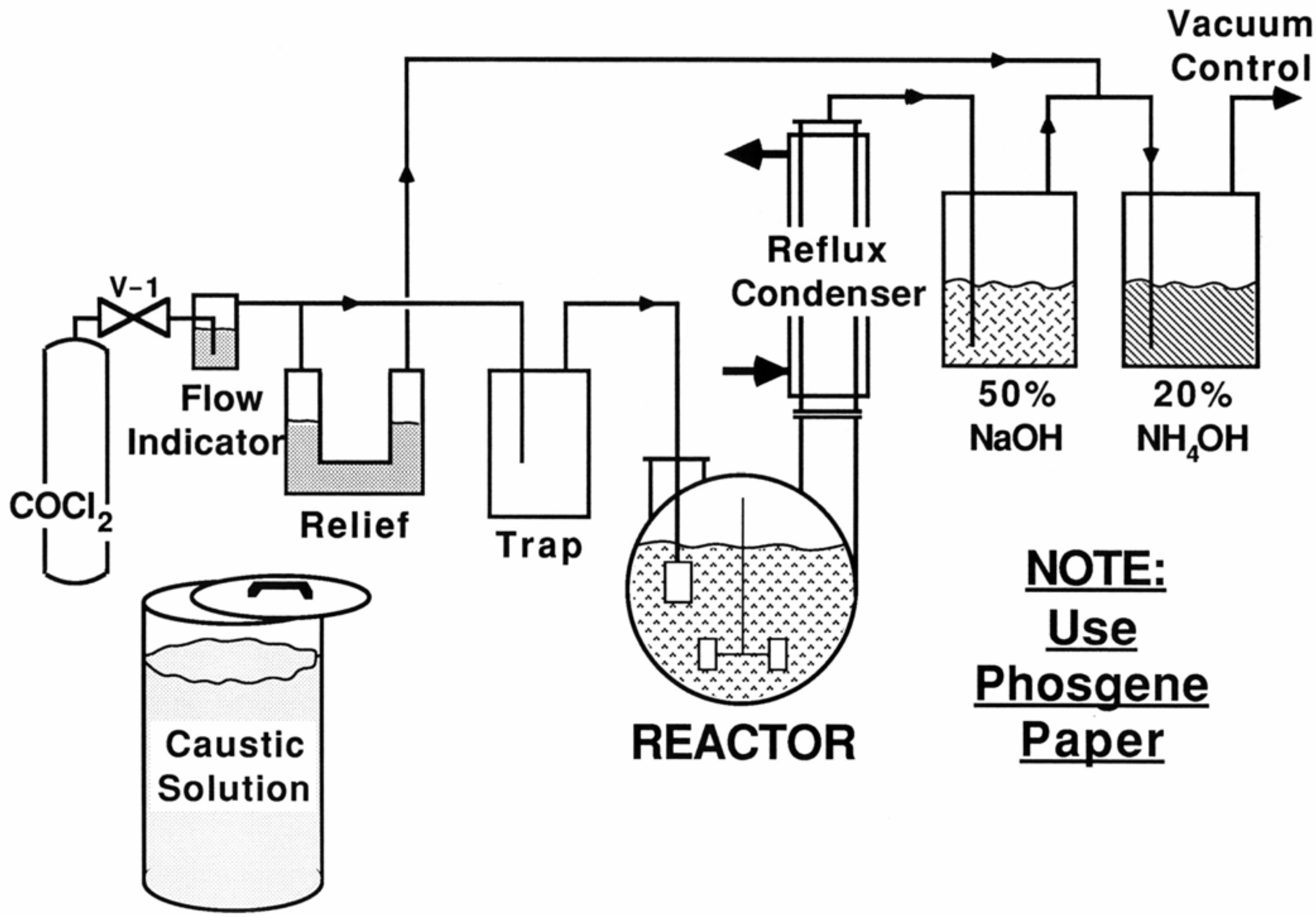

Figure 4/1-3: Final design for phosgene reactor after informal safety review.

DVD 4: SAFETY REVIEWS

PART 2

INTRODUCTION TO FORMAL SAFETY REVIEWS

OVERVEW

There are many types of management systems which are used to anticipate and prevent the existence of safety problems. This unit introduces a particular type of management system: The formal safety review.

OBJECTIVES

After completing this unit, you should be able to:

- understand the necessity for safety reviews.
- contrast a formal safety review with an informal safety review.
- describe the sections of a formal safety review report.
- specify the members of a formal safety review committee.
- describe the formal safety review procedure.

INTRODUCER

John Davenport

BASF PRESENTER

Joe Louvar

KEY TERMS

Dow fire and explosion Index

Event trees

Fault trees

Fail safe

Formal safety review

Hazard and operability studies (HAZOP)

Informal safety review

Safety checklist

Safety review

Introduction to Formal Safety Reviews

SUPPORTING MATERIALS AND REFERENCES

1. Appendix II: Formal Safety Review Report

2. D. A. Crow] and J. F. Louvar, *Chemical Process Safety, Fundamentals with Applications,* 2nd ed. (Upper Saddle River, NJ: Prentice Hall, 2002), Chapter 10: Hazards Identification.

3. *Dow Fire and Explosion Index Hazard Classification Guide,* 7th Edition (New York, NY: American Institute of Chemical Engineers, 1994).

4. *Guidelines for Hazard Evaluation Procedures*, 2nd ed. (New York, NY: American Institute of Chemical Engineers, 1992).

5. T. A. Kletz, *HAZOP and HAZAN, 2nd Edition* (Warwickshire, England: The Institution of Chemical Engineers, 1986).

OUTLINE | NOTES

I. Common management systems
   - A. Hazard and Operability studies (HAZOP)
   - B. Fault trees
   - C. Event trees
   - D. Dow Fire and Explosion Index

II. Formal safety review useful for
   - A. New processes
   - B. Substantial changes in existing processes
   - C. Processes which haven't been reviewed recently

III. Formal safety review procedure
   - A. Three step procedure
     1. Review report
     2. Committee review
     3. Develop and implement recommendations
   - B. Formal safety review report (memo) sections:
     1. Introduction
        - a. process summary
        - b. reactions and stoichiometry

c. engineering data

2. raw materials and products (refer to hazards and special handling requirements)

3. equipment set-up

   a. equipment description

   b. equipment specifications

4. procedures

   a. normal operating procedures

   b. safety procedures

      (1) emergency shutdown

      (2) fail-safe procedures

      (3) major release procedures

   c. waste disposal procedure

   d. clean-up procedures

5. safety checklists

6. chemical hazard sheet

C. Committee review

1. members of the committee

   a. environmentalist

   b. industrial hygienist

   c. safety department representative

   d. chemist

   e. staff member

   f. supervisor

   g. technician or operator

Introduction to Formal Safety Reviews

OUTLINE

NOTES

h. consultant

2. formal safety review meeting

a. questions and answers

b. tour of system

c. develop action plan

D. Recommendations

DVD 4: SAFETY REVIEWS

PART 3

FORMAL SAFETY REVIEW

OVERVIEW

A demonstration of a formal safety review is performed on a toluene water-wash process. The initial design is shown and suggestions and improvements are made to the original process following the committee review procedures.

OBECTIVES

After completing this unit, you should be able to:

- describe how a formal safety review is performed.
- understand the importance of the safety review procedure:

INTRODUCER

John Davenport

BASF PRESENTERS

Gerry Boicourt, Mike Capraro, Joe Louvar, Rick Malechuk, Jim Strickland

KEY TERMS

Bonding

Colorimetric indicator or Drager tube

Dip Leg

Elephant trunk

Formal safety review

Grounding

Informal safety review

Podbielniak extractor

SUPPORTING MATERIALS AND REFERENCES

1. Appendix II: Formal Safety Review Report

2. D. A. Crowl and J. F. Louvar, *Chemical Process* Safety, Fundamentals with Applications, 2nd ed. (Upper Saddle River, NJ: Prentice Hall, 2002), Chapter 10: Hazard Identification.

3. *Guidelines for Hazard Evaluation Procedures*, 2nd ed. (New York, NY: American Institute of Chemical Engineers, 1992).

Formal Safety Review

OUTLINE | NOTES

I. Formal safety review procedure

   A. Formal safety review report

   B. Formal safety review committee review

   C. Implement recommendations

II. Toluene water-wash process

   A. Function: to wash impurities from toluene using water

   B. Initial process design before review – see Figure 4/3-1

      1. contaminated toluene pumped into Podbielniak centrifugal extractor (POD)

      2. liquid separated by centrifugal force using difference in densities

      3. light phase goes to center of centrifuge

      4. water is pumped into center of centrifuge and removed from periphery of the bowl

   C. Final process design - see Figure 4/3-2

III. Committee review changes and additions:

   A. Equipment changes:

      1. All solvent vessels must have:

         a. inerting

         b. grounding and bonding

         c. dip leg to prevent static charge

         d. elephant trunk for ventilation

      2. Heat exchangers added to exit lines for both solvent line and water discharge lines

      3. Add temperature gauges to heat exchangers

Formal Safety Review

OUTLINE NOTES

B. Procedure changes:

1. Periodic checking with colorimetric indicator tubes (Drager tubes)
2. Charge solvent under vacuum thru dip leg using grounding and bonding
3. 90°F sizing on heat exchangers
4. Purge all solvent vessels with nitrogen
5. Check temperature arid pressures periodically during operation

C. Emergency procedures for spills:

1. Spill alarm activated for solvent spill
2. Ventilation tripped into high speed
3. Sewer isolation valve tripped
4. Check area with explosive vapor meter

D. Checklist changes:

1. Purge all solvent containing vessels with nitrogen
2. Check exit lines on heat exchangers

E. Relief valve sizing:

1. Scenarios:
   a. water valve failure
   b. steam jacket failure
   c. nitrogen regulator failure
   d. fire external to vessel
2. Fire is limiting case.

Formal Safety Review

<u>OUTLINE</u> <u>NOTES</u>

IV. Advantages to formal safety review procedure

A. Can be used immediately

B. Easy to comprehend

C. Results proven to be very effective

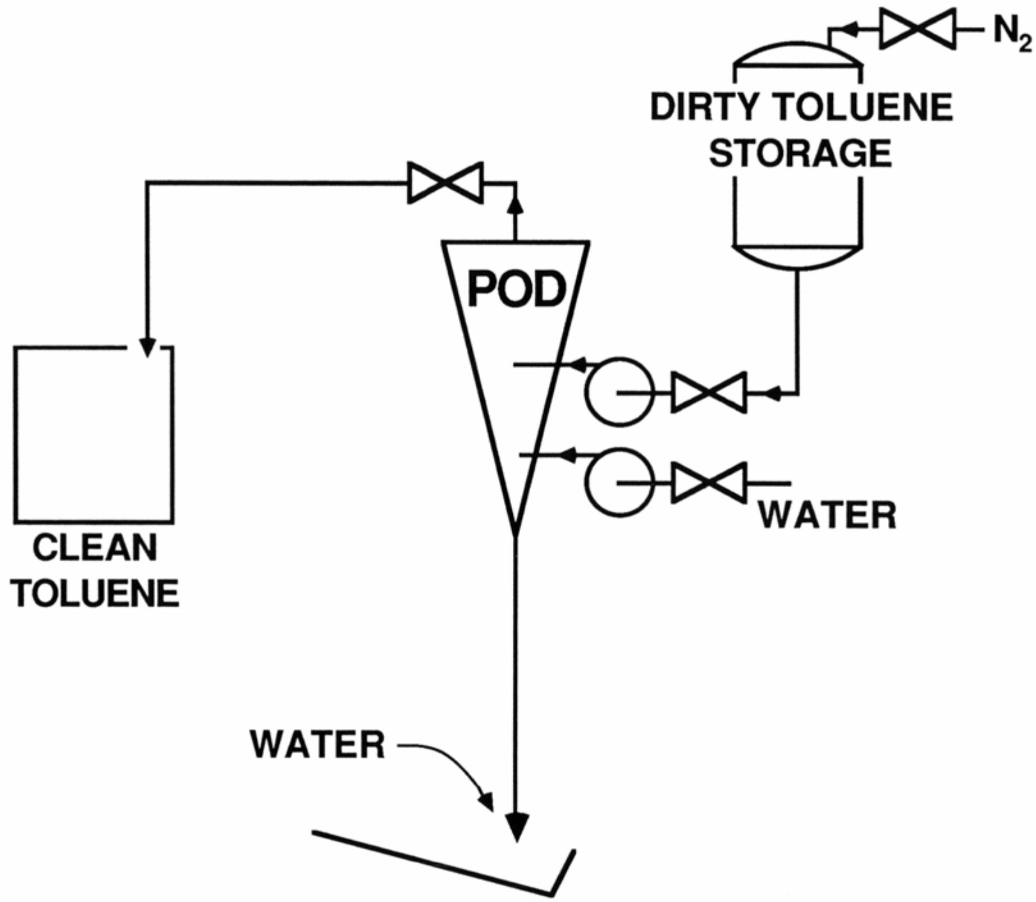

Figure 4/3-1: Toluene water-wash process before safety review

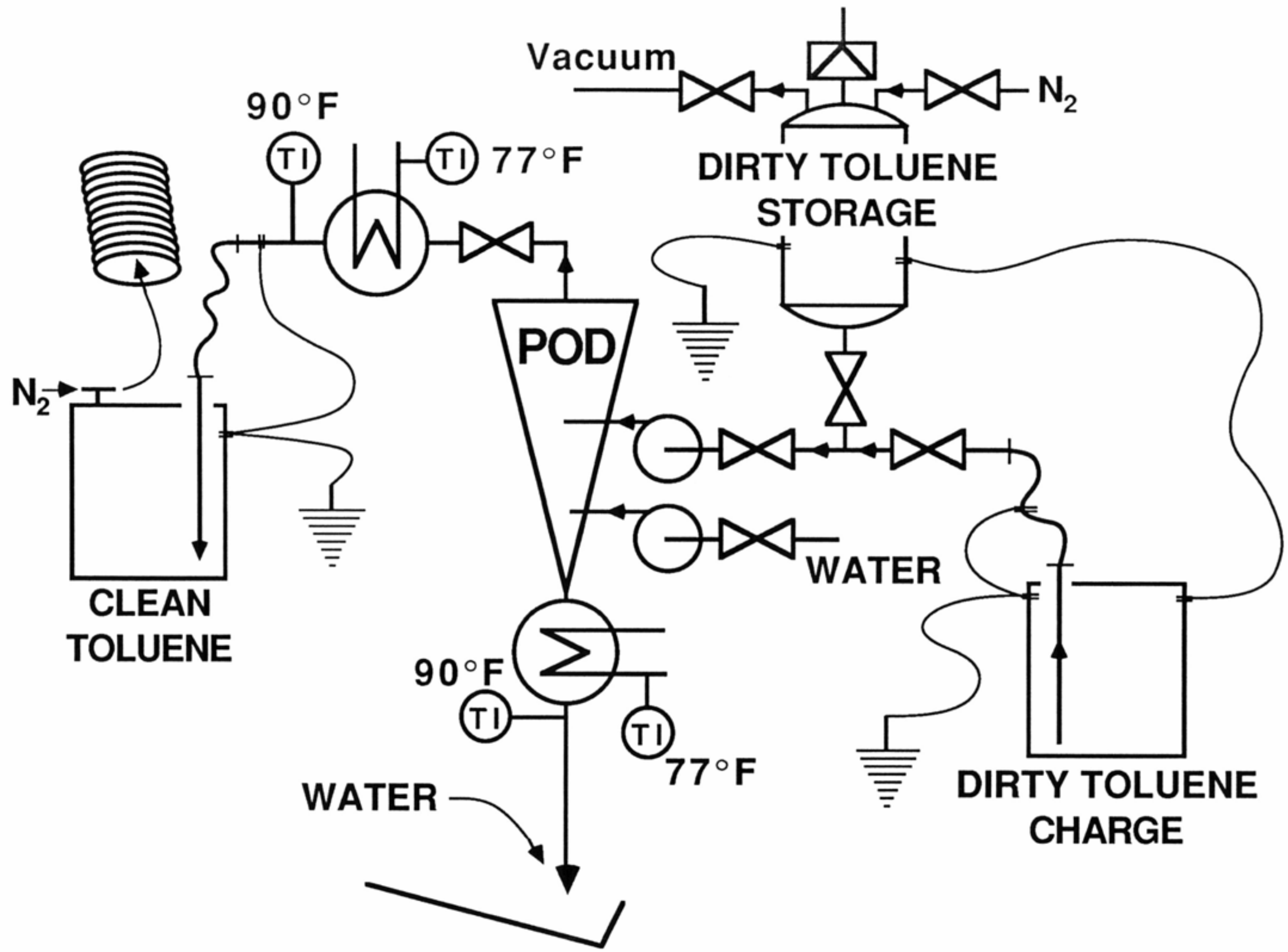

Figure 4/3-2: Toluene water-wash system after formal safety review.

APPENDIX I

GLOSSARY

Adiabatic Calorimeter is a vessel designed to study the thermal nature of a reaction system. Heat losses are minimized to approach adiabatic behavior.

Airline Hood is a respirator that consists of a hood completely enclosing the head. Air is supplied from a dedicated airline and source. Care must be taken to insure the integrity of the air supply.

Blowdown Experiments are experiments run on the Vent Sizing Package (VSP) to determine the relief nature of viscous reaction materials.

Blowout Panel is a panel designed to yield in a controlled fashion during an explosion situation. This prevents pressure increases and reduces damage to personnel and equipment.

Bonding is a procedure used to prevent the buildup of static electricity in process units and vessels. This procedure involves connecting process units together using bonding clamps.

Bonding Clamp is a clamp used to connect two containers or process vessels together to eliminate the buildup of static electricity charges during a material transfer operation.

Canister Respirator is a respirator consisting of a full face mask and a frontal hose leading to a canister. Air flows through the canister and up the hose to the face mask. A canister respirator provides considerably more protection than a cartridge respirator, although they both work on the same principle.

Cartridge Respirator is a small respirator that just fits over the mouth and nose. The air is purified by two small cartridges that attach to the front of the device.

Check Valve is a special type of valve used to prevent the backward flow of process fluids through pipes.

Colorimetric Tubes are small tubes containing a sensitive chemical powder which changes color in the presence of certain chemical vapors. Air is drawn through the tubes and the color change is used to determine the concentration of vapor present.

Confined Space is defined as a hole or trench, diked area, reactor vessel, storage vessel, or a large pipe. A confined space entry procedure is required before workers can enter a confined space.

Deflagration Index is an index used to characterize dust and vapor explosions. The higher the index the more robust the explosion.

Design Institute for Emergency Relief Systems (DIERS) is an Institute formed by the American Institute of Chemical Engineers to study reactor relief systems. They were particularly interested in two-phase flow through reliefs related to reactor runaways.

Appendix I: Glossary

Dielectric Union is a special union used to connect two pipes of dissimilar metals. The union prevents or reduces galvanic action leading to subsequent corrosion of the pipe.

Dip Leg is a pipe extending from a vessel feed line down into the liquid level. A dip leg prevents the free fall of process fluids leading to accumulation of static charge.

Double Block and Bleed is a safety feature used to prevent hazardous materials from inadvertently entering a vessel. It consists of three valves arranged in a T configuration: two valves are block valves and the third valve is the bleed valve.

Dow Fire and Explosion Index is a hazards identification technique developed by Dow Chemical Company to determine the fire and explosion hazard of process equipment.

Elephant Trunk consists of a long, flexible tube through which ventilation air flows. The opening of the elephant trunk can be placed near a source of vapors to reduce the quantity of material escaping into adjacent work areas.

Event Tree is a probabilistic method used to determine the probability of a hazard resulting in an accident. This technique works from an initiating event forward to a final result.

Explosion Proof (XP) is specially designed equipment that reduces ignition sources for flammable vapors. The major feature of a XP equipment is the electrical classification, which requires all arc producing devices to be contained in specially designed boxes with sealed conduits.

Face Velocity is the velocity of air entering the opening in a hood. A minimum face *velocity* is required to insure that toxic vapors do not leave the hood enclosure.

Fail Safe is a concept used to insure that process equipment fails in a state which minimizes hazard.

Fault Tree is a method used to determine the conditions leading to a final or top unsafe event.

Flange Unions are used to connect pipes. They consist of a flat, circular, metal plates with bolt holes near the circumference. The flange is attached to the pipe via a central hole.

Formal Safety Review is a management technique used to prevent the existence of hazards. It involves an extensive report and a full committee review.

Fusible Link is a device that melts at a certain temperature. These devices are used to initiate the mechanical process to seal windows and doors, close valves and ventilator ducts, and so forth, reducing the impact of a fire.

Grounding is a procedure used to prevent the buildup of static electricity charges. This procedure involves connecting applicable units to electrical ground.

Appendix I: Glossary

Grounding Clamp is a clamp used to connect a process or process vessel to the ground system. This reduces the buildup of static electricity charge in the process.

Grounding Network is a system of wires buried underground that provides the electrical ground for process units. This reduces the buildup of static electricity charge.

Health refers to the well-being of people relative to industrially-related illnesses, both outside and inside the plant, due to normal and unplanned exposures, emissions, and releases.

Hazard and Operability Study is a technique similar to a safety review, but provides a more rigorous approach for determining the hazards associated with process equipment.

Hot Work Permit is a permit required before the following can be performed in an Electrically rated area: burning and welding, using non-explosion tools or fork truck, sparking or grinding.

Industrial Hygiene is a science devoted to the minimization or elimination of workplace exposures. This includes identifying the hazard, determining the magnitude of the hazard, and providing effective control techniques.

Informal Safety Review is a management technique used to prevent the existence of hazards. This approach is less rigorous than the Formal Safety Review.

Inerting is a procedure by which the vapor space above flammable liquids is purged with nitrogen or other inert gas to reduce the oxygen concentration to below a target concentration. This eliminates the chance for ignition since the vapor concentration is not flammable.

Interlock is a mechanism used to insure that events occur in a proper sequence. For instance, a reactor feed pump might be interlocked to allow reactant feed only if the coolant pump is operating.

Lock - Tag - Try is a procedure used to de-energize equipment in a process to prevent activation while workers are exposed.

Loss Prevention refers to elimination or minimization of injury to people, damage to environment and facilities, and loss of production and income.

Lower Explosion Limit is the minimum concentration in air of a flammable vapor below which explosion does not occur.

Manufacturer's Technical Information is technical information regarding a chemical supplied by the manufacturer.

Material Safety Data Sheet (MSDS) is a sheet providing technical information on a substance relevent to safety and ecology.

Appendix I: Glossary

Normally Closed means that a valve is closed when the air pressure or other signal is missing.

Normally Open means that a valve is open when the air pressure or other signal is missing.

Odor Threshold is the concentration below which the human nose is incapable of smelling a vapor substance.

Phosgene Paper is a specially treated paper which turns brown when exposed to
0.1 PPM of phosgene or greater.

Podbielniak Extractor or POD is a centrifugal extractor that separates two liquids based on a difference in densities.

Purging is a procedure where the oxygen is removed from a vessel using an inert gas such as nitrogen. This is performed prior to charging flammable materials into the vessel. Purging can be accomplished using a pressurization technique (using repeated pressurization cycles with an inert gas or by a continuous flow technique.

Relief Device is a device used to protect a vessel from excessive pressure. It performs this function by expelling part of the vessel contents.

Runaway Reaction is a reaction out of control. It usually begins with loss of coolant in a reactor, leading to a high reactor temperature and increased heat production. This results in a higher reactor temperature and so forth**.**

Rupture Disk is a specially calibrated sheet of metal or other material designed to burst at a well-specified pressure.

Safety is comprised of health and loss prevention.

Safety Audit is a review of an industrial facility's safety performance and program to determine if it is effective. The safety audit is performed by a team of highly skilled safety professionals.

Safety Checklist is a checklist involving safety features of a process that must be checked before and during the operation of a process.

Safety Relief Valve is a device used to protect a vessel from overpressure. See Rupture Disk and Relief Device.

Safety Review is a management system used to prevent the existence of hazards.

Self Contained Breathing Apparatus is a special type of respiratory equipment that contains its own air supply.

Spill Alarm is an alarm used to indicate a spill of hazardous materials. This prevents workers from entering the area until the spill is cleaned up.

Appendix I: Glossary

Telltale Gauge is a pressure gauge between a rupture disk and a spring relief valve. This gauge is used to detect the presence of a leak in the rupture disk.

Threshold Limit Value (TLV) is an airborne concentration that correspond to conditions where no adverse effects are normally expected during a worker's lifetime. The TLV is based on exposures using an 8-hour workday or a 40-hour work week.

Toxicology is a science devoted to studying the ways in which toxicants enter living organisms, how toxicants affect living organisms, and how toxicants are eliminated from living organisms.

Two-Phase Flow is a flow that contains both liquid and vapor fractions. Frequently the liquid and vapor are combined in a foam type discharge.

Upper Explosion Limit (UEL) is the maximum concentration in air of a flammable vapor above which explosion does not occur.

Velometer is a device used to measure the velocity of moving air. In its most simplest form it is just a calibrated propeller.

Vent Sizing Package (VSP) is an experimental apparatus developed by the Design Institute for Emergency Relief Systems to study reactor runaways and relief systems.

Vessel Pressure Test is a test used to determine the pressure integrity of process vessels. It is always performed using water.

RESEARCH MEMORANDUM

CHEMICAL ENGINEERING

SAFETY REVIEW FOR PILOT PODBIELNIAK
LIQUID - LIQUID EXTRACTION SYSTEM

AUTHOR: J. Doe   SUPERVISOR: W. Smith

November 8, 1988

SUMMARY

Chemical Engineering's Podbielniak (POD) liquid-liquid extraction pilot system has been reassembled. It will be used to evaluate the water-washability of toluene. A formal safety review was held 10/10/88. Main action items from that review included: 1) padding all vessels containing solvent with nitrogen, 2) grounding and bonding all tanks containing solvent, 3) adding dip legs to all vessels, 4) using elephant trunks at drum openings, 5) adding heat exchangers equipped with temperature gauges to cool hot solvent, 6) purging all vessels containing solvent with nitrogen prior to startup, 7) changing the emergency procedure to activate the spill alarm in the event of a spill and to trip the sewer isolation valve, and 8) adding receiving drums for all output streams containing solvent.

Subsequently, a few equipment changes were made during initial system check-out and test runs. These changes were made to enhance operability, not safety; e.g. 1) the pump (P1) generated insufficient head and a stronger spring was installed; and 2) a light-liquid in sample point, a few check valves and additional temperature and pressure gauges were installed.

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REPORT NUMBER 88-5
SECURITY CLASS None
PROJECT NUMBER 6280
SUPERVISOR(S) APPROVAL(S)

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Appendix II: Formal Safety Review Report

I. INTRODUCTION

A. Process Summary

The following procedure is used to wash toluene in the equipment provided:

1) An appropriate amount of solvent is transferred from the solvent storage tank to the emulsion tank.

2) Water is added to the solvent to form an emulsion.

3) The emulsion is heated to 190°F.

4) The emulsion is separated in the centrifugal contactor (POD) which produces a stream containing water soluble impurities and a stream of washed solvent.

B. Reactions and Stoichiometry

No reaction takes place. As far as stoichiometry is concerned, typically one part water is added to one part solvent. Flow rates for the above are based on a maximum of 1000 cc/min solvent to the POD.

C. Engineering Data

Toluene has a vapor pressure of 7.7 psi at 190°F. System operating pressures will normally be 40-50 psig around the POD, with pumps capable of delivering 140 psig. System temperatures will be maintained between 190 and 200°F. Typical viscosities will be under 10 cp at this temperature.

II. RAW MATERIALS AND PRODUCTS

Solvents

The most frequently used solvent is toluene. Toluene boils at 231°F, but forms an azeotrope with water boiling at 183°F. Since this is below the system operating temperature, hazards are present due to flammability and volatility. In addition, toluene presents special problems from a personnel exposure viewpoint as a suspected teratagen.

To minimize hazards, the following precautions will be taken:

1) All vessels containing solvent are N_2 padded and grounded.

2) All potential solvent exposure points will be in close proximity to "elephant trunk" exhaust ducts for ventilation.

3) All product streams are cooled before discharge or sampling.

4) Colorimetric sampling tubes will be available for ambient air monitoring.

The possibility exists for using other solvents in the system. Safety reviews for each will be conducted as needed.

III. EQUIPMENT SET-UP

A. Equipment Description (Sketches attached)

1) Emulsion Tank: The emulsion tank consists of a jacketed, agitated, 50-gal. glass lined Pfaudler reactor with N_2 pad and relief valve. Emulsion is heated in the vessel by applying steam to the jacket. Temperature is controlled by means of a temperature indicating controller which measures the temperature in the vessel. The controller modulates a control valve in the steam line to the jacket. Emulsion is circulated from the bottom of the reactor to the POD system and back to the reactor top by means of a Viking pump driven by a 2-hp 1745 rpm motor.

A slipstream is fed from this loop to the POD system. Pressure in this circulating loop is controlled by means of a back pressure controller located in the return line to the top of the reactor.

2) Solvent System: The solvent storage tank is a 75-gal. stainless steel pressure vessel (112 psi @ 70°F) with an integral sight glass, N_2 pad and relief valve. Solvent is pumped from the bottom of the storage tank to the emulsion tank. The pump is a Burks turbine pump driven by an XP rated, 3/4 hp 3450 rpm motor. A dip pipe is used to vacuum charge solvent through a dip leg in the vessel where grounding and bonding is secured.

3) POD System: The POD system consists of a Baker-Perkins Model A-1 Contactor (i.e. a Podbielniak centrifugal contactor) fabricated in 316 stainless. A variable speed drive is capable of rotating the unit at speeds up to 10,000 rpm. The normal operating speed is 8100 rpm.

The solvent/water emulsion is heated in its subsystem, and flows through a Micro Motion mass flow meter. The emulsion is fed to the POD where the water and organic phases are separated. Through this contact and separation, the impurities are extracted into the aqueous phase. This results in a relatively clean solvent.

5) Washed Solvent System: The washed solvent tank is a grounded 55-gallon drum. An elephant trunk positioned over the bung vents the drum to the exhaust system. Material fed to the drum is cooled from the POD operating temperature of approximately 190°F to 80-110°F by a stainless steel heat exchanger.

6) Waste Water System: The waste water tank is also a grounded, 55-gal. drum vented to the exhaust system. The heavy liquid out (HLO) stream from the POD system is cooled before discharge into the drum by a stainless steel heat exchanger. Disposal will depend on the solvent used, its solubility in water and environmental constraints.

B. Equipment Specifications

1) Emulsion System

Reactor - 50-gal., glass-lined, jacketed Pfaudler;
Operating pressures: reactor - 150 psi @ 450°F
jacket - 130 psi
Safety relief valves: reactor - 60 psi
jacket - 125 psi

Agitator - turbine, 3.6 hp, 1750 rpm, XP rated motor, variable speed drive.

Circulating pump - Viking series HL124, motor - 2 hp, 1745 rpm, XP rated.

Micro Motion Mass Flowmeter - 316L stainless steel, 0-80 lb/min mass flow range, accuracy of 0.4% of range, XP rated with electronics unit mounted separately in non-hazardous area.

2) Solvent System

Tank - 75 gal., stainless steel, rupture disk set at 112 psi.

Pump - Burks turbine, model ET6MYSS; motor: 3/4 hp, 3450 rpm, XP rated.

3) POD System

POD - Baker-Perkins A-1 centrifugal contactor, 316 SS, max. temp: 250°F, max. pressure: 250 psig, max. speed: 10,000 rpm.

Drive - variable speed Reeves Motodrive, 935-3950 rpm, 3 hp, 1745 rpm motor, XP rated.

4) Washed Solvent System

Tank - 55-gallon drum.

Light liquid out (LLO) Cooler - American Standard, single pass, SS, model 5-160-03-024-001, max. temperature: 450°F, max. working pressure: 225 psig shell, 150 psig tube.

5) Waste Water System

Tank - 55 gallon drum.

HLO Cooler - Same as LLO cooler.

IV. PROCEDURES

A. Normal Operating Procedures

1. Purge solvent and emulsion tanks with nitrogen via valves 1(a) and 1(b).

2. If necessary, solvent and emulsion tanks are vented to "elephant trunks" and into the exhaust system through valves 2(a) and 2(b).

3. Pull a vacuum (15 in. Hg) on the solvent storage tank and charge with solvent by sucking it from the appropriate drum. Check the tank level using the level glass. Periodically check the air for toluene by using colorimetric tubes.

4. Break the vacuum and pad with nitrogen through valve 1(a).

5. Make sure valve 3 is closed from the water head tank to the emulsion tank.

6. Charge the proper amount of softened water through valve 4 to the water head tank located above the emulsion tank.

7. Close valve 4 and pad the water head tank with nitrogen through valve 5.

8. Turn on the emulsion tank agitator.

9. Pump solvent from the solvent storage tank to the emulsion tank:

   a. Line up valves from solvent storage tank through pump P2, to the top of the emulsion tank.

   b. Start pump P2.

   c. Stop pump and close valves when addition is complete.

10. Open valve 3 and add water in the head tank to the emulsion tank. Close valve 3 when addition is complete.

11. Establish circulation in the emulsion system:

    a. Close valve 6 on the feed stream to the Micro Motion.

    b. Line up valves from the bottom of the tank to pump P1 and from the return line back to the top of the vessel.

    c. Start pump P1.

    d. Open steam flow to the jacket of the feed tank.

    e. Bring emulsion up to temperature (190°F).

12. Turn on cooling water to the solvent (LLO) discharge cooler and to the aqueous (HLO) discharge cooler.

13. Line up valves on the HLO and LLO streams from the POD, to the coolers, and to their respective waste tanks.

14. Open valve 10 to fill the POD.

15. Start the motor for the POD and slowly bring up to the desired rpm.

16. Open valve 6 to begin emulsion flow.

17. Adjust flow to obtain desired rate on Micro Motion meter.

18. Control back pressure on the POD LLO and HLO streams by adjusting valves 11(a) and 11(b) respectively.

19. Samples can be obtained from the LLO stream via valve 12(a) and from the HLO stream via valve 12(b).

20. To shut down the POD after a run has been completed:

    a. Close valve 6.

    b. Reduce pressure on the LLO stream (valve 11a) and slowly reduce rotor speed.

    c. Turn off POD motor.

    d. Close valve 10 after the rotor has stopped.

    e. Shut down emulsion system.

    f. Shut off steam and cooling water.

B. Safety Procedures

The safety concerns unique to this operation are due to:

a. The solvent used is volatile and flammable and is also being used at a temperature above its normal atmospheric boiling point.

b. The materials are all hot -- 190°F or greater -- and capable of producing thermal burns.

c. Toluene presents a special handling problem due to potential health hazards.

The specific procedures to be followed to minimize the risks associated with the above are:

a. Flammable Solvents:

(1) Solvents are exposed to atmosphere only with adequate ventilation.

(2) Solvents are only transferred into and out of the system when cold. Do not operate if coolers are not functioning properly.

(3) All solvent containing process vessels are N_2 purged and maintained under N_2 pad or blanket.

(4) Vapors containing solvent are vented only to the exhaust ducts, never into the worker area.

(5) Initial opening of sample and product valves to atmosphere is done slowly to avoid flashing.

(6) All transfers of solvent-containing streams to or from drums are done in accordance with accepted bonding and grounding procedures.

(7) All equipment is electrically grounded.

b. Hot Material:

(1) Avoid contact with hot process lines and vessels. Most lines are insulated for personnel protection.

(2) Wear gloves when working on potentially hot equipment.

(3) Periodically check stream temperatures and cooling water flow to insure coolers are working properly.

c. Health Hazards (Toxicity, etc.):

(1) Handle potentially hazardous material only when material is cool and adequate ventilation is present.

(2) Periodically check operating area for leaks with colorimetric tubes.

(3) Repair any leaks immediately.

1. Emergency Shutdown:

a. Close solvent valve at bottom of solvent storage tank (if open).

b. Shut off solvent pump P2 (if operating).

c. Close valve at bottom of emulsion tank.

d. Shut off emulsion pump P1.

e. Shut off steam to the emulsion tank jacket.

f. Shut down POD drive system.

2. Fail Safe Procedures:

a. Steam failure - no negative consequences.

b. Cooling water failure - shut down system.

(1) LLO to washed solvent drum will flash and be sucked into vent system.

(2) HLO to waste drum - some solvent may flash off and be sucked into vent system.

c. Electrical failure - close HLO and LLO valves to protect the unit while it coasts to a stop.

d. N_2 failure - stop any operational procedures.

e. Exhaust system failure - shut down system.

f. Pump failure - shut down system.

g. Air failure - all steam control valves fail closed. All cooling water control valves fail open.

3. Spill and Release Procedures

a. Solvent spill - follow hazardous spill response as outlined in Safety Manual.

(1) Sound alarm and evacuate if warranted (e.g., large drum quantity spill or hot solvent spill).

(2) Vent system on high speed.

(3) Trip sewer isolation valves.

(4) If safe to do so: isolate equipment/ignition sources. Absorb / dike spill.

(5) Allow excess to evaporate. Check area with explosimeter and colorimetric tubes. Do not enter explosive atmosphere.

(6) When safe to do so, sweep up any absorbant into waste drums for proper disposal.

(7) Consult with Environmental department if material is trapped in sewer system.

C. WASTE DISPOSAL

The washed solvent is collected in drums for disposal. The aqueous stream, after analysis, can be sent directly to the publically owned treatment works (POTW). Limits have not yet been set for dumping vs waste disposal in drums. If the solvent being used is a regulated substance (such as toluene), drum disposal of the HLO may be the only acceptable way.

D. CLEAN-UP PROCEDURE

Minor spills are soaked up with absorbant material and disposed of in drums. Equipment is washed with hot and/or cold water as necessary.

V. SAFETY CHECKLIST

_____ Purge emulsion tank with nitrogen, fill, establish nitrogen pad.

_____ Purge solvent storage tank with nitrogen, fill, establish nitrogen pad.

_____ Purge washed solvent tank with nitrogen, establish nitrogen pad.

_____ Check cooling water flow in two coolers.

_____ Vent system operational.

_____ Availability of absorbant material and disposal drum.

_____ Availability of impervious gloves, goggles/face shield.

_____ Sniff area with colorimetric tubes for hazardous solvents.

_____ Availability of air line hood.

_____ Check all drums for proper grounding.

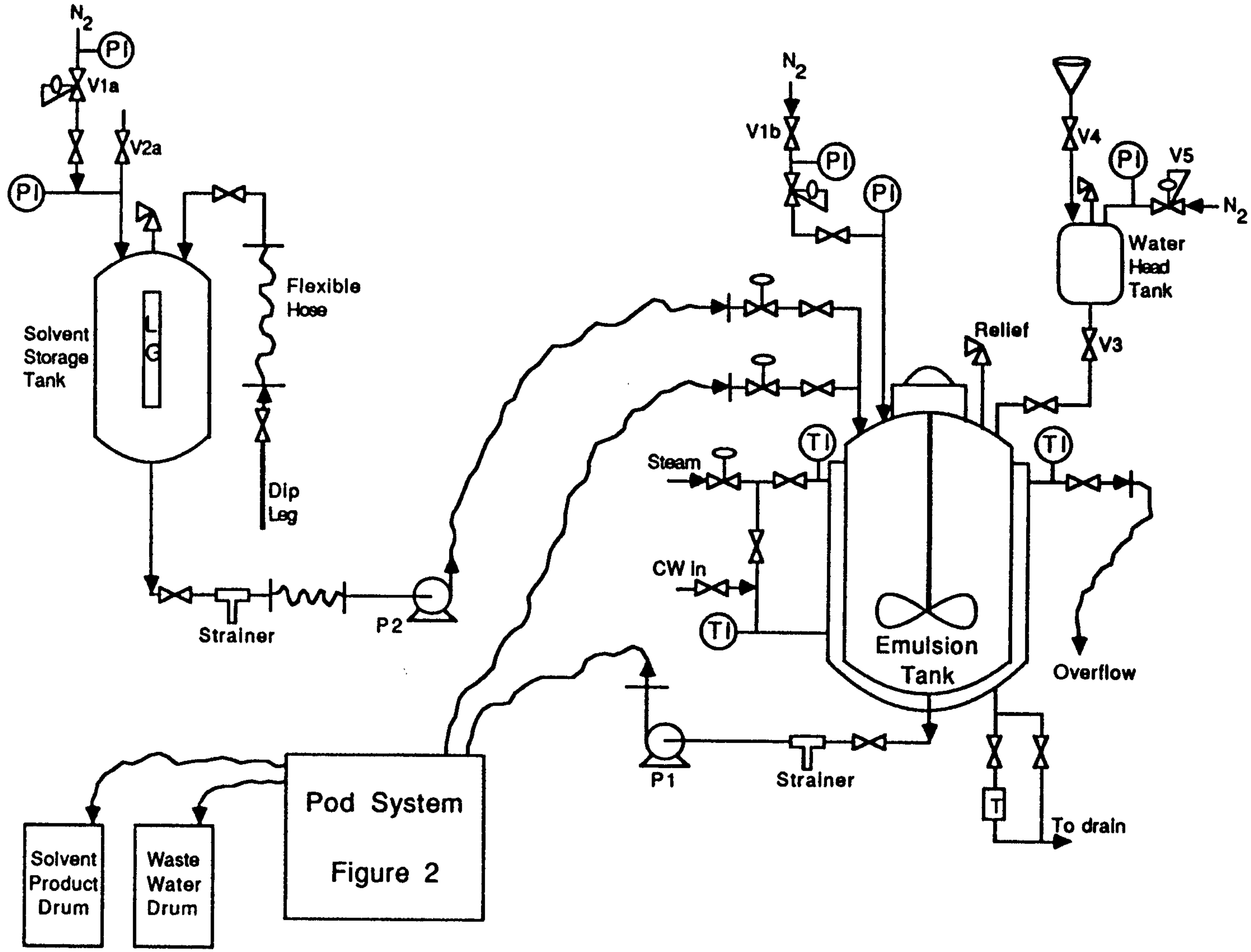

Figure 1: Podbielniak extraction system

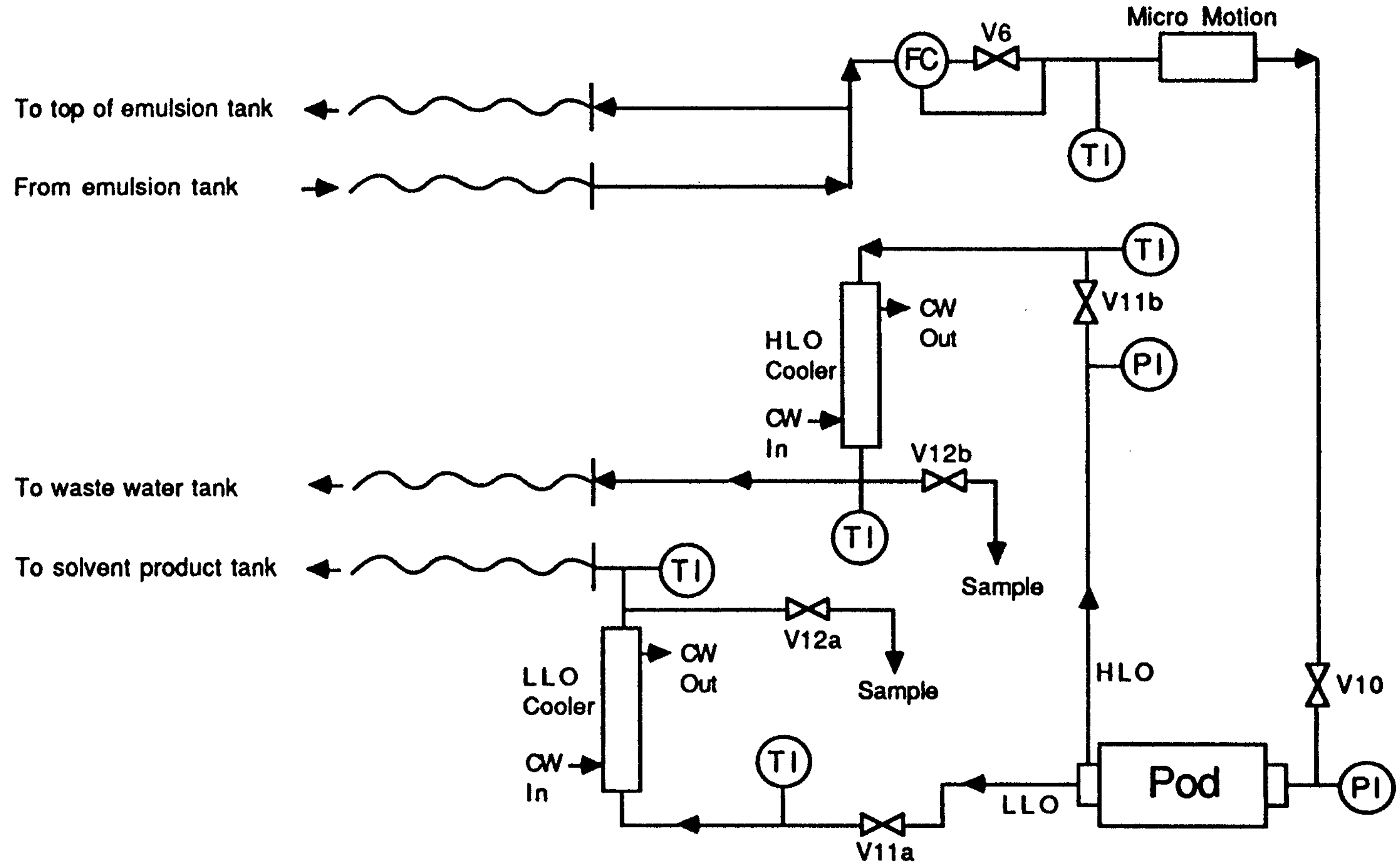

Figure 2: Piping diagram for Podbielniak solvent water wash system

Appendix II: Formal Safety Review Report

MATERIAL SAFETY DATA SHEET

Common chemical name: Toluene	**Physical state:** Colorless liquid	**Odor:** sweet, pungent	
Synonym: Methylbenzene	**Molecular weight:** 92.13	**Odor Threshold:** 2 - 4 ppm	**CAS No:** 108-88-3
Chemical formula: C_7H_8	**Explosive limits:** 1.27 - 7.0%	**Vapor pressure:** 36.7 mm Hg @ 30°C	**PEL:** 100 ppm-skin

Toxic Properties:

Eyes:	Moderately irritating
Skin:	Moderately irritating
Inhalation:	CNS effects
Ingestion:	Moderately toxic

Vapors may cause eye irritation. Eye contact with liquid may result in corneal damage and conjunctival irritation which lasts for 48 hours. Inhalation may be irritating and result in fatigue, headaches, CNS effects, and narcosis at high concentrations. Toluene is skin absorbed. Repeated or prolonged skin contact may result in irritation, defatting, and dermatitis.

Occasionally, chronic poisoning may result in anemia, leukopenia, and enlarged liver.

Some commercial grades of toluene contain small amounts of benzene as an impurity. Benzene is an OSHA regulated material.

Personal Protection:

Goggles, impervious gloves, protective clothes and shoes are recommended. Chemical cartridge respirators are sufficient for routine handling. Air-line respirators or self-contained breathing apparatus are recommended for high concentrations.

First Aid:

Eyes: Flush thoroughly with water. Consult a physician.

Skin: Wash affected areas with plenty of water. If irritation persists, get medical attention.

Inhalation: Remove to fresh air. Aid in breathing if necessary. Consult a physician.

Ingestion: If swallowed, do <u>not</u> induce vomiting. Call a physician immediately.

Special Precautions/Considerations:

This is a flammable liquid. The flash point is 40°F and should be handled accordingly. During transport and storage, protect against physical damage. Outside or detached storage is preferable. Separate from oxidizing materials.