Fires and Explosions: What You Need to Know to Prevent Them

CSChE PSM Symposium
Edmonton, Alberta
2007

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Objectives

- Understand
  - Characteristics of Flammable Liquids & Vapours
  - Effect of Temperature and Pressure on flammability
  - Effect of Inert Substances on fires
  - Ignition Hazards
- Practical knowledge required to prevent Process Fires

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What is a Fire ?

Fire is a Chemical Reaction

- Fuel reacts with oxidizers
- Produces, heat, light, products of combustion

$$CH_4 + 2O_2 \Rightarrow CO_2 + 2H_2O$$

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Understand What Burns!

- What Burns – Solids, Liquids or Vapours (Gases)?

- Only Vapours (Gases) Burn!

- Solids and Liquids have to be converted to vapours before they burn.

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Conditions of a Fire

- It's not a simple triangle but a Fire Pyramid:
  - Combustible Material,
  - Oxygen,
  - Heat or Source of Ignition and
  - Free Radicals
- Ignition source needed until fire is self-sustaining:
  - Very quick for vapors
  - More time for Liquids & Solids
  - Duration & temperature of ignition source are important

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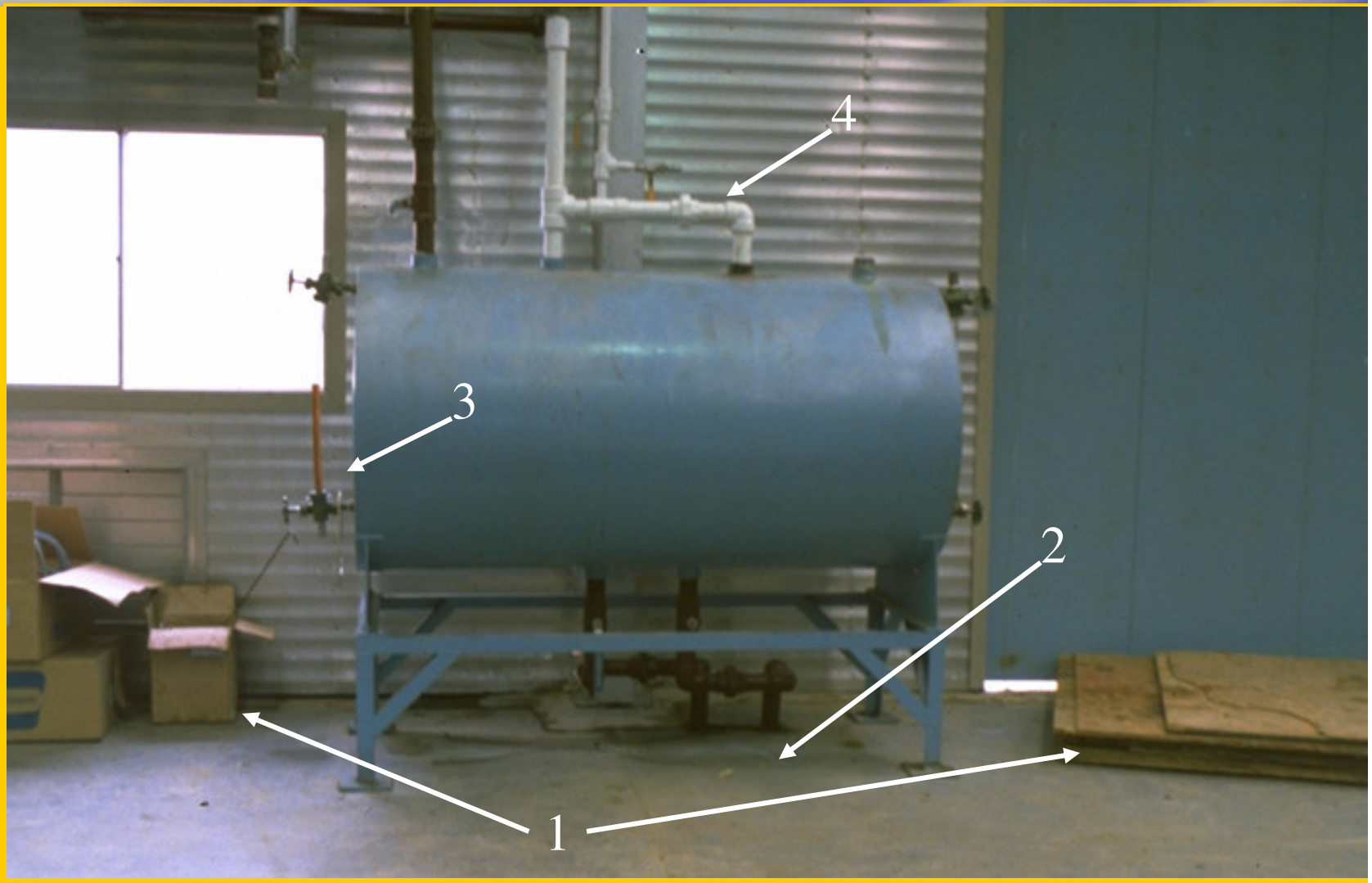
Compressor Building Fire Hazards



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Flammability Parameters

- No single parameter defines flammability, but the major ones that influence it are:
  - Flash Point
  - Flammable Range
  - Auto Ignition Temperature
  - Minimum Ignition Energy

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Flash Point

- Flash Point is the minimum temperature at which a liquid gives off vapor in sufficient concentration to form an ignitable mixture with air near the surface of the liquid
- Note that published values are for pure components, under laboratory conditions
- Example

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Flammable Liquids Storage Cabinet

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Use of Adsorbent Pads

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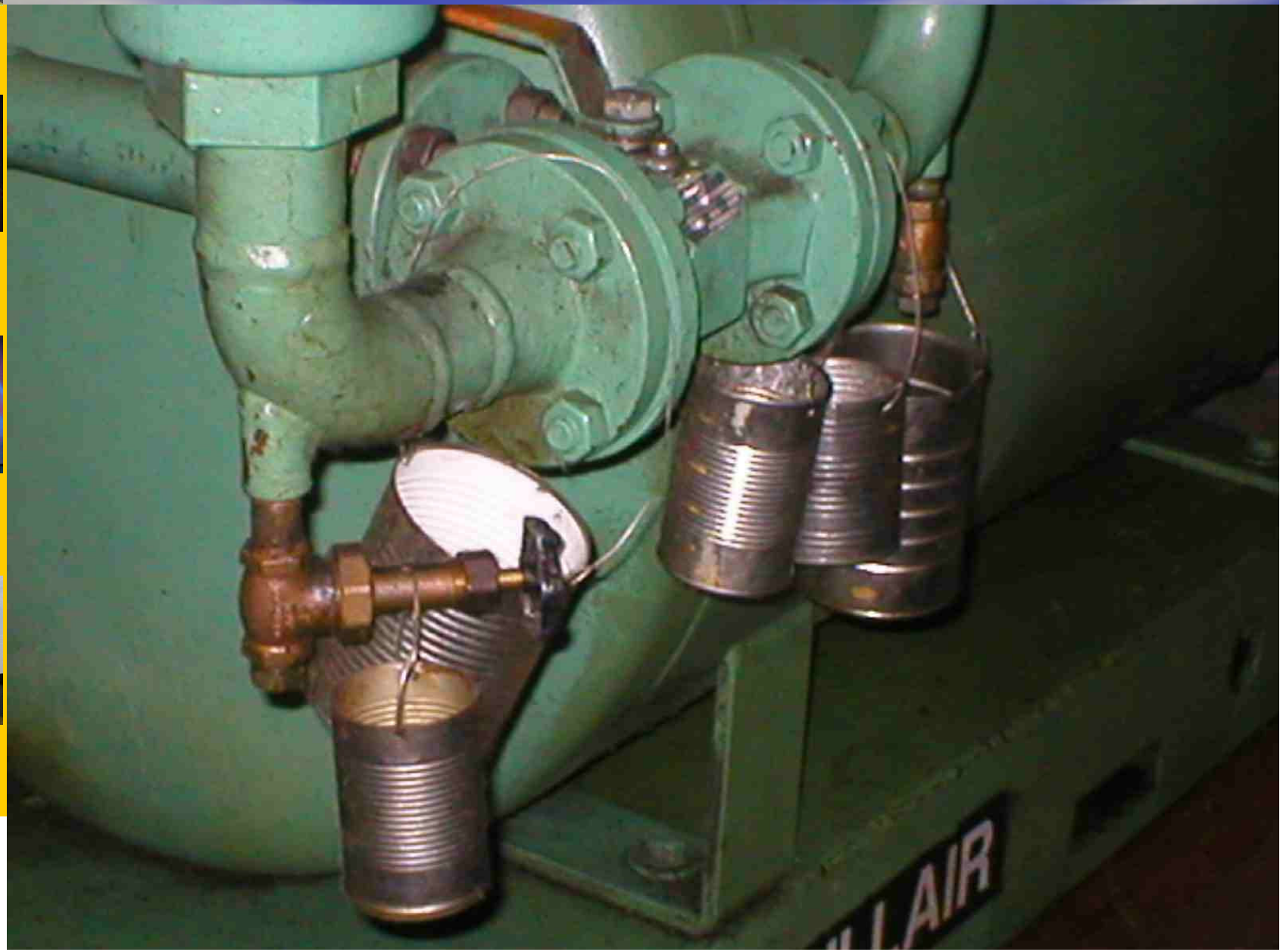
Collecting Oil Leaks



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Flammable Materials Classification

Material	Flash Point	Vapour Press
Liquified Gas	< 37.8 C	>= 275.8 kPa
Flammable Liquid	< 37.5 C	< 275.8 kPa
Combustible Liquid	>= 37.8 C < 93.8 C	

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Compressed Liquefied Gases & Cryogenic Combustibles

- **Compressed Liquefied Gases**
  - Flammable Gases stored above their normal boiling point but kept in liquid state by pressure.
  - When released, liquid expands and vaporizes, creating large volumes of cold gas
  - The cold gas behaves like a heavier-than-air gas
- **Cryogenic Flammable Liquid**
  - Cryogenic liquids are generally below -101°C
  - Behave like flammable liquids when spilled
  - Liquid absorbs heat & vaporizes forming ignitable mixture

Which is the worst fire hazard?

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Location of Equipment

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Excellent Fire Protection

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Passive Protection?

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Flammable Materials Classification

Material	Flash Point	Vapour Press
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Flammable Liquid	< 37.5 C	< 275.8 kPa
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Nitrogen Pad on Storage Tank

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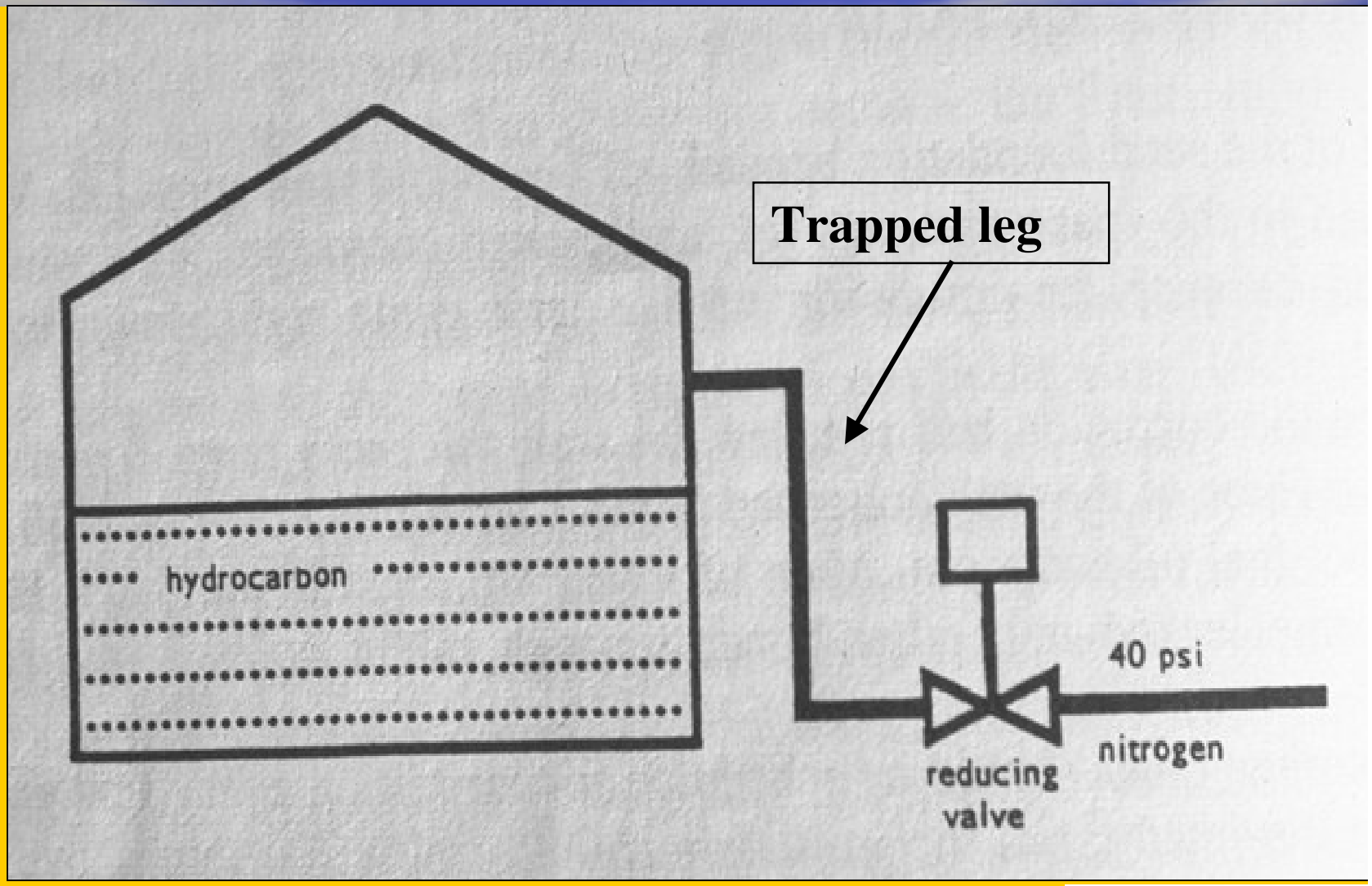
Nitrogen Pad Supply



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Methanol Storage Tank

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Tanks Suck!

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Flammable Materials Classification

Material	Flash Point	Vapour Press
Liquified Gas	< 37.8 C	>= 275.8 kPa
Flammable Liquid	< 37.5 C	< 275.8 kPa
Combustible Liquid	>= 37.8 C < 93.8 C	

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What is the problem here?

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Whoops!

A10 CALGARY HERALD Wednesday, February 14, 2001

Oil truck blast a close shave for driver

THE CANADIAN PRESS
TORONTO

A man dropping off a load of oil byproducts was blasted by an explosion Tuesday when he used his lighter to see if he had finished emptying his load.

The blast knocked the 39-year-old resident of Laval, Que., four metres, singeing his eyebrows and half his beard.

The man, who was dropping the load at a Petro-Canada plant in Mississauga, Ont., west of Toronto, was able to walk on his own after the blast.

"I've definitely never seen anything like this," said Const. Heather Andrews. "It was one of those things where just before the explosion happened, he said, 'Oh-oh. What did I do?'

"He should just buy a razor the next time he wants to get rid of his beard."

The driver was not identified.

Lack of understanding of flash point

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Storing Flammable Materials

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Combustible Gases

- **Lighter-than-Air**
  - **Dissipate rapidly in the atmosphere**
  - **Affect Smaller area than heavier-than-air gases**
  - **Seldom accumulate to form ignitable mixture at grade - Unless confirmed or Sub-cooled**
- **Heavier-than-Air**
  - **Flow to grade when released**
  - **Disperse by natural or forced ventilation**
  - **When vented may behave as a lighter-than-air gas**

Location of release points

Ventillation

Ignition sources

As the gas disperses into the surrounding air, the density of the mixture approaches that of air.

What has this to do with Preventing Process Fires?

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What is the Hazard?

Natural Gas Regulator Vents

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Natural Gas Regulator

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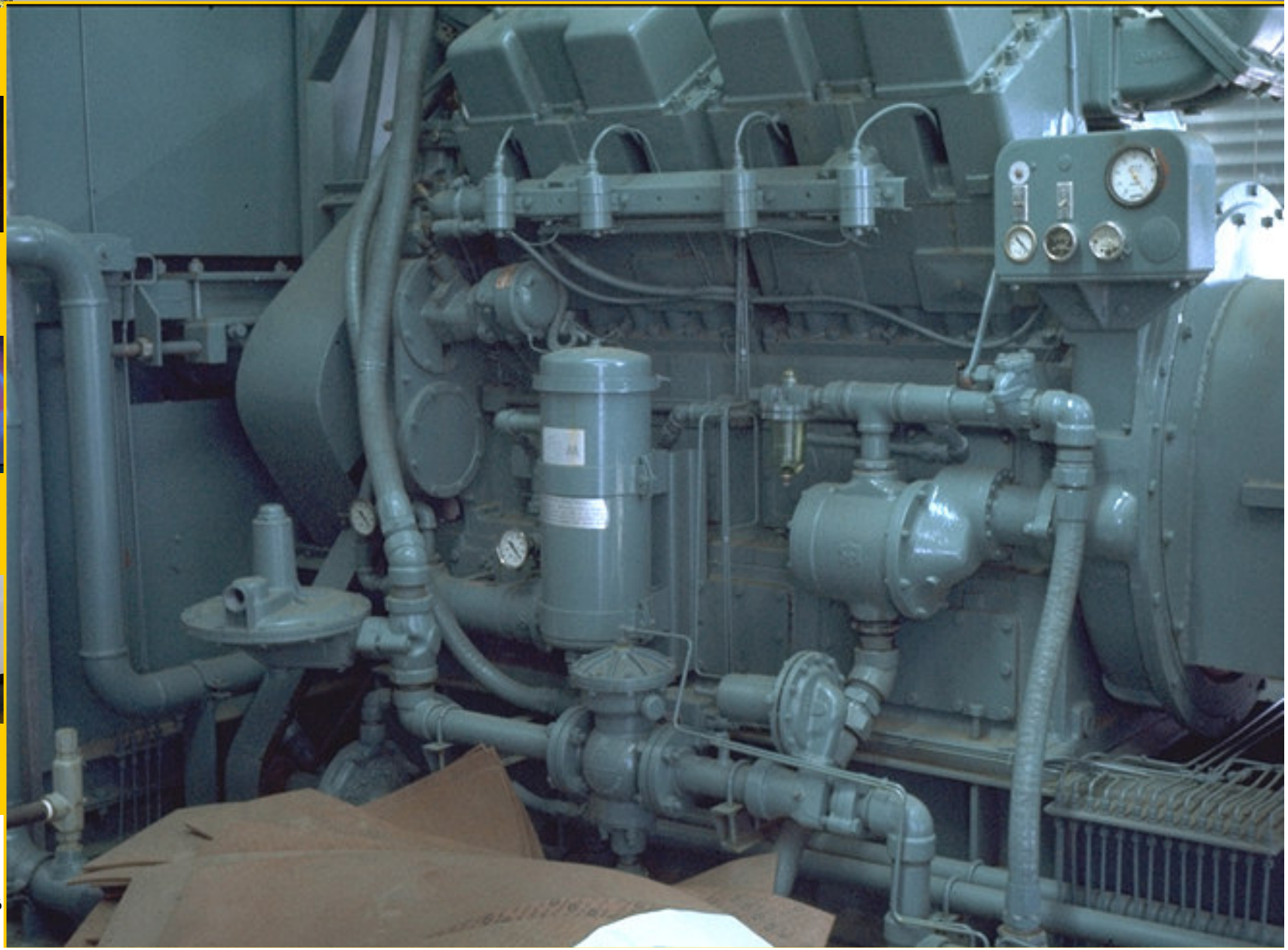

Autoignition Temperature

- AIT – The minimum temperature required to initiate or cause self-sustained combustion of a solid, liquid, or gas independently of the heating or heated element.
- Before anything burns its AIT must be exceeded.

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Wood Scaffold near Hot Pipe

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Autoignition Temperatures

Material	Autoignition Temperature		%LFL	%UFL
	C	F		
i-Pentane	243	469	1.4	7.6
cPentane	361	682	1.1	8.7
Natural Gas	630	1166	5.0	15.0
Benzene	498	928	1.2	7.8
Styrene	490	914	0.9	6.8

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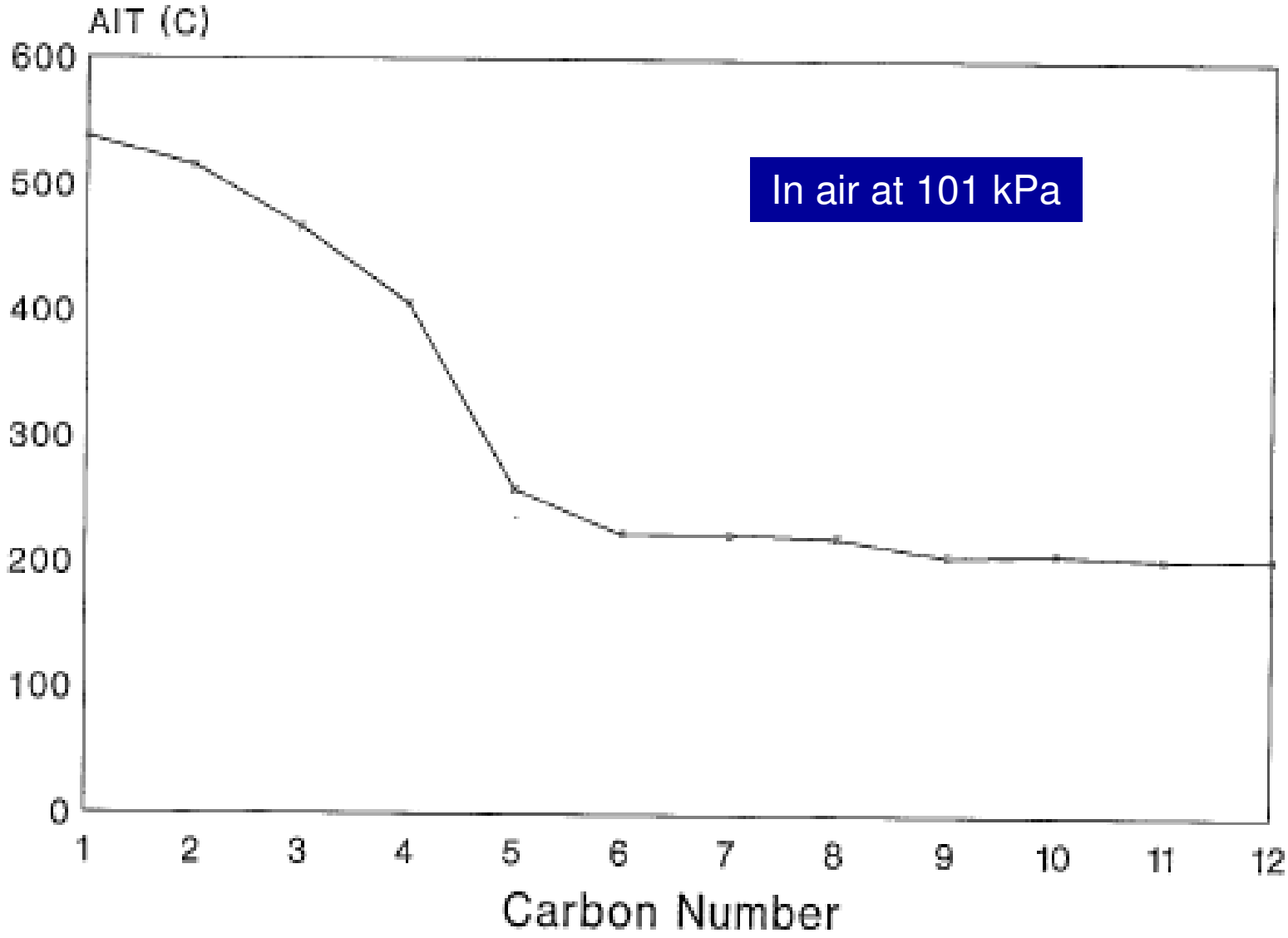
Effect of Molecular Weight on AIT



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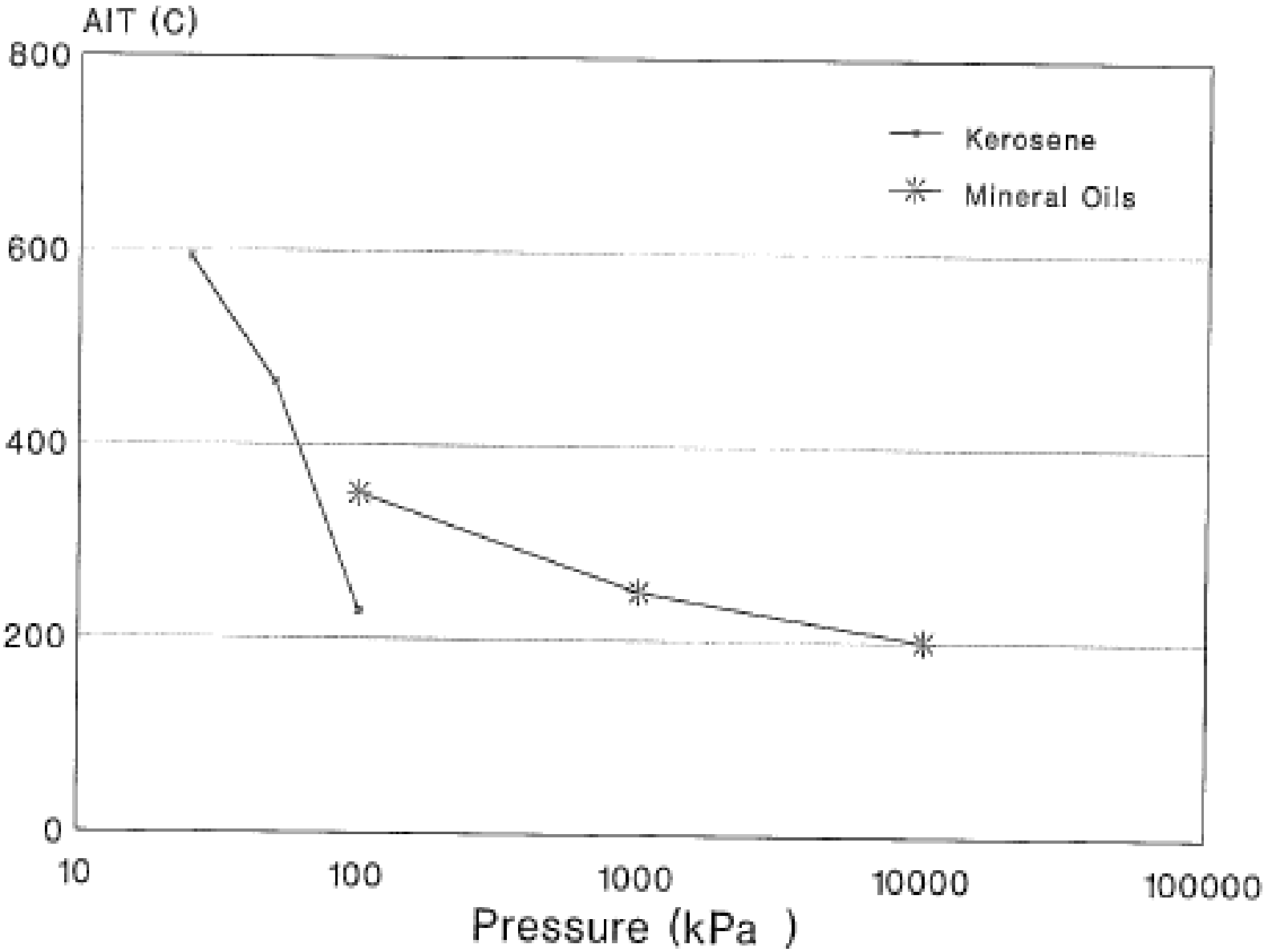
Effects of Pressure on AIT



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Oil Soaked Insulation

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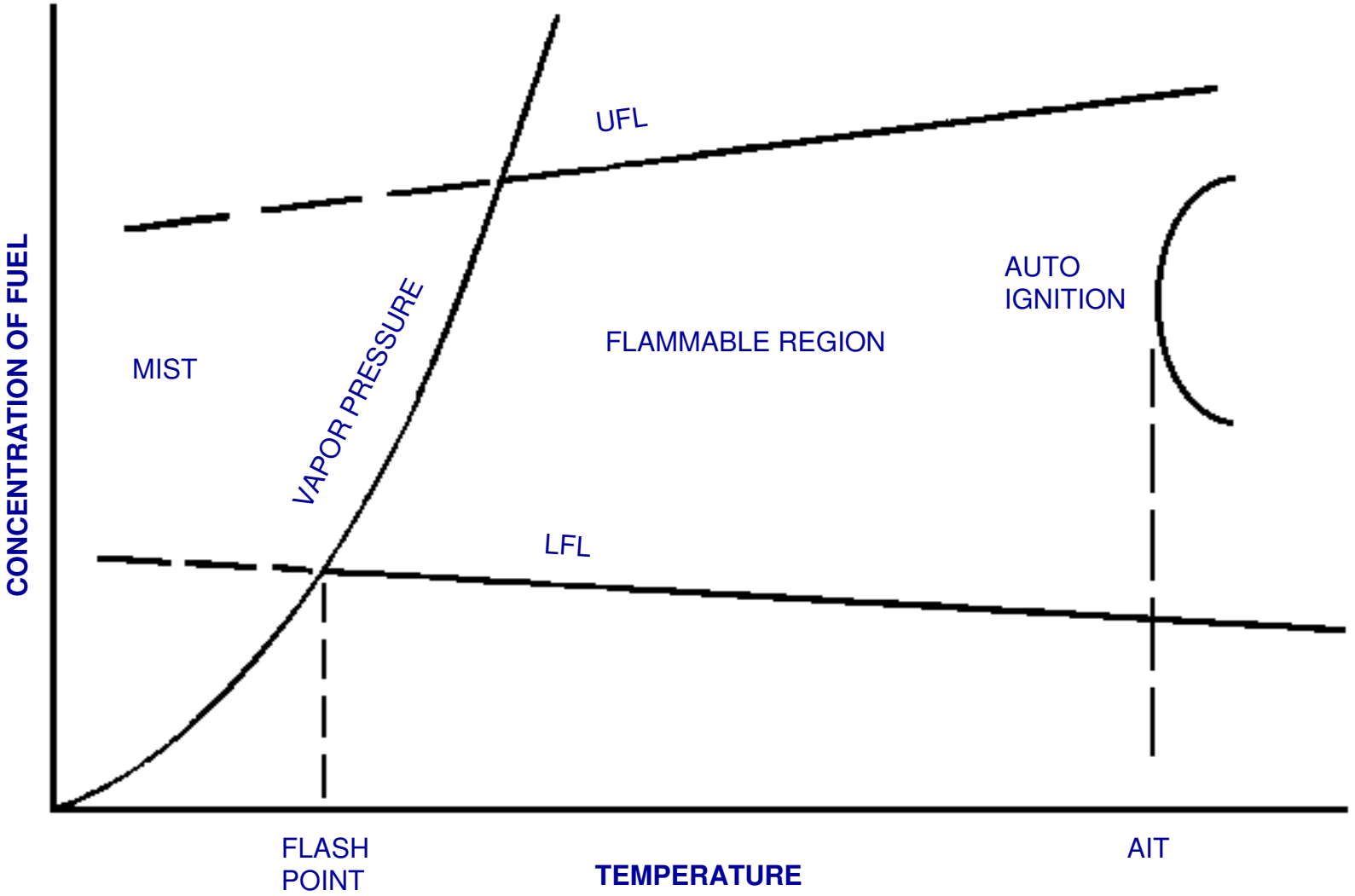
Flammability Relationships



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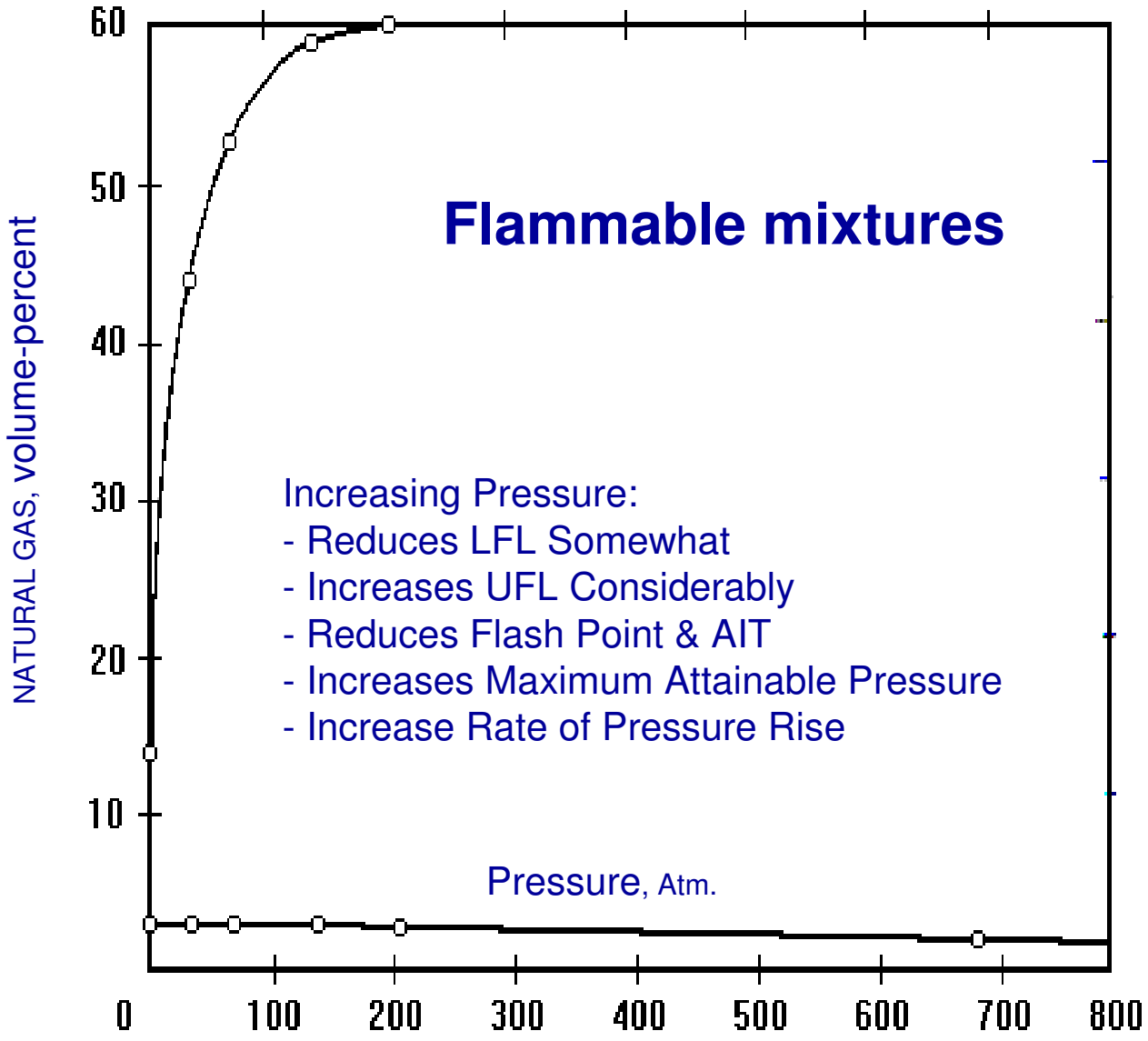
Effect of Pressure on Flammability of Natural Gas in Air at 28°C



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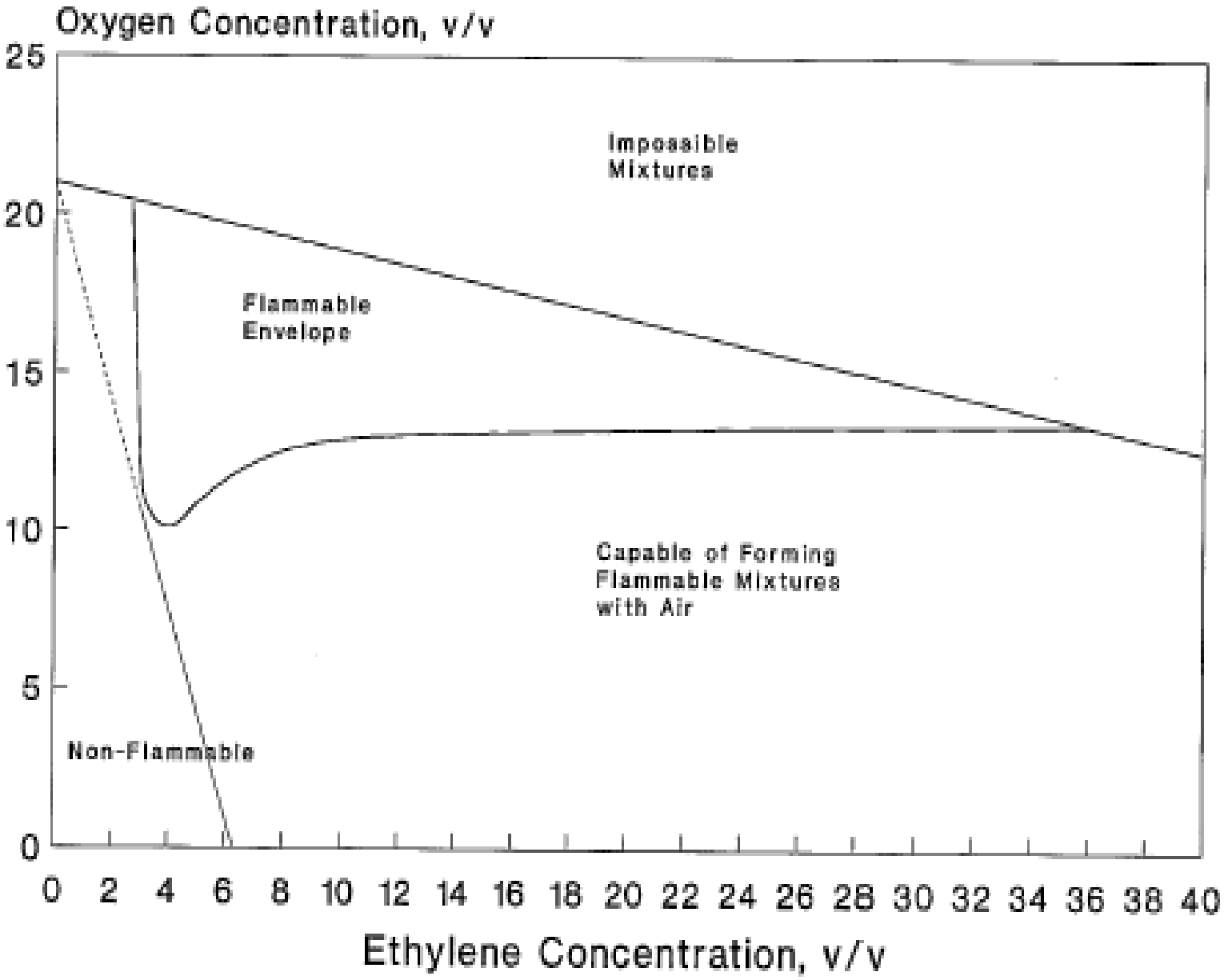
Flammability of Ethylene in Nitrogen



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Flammability of Pentane in Nitrogen

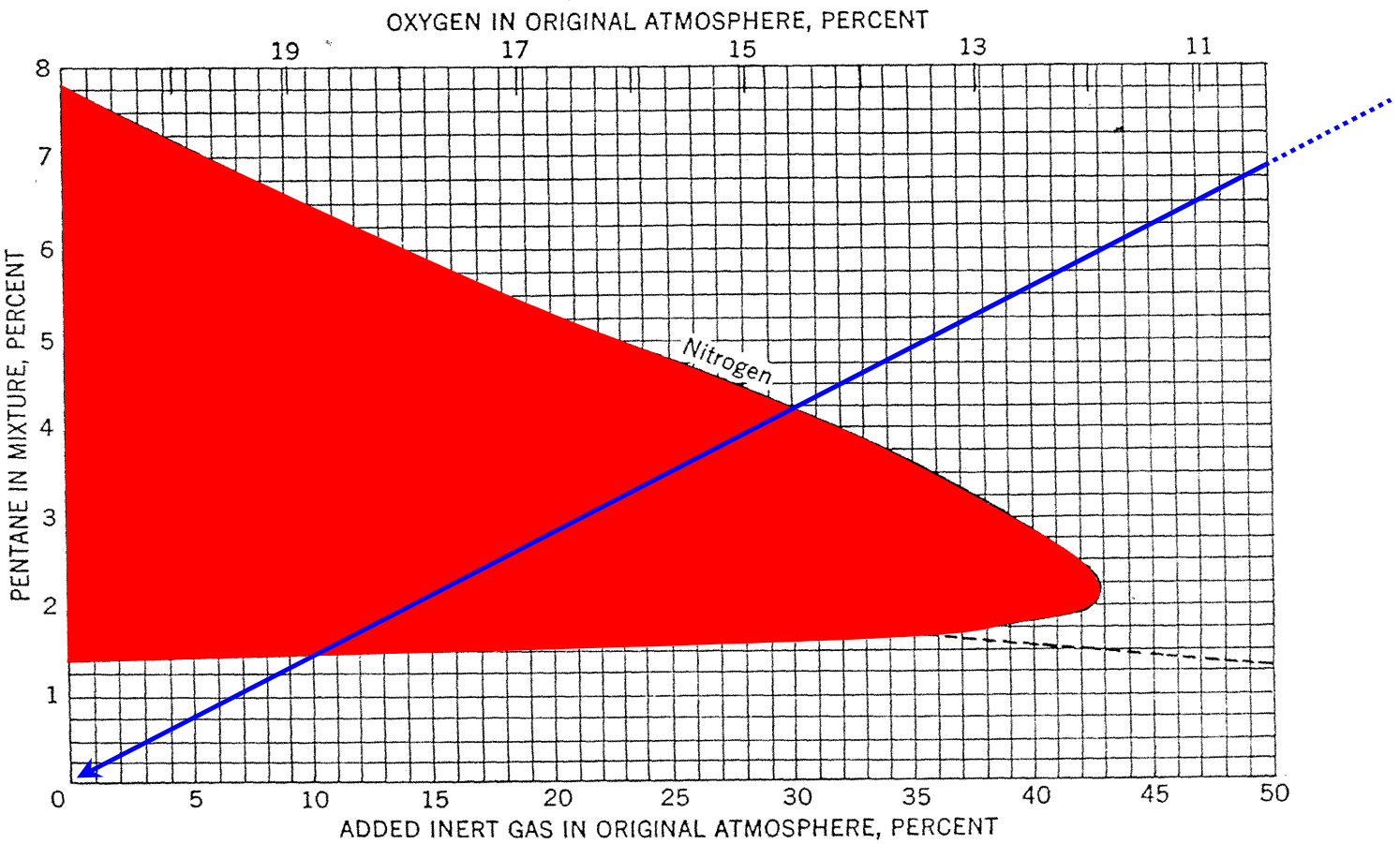

FIGURE 35.—Limits of Flammability of Pentane in Mixtures of Air and Nitrogen, and of Air and Carbon Dioxide.

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Sources of Ignition

- **Electrical Ignition Sources**
- Hot Equipment or Piping
- Mechanical Heat Energy
- Chemical Heat Energy
- Heat of Compression

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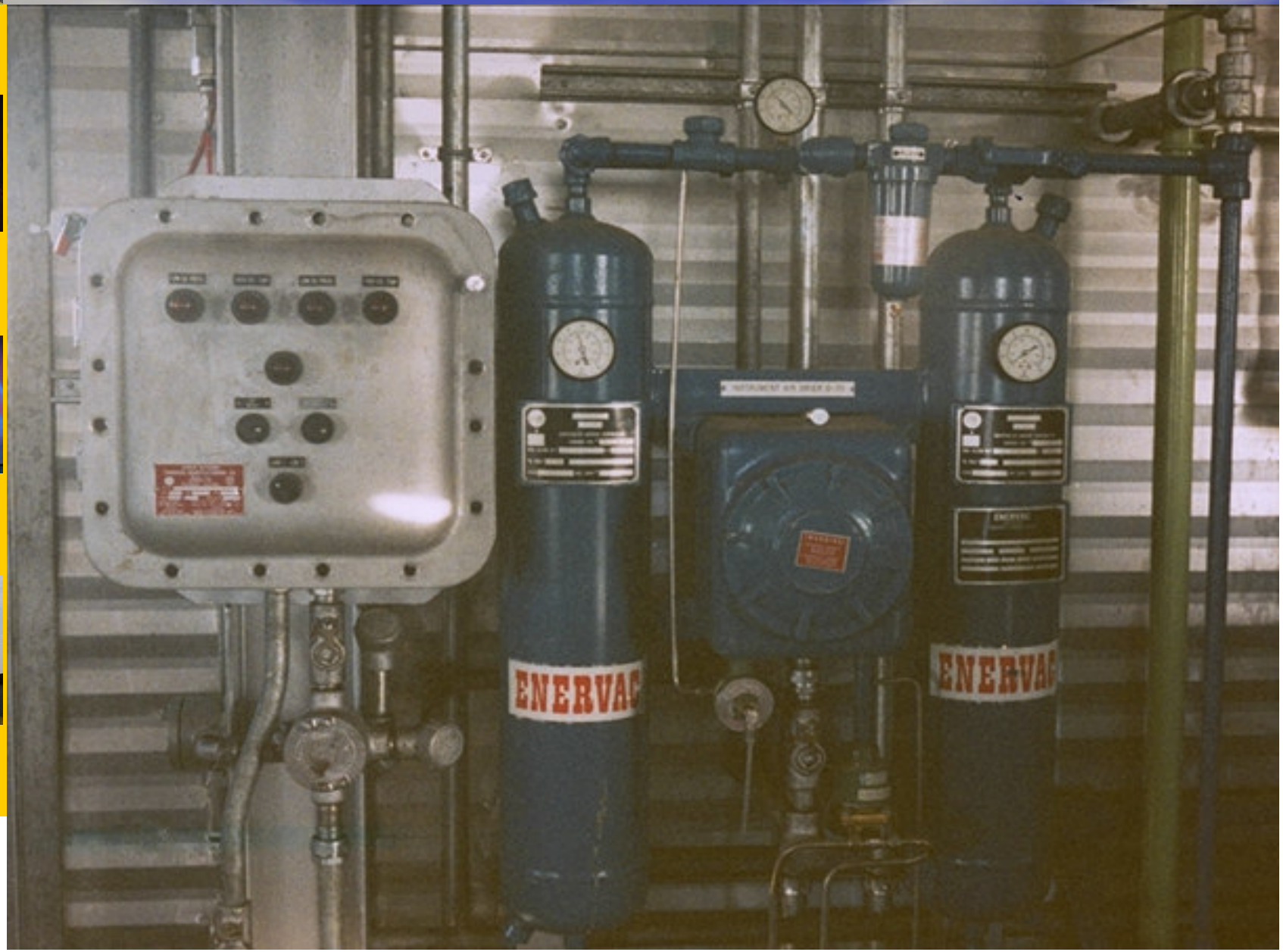
Explosion Proof Panel



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Electrical Equipment Joint

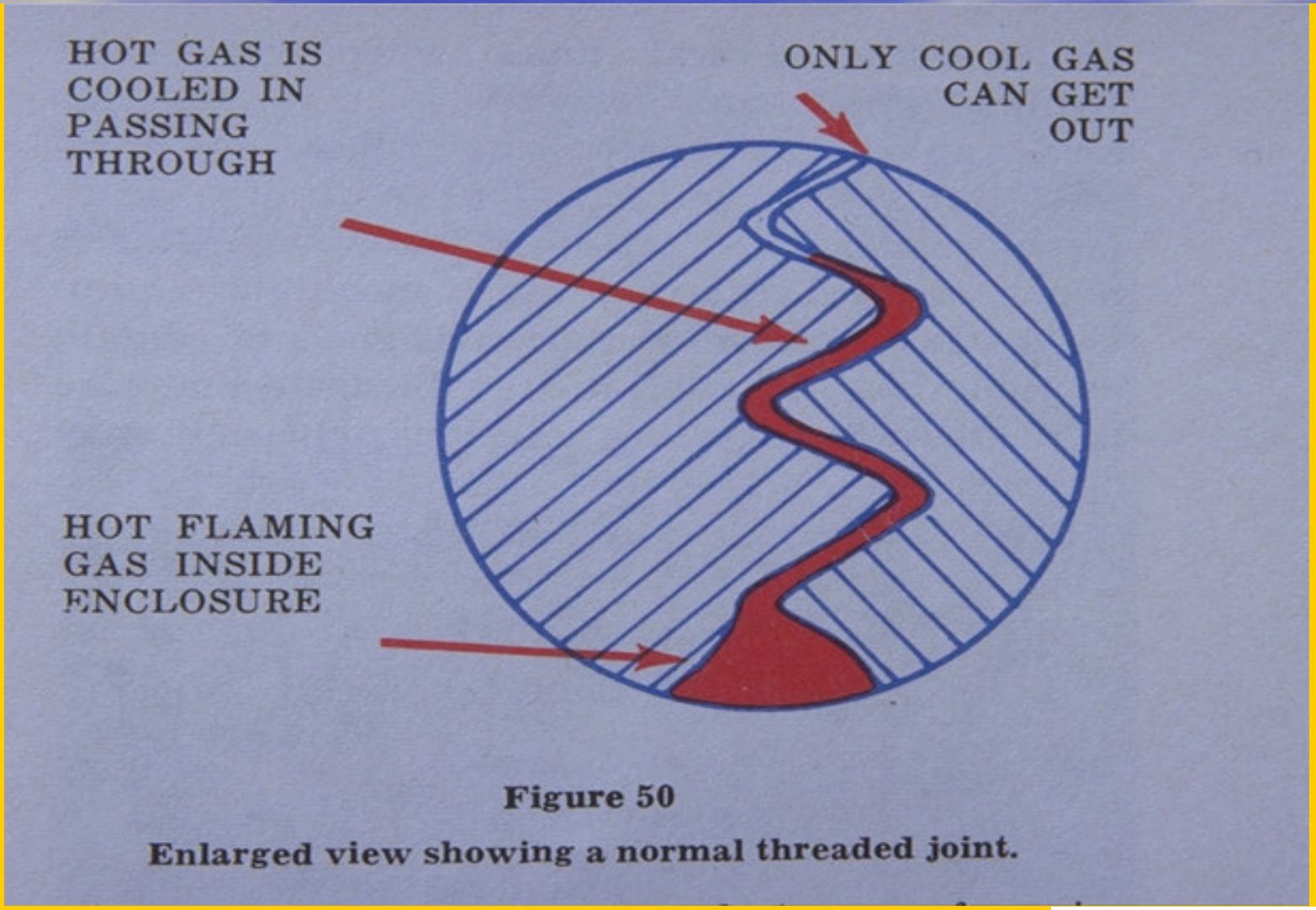

Figure 50

Enlarged view showing a normal threaded joint.

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Electrical Seal – What is it?

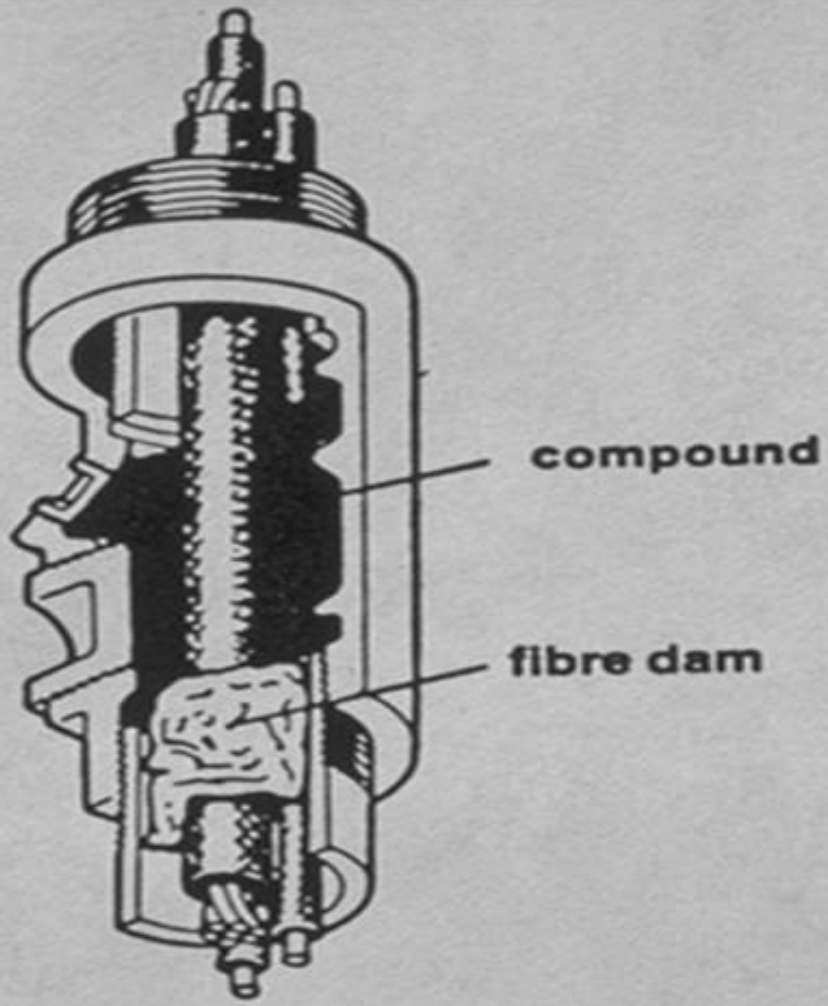

Fig. 7-2. Typical fitting for vertical conduit run.

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Storage in an Electrical Room

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Sources of Ignition

- Electrical Ignition Sources
- **Hot Equipment or Piping**
- Mechanical Heat Energy
- Chemical Heat Energy
- Heat of Compression

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Providing the Match

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Sources of Ignition

- Electrical Ignition Sources
- Hot Equipment or Piping
- **Mechanical Heat Energy**
- Chemical Heat Energy
- Heat of Compression

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Belgian Pipeline Explosion

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Sources of Ignition

- Electrical Ignition Sources
- Hot Equipment or Piping
- Mechanical Heat Energy
- **Chemical Heat Energy**
- Heat of Compression

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Pyrophoric Catalyst Storage

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Special Hazardous Chemicals

- Hydrogen
- Natural Gas
- Pyrophorics

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Battery Room Explosion

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Explosion Theory Objectives

- Be aware of conditions required for gas and dust explosions
- Understand the types of explosions and their effects

- Understand how various properties affect explosion potential.

- Be aware of methods to prevent and protect against explosions

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Ignition Energies

Material	Min Ignition Energy
Propane/Oxygen	0.002 mJ
Hydrogen/Air	0.02
Hydrocarbon/Air	0.25
Corn Starch	50

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Ignition Energy Sources

Energy Source	Energy Potential (mJ)
Spark Plug	20 – 30
Person with Rubber Soled Shoes	0.05 – 0.10
Person with Rubber Soled Shoes on a Carpet	15 – 40

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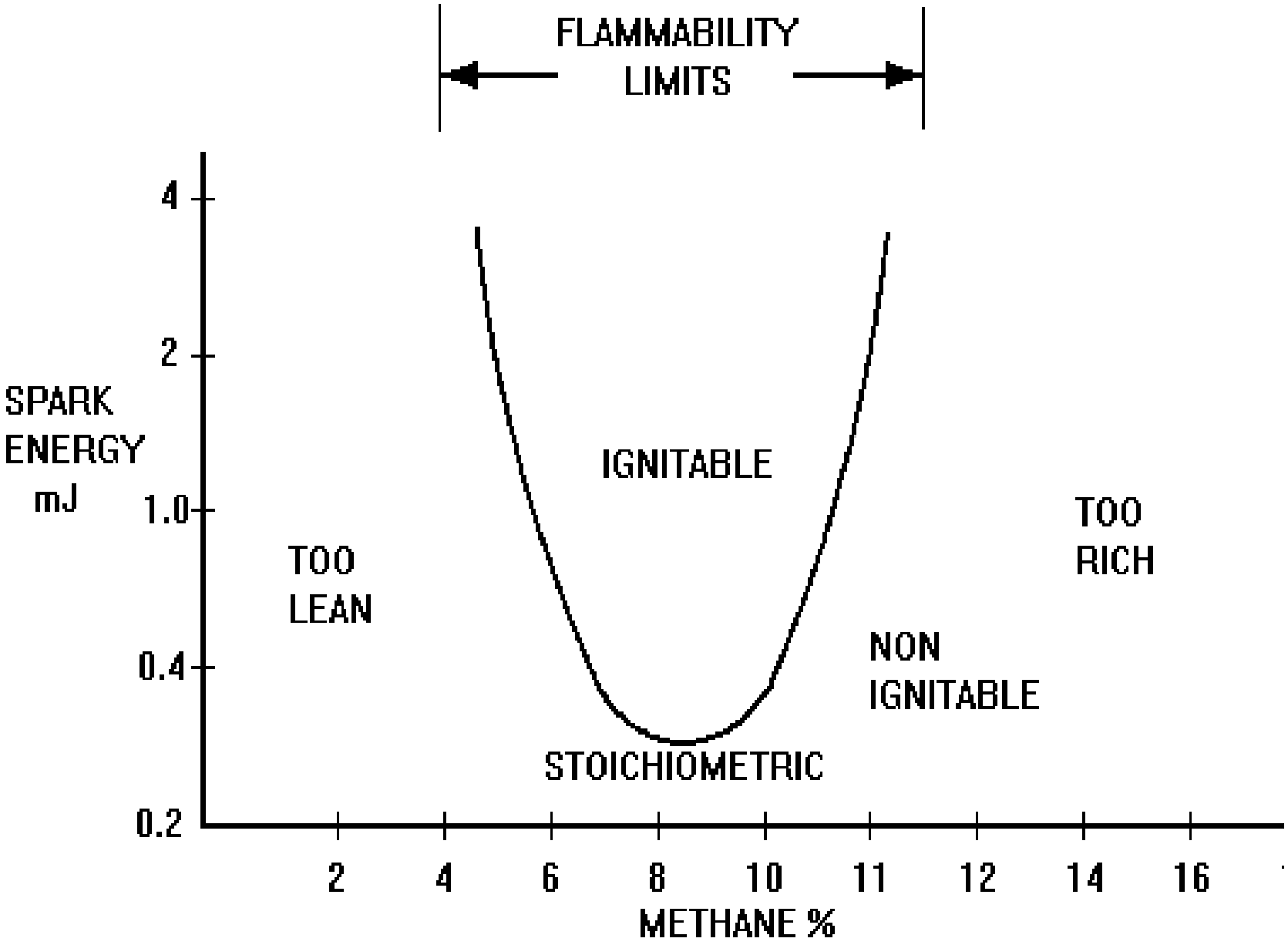
Effects of Stoichiometry on MIE



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Classes of Explosions

- Loss of Containment
- Deflagration
- Detonation
- BLEVE
- UVCE

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Effects of Material Properties on Gas/Vapour Explosions

- Flammable Range
- Minimum Ignition Energy
- Heat of Combustion
- Burning Velocity
- Rate of Pressure Rise

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Maximum Flame Speed

Material	Flame Speed
Methane	0.34 m/s
Ethane	0.40
Propane	0.40
Butane	0.37
Hydrogen	2.65
Ethylene	0.67
Propylene	0.43
Butene	0.43

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Effects of Material Properties on Dust Explosions

- Minimum Explosible Concentration
- Particle Size vs. MIE
- Particle Size vs. Reaction Rate
- Moisture Content

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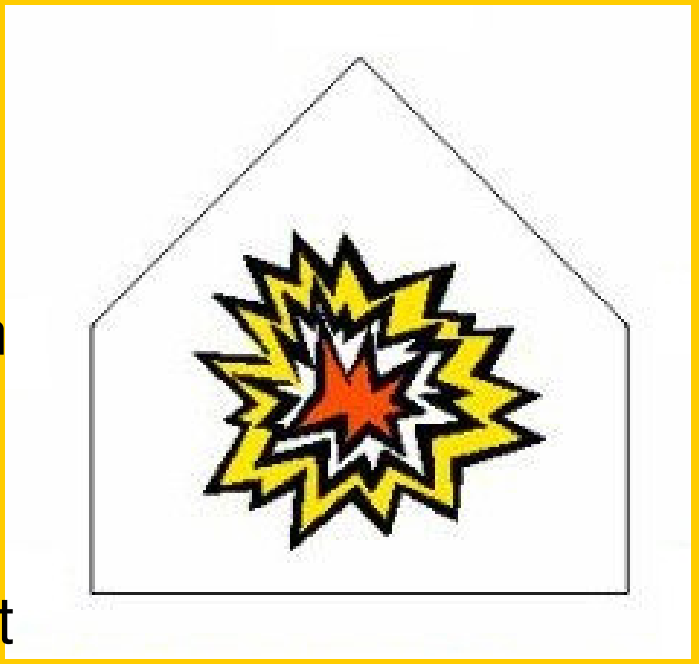
Dust Explosion Pentagon

Fuel

Dispersion



Oxygen

Confinement

Ignition

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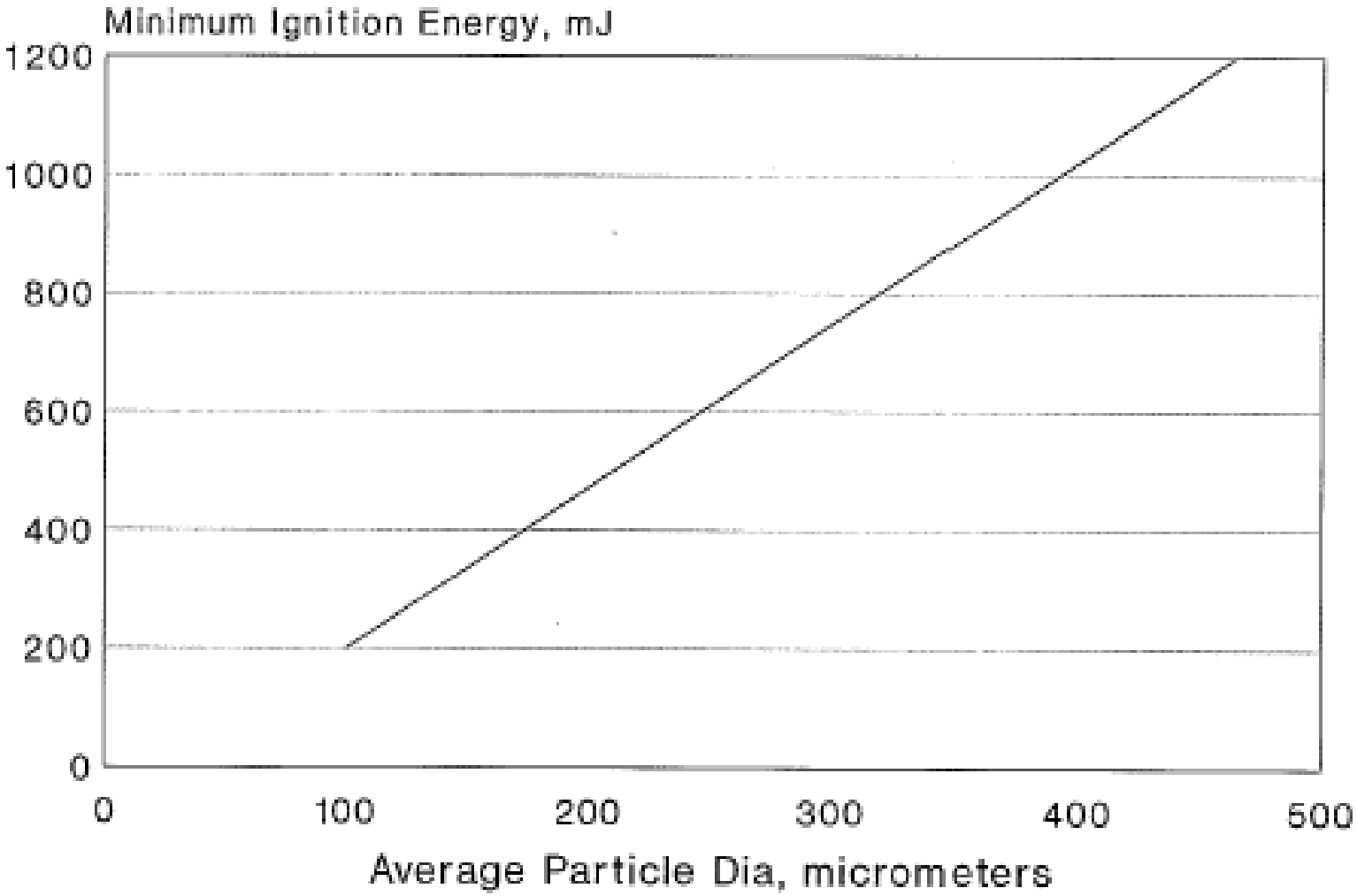
Minimum Ignition Energy vs. Particle Size – Cellulose Acetate



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Effects of Process Variables on Unvented Vessels

- Temperature
- Initial Pressure

- Turbulence

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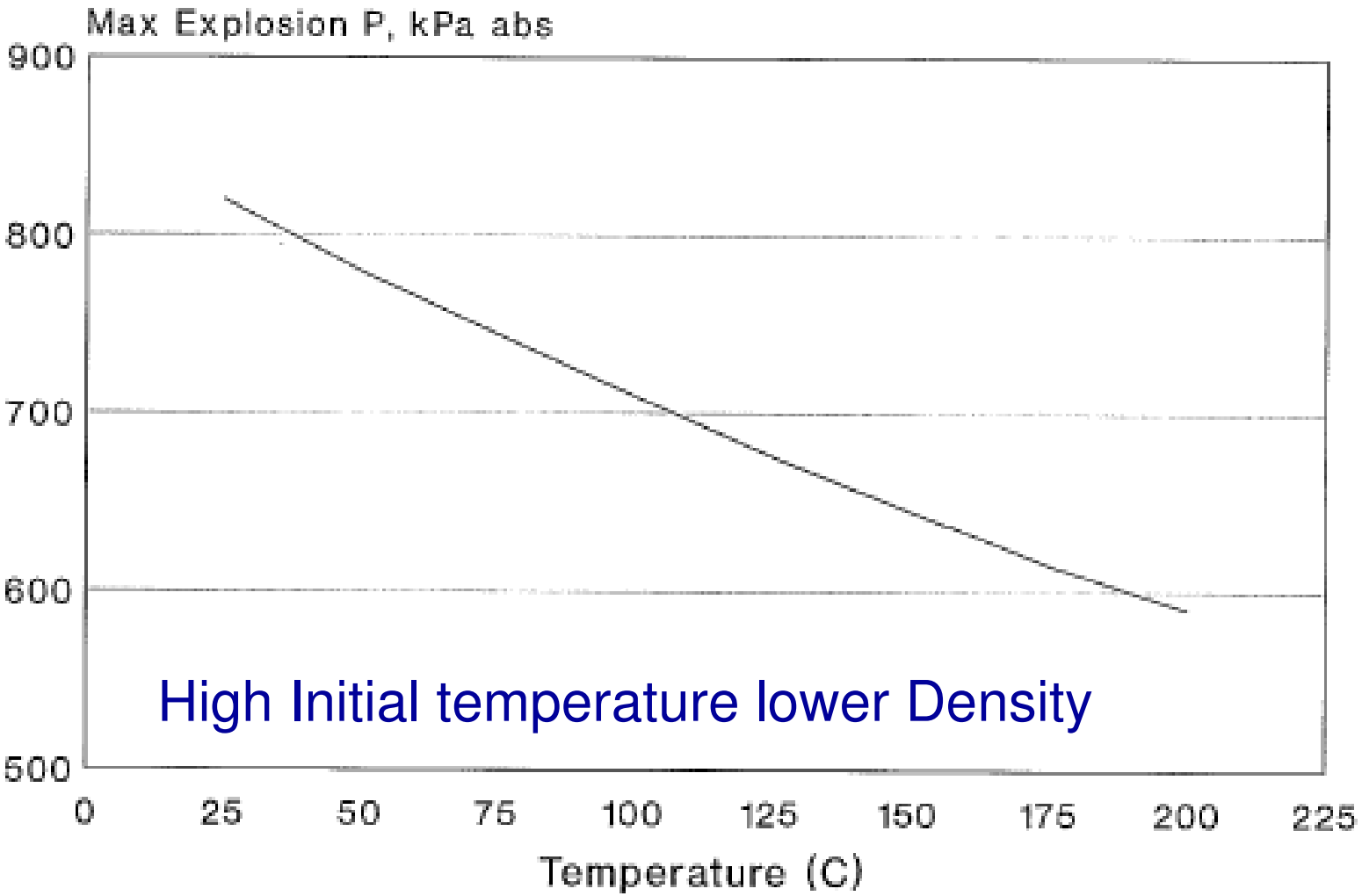
Effect of Temperature on Maximum Explosion Pressure for 5% Propane



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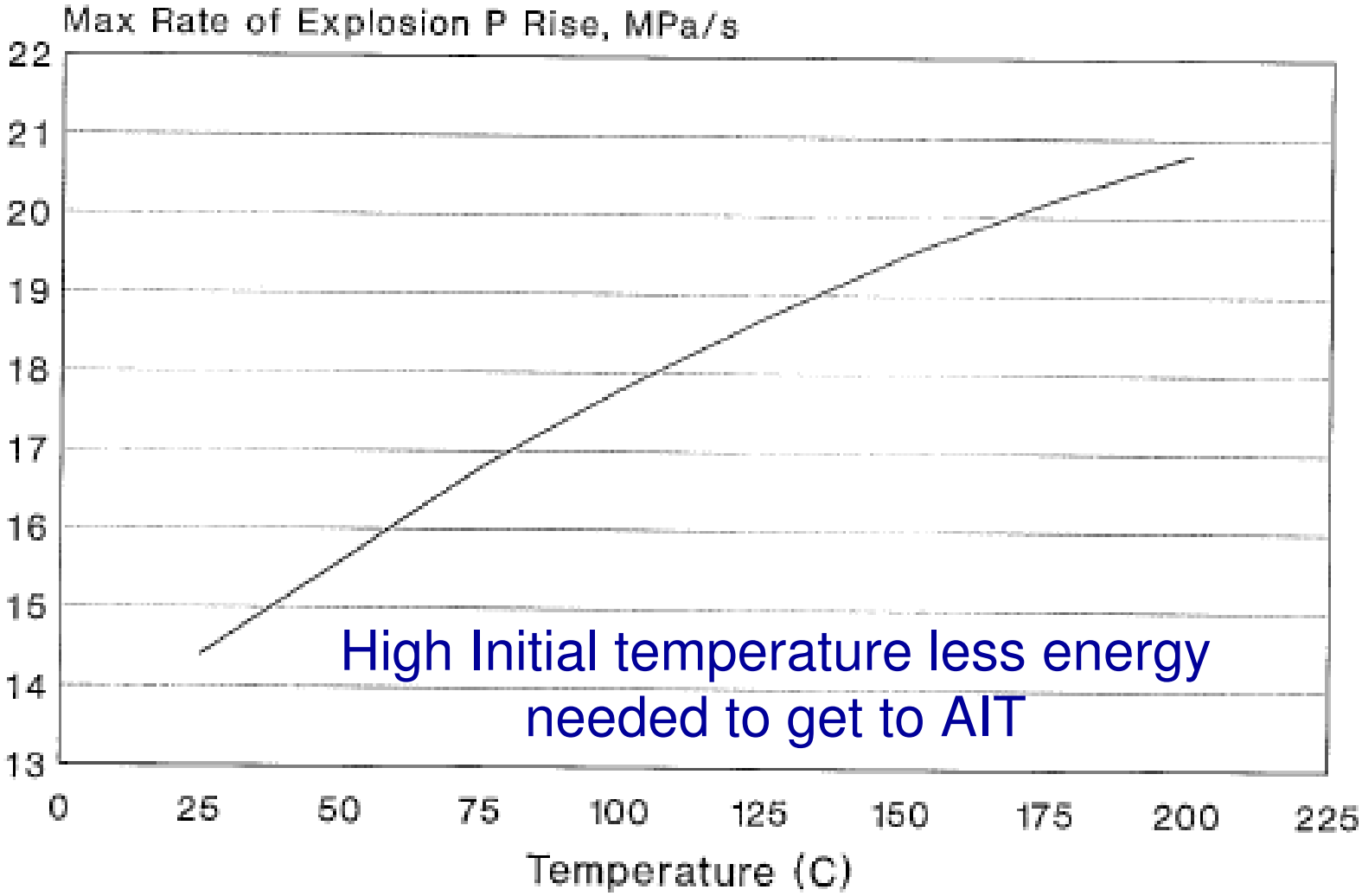
Effect of Temperature on Maximum Pressure Rise for 5% Propane



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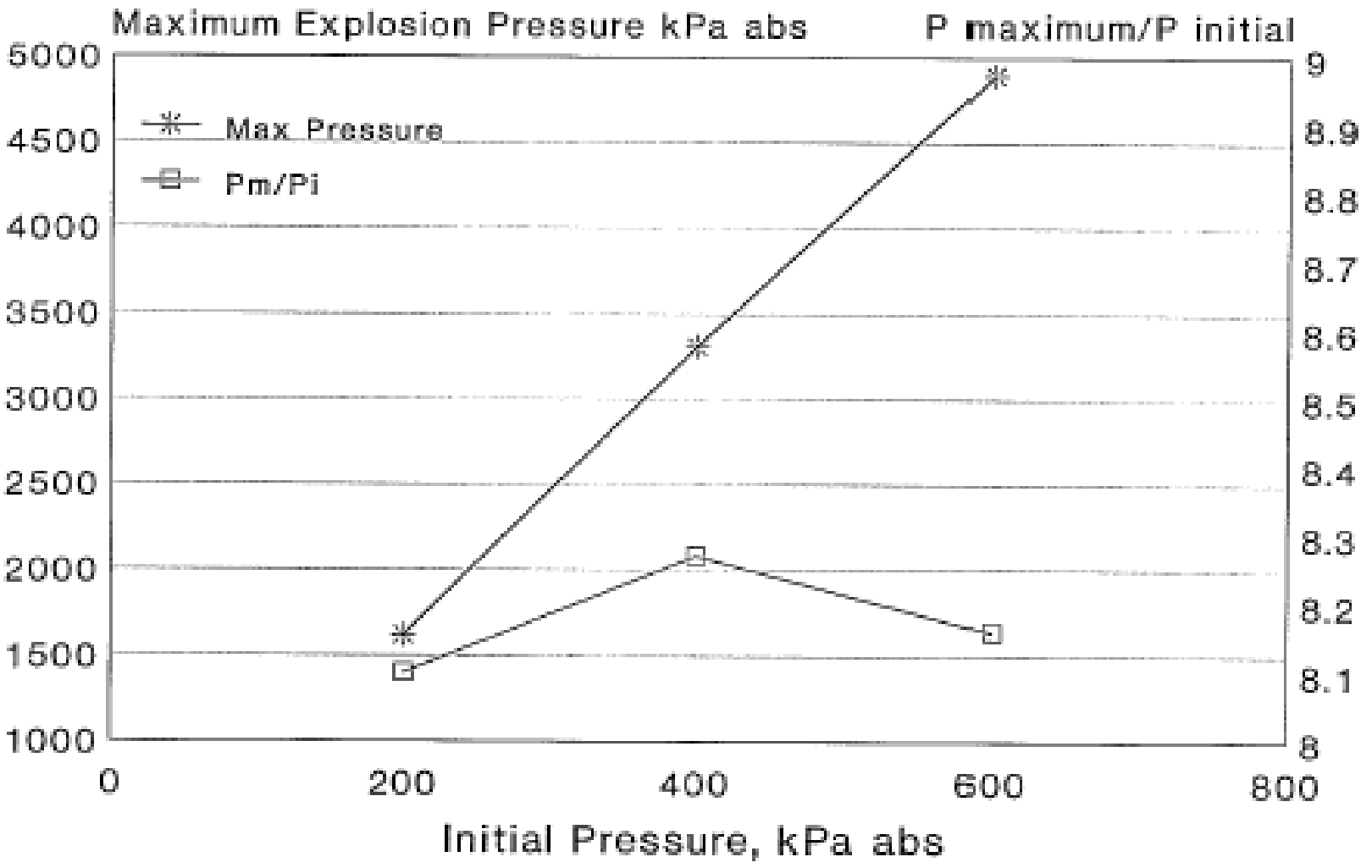
Effect of Initial Pressure on Maximum Explosion Pressure for 5% Propane



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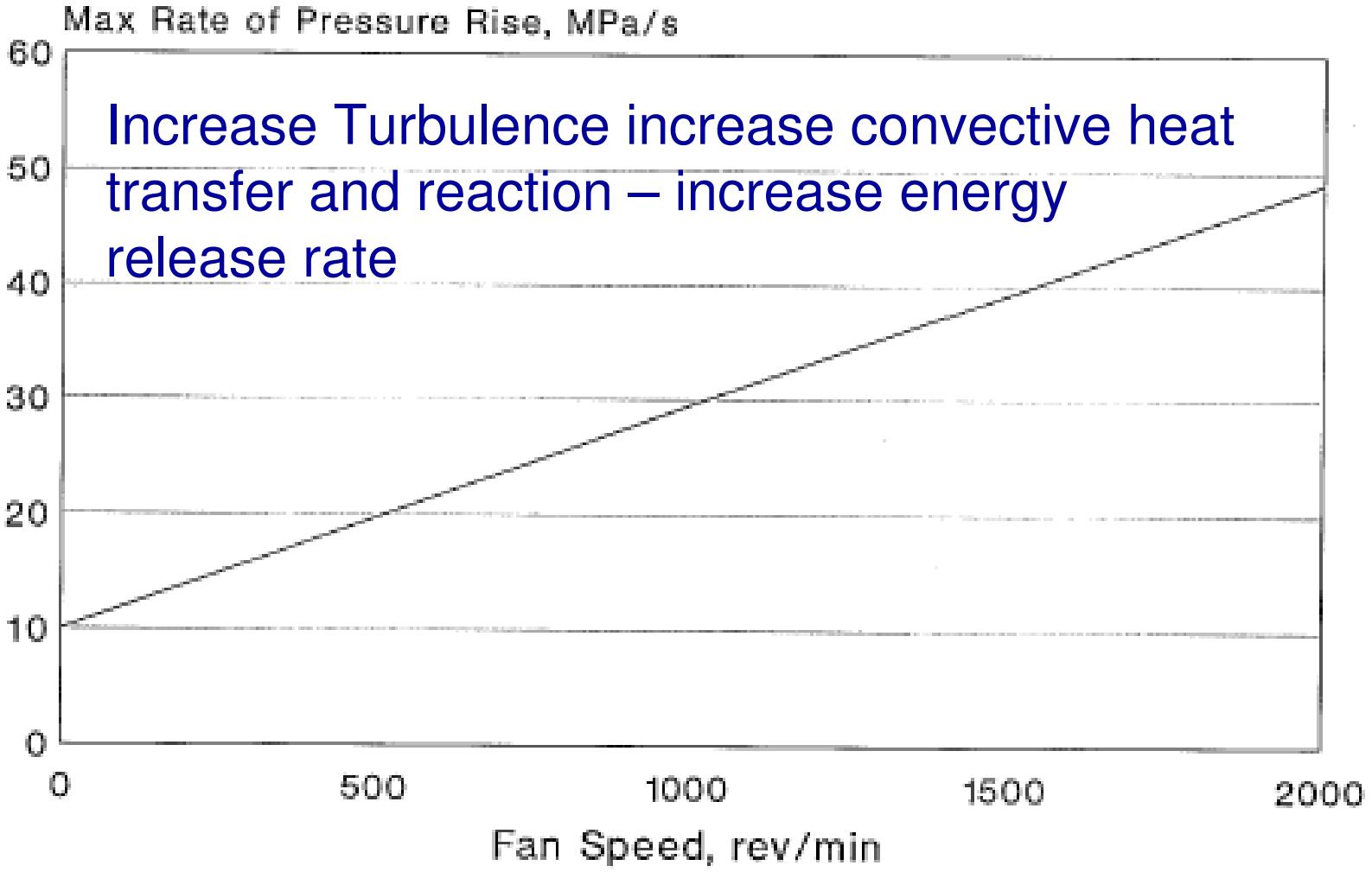
Rate of Explosion Pressure Rise vs. Turbulence



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Explosion Prevention

- **Ventilation**
- Inert Gas Blanketing / Purging
- Grounding & Bonding

- Flame Arresters
- Control of electric equipment

- Plant Layout

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Ventilation of Analyzer Room

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Differential Pressure

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Hydrocarbon Detection

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What Could Have Caused this!

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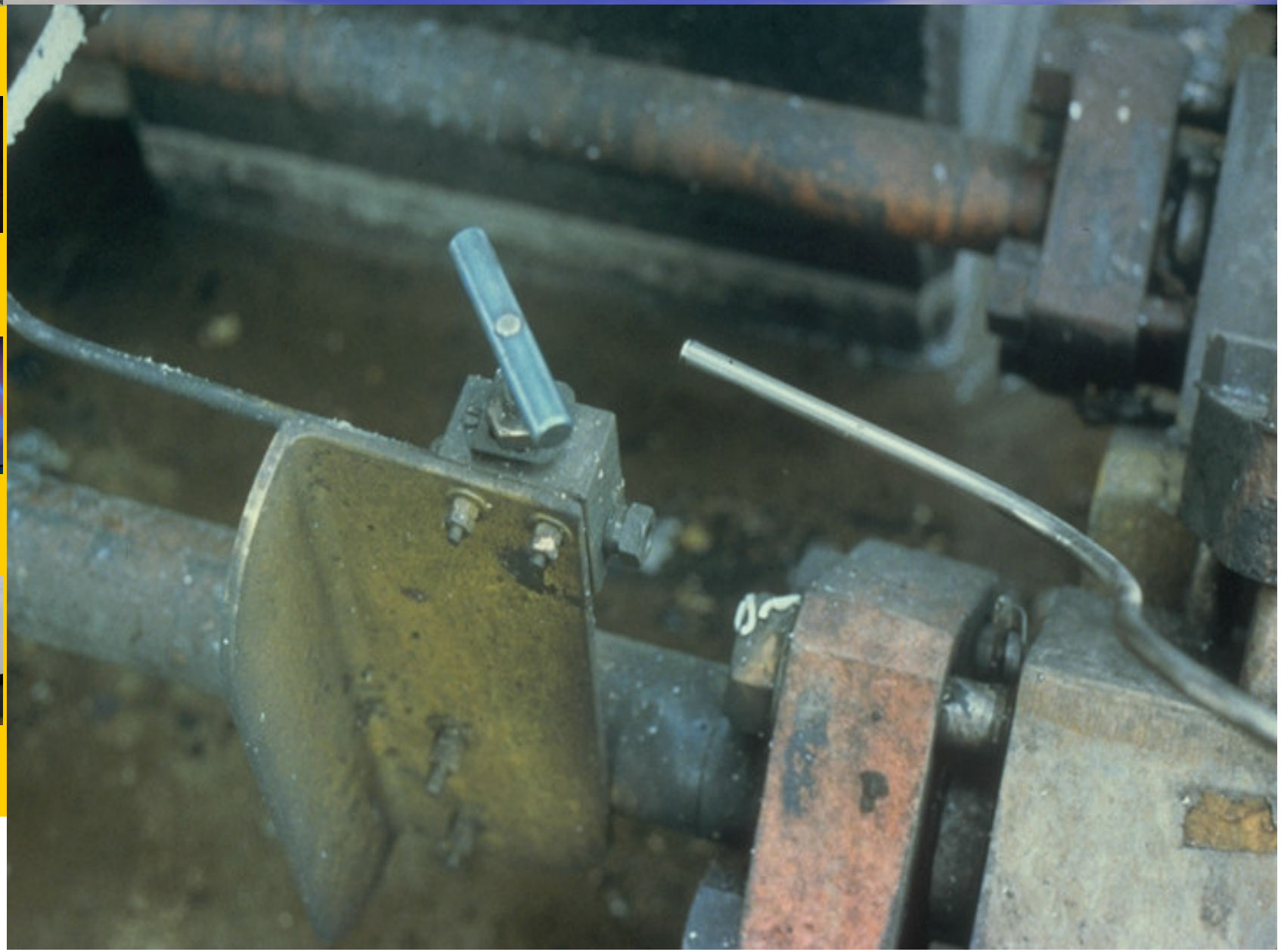
Small Bore Piping



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A Failed Small Bore Fitting

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Explosion Prevention

- Ventilation
- **Inert Gas Blanketing / Purging**
- Grounding & Bonding
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- Plant Layout

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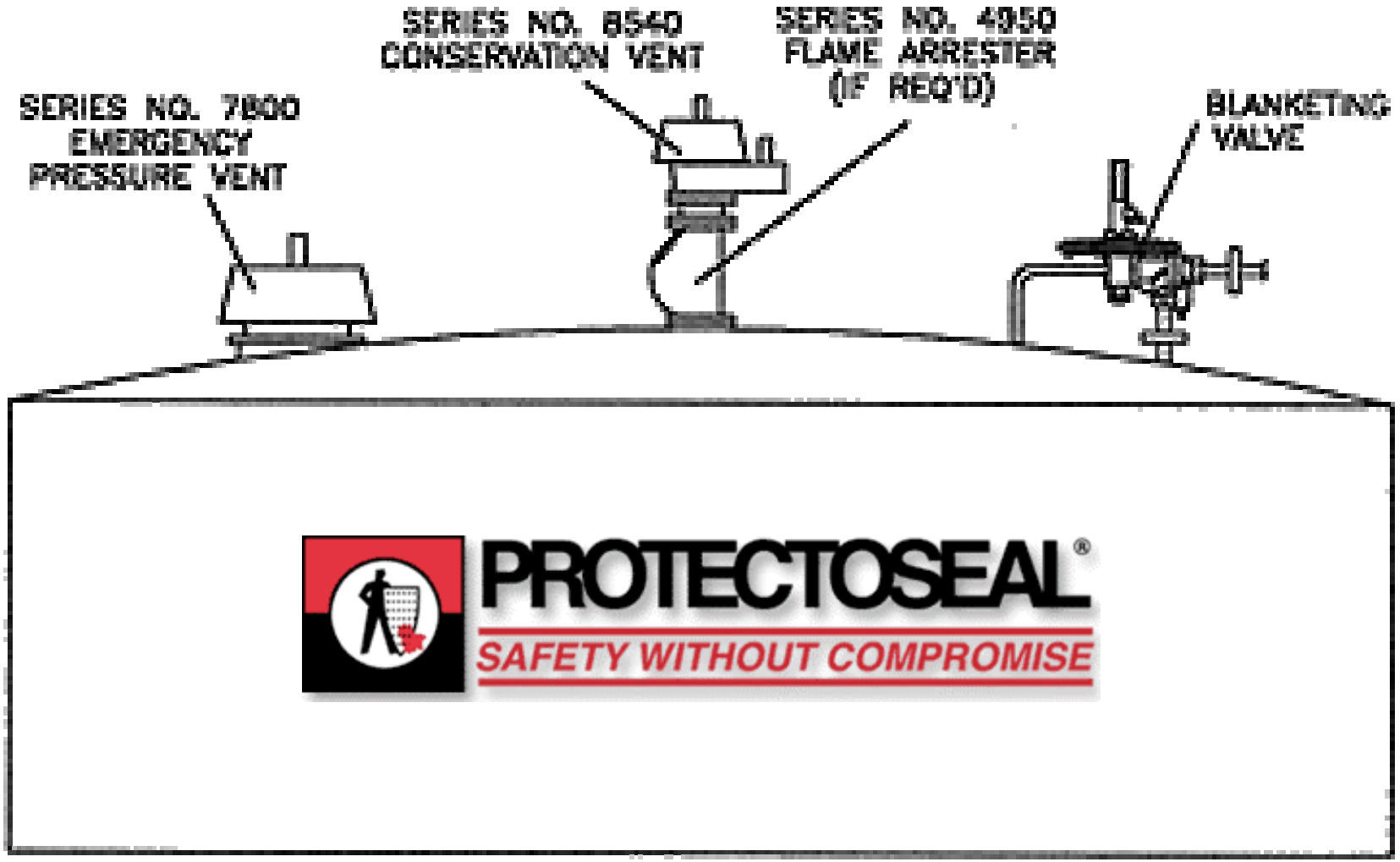

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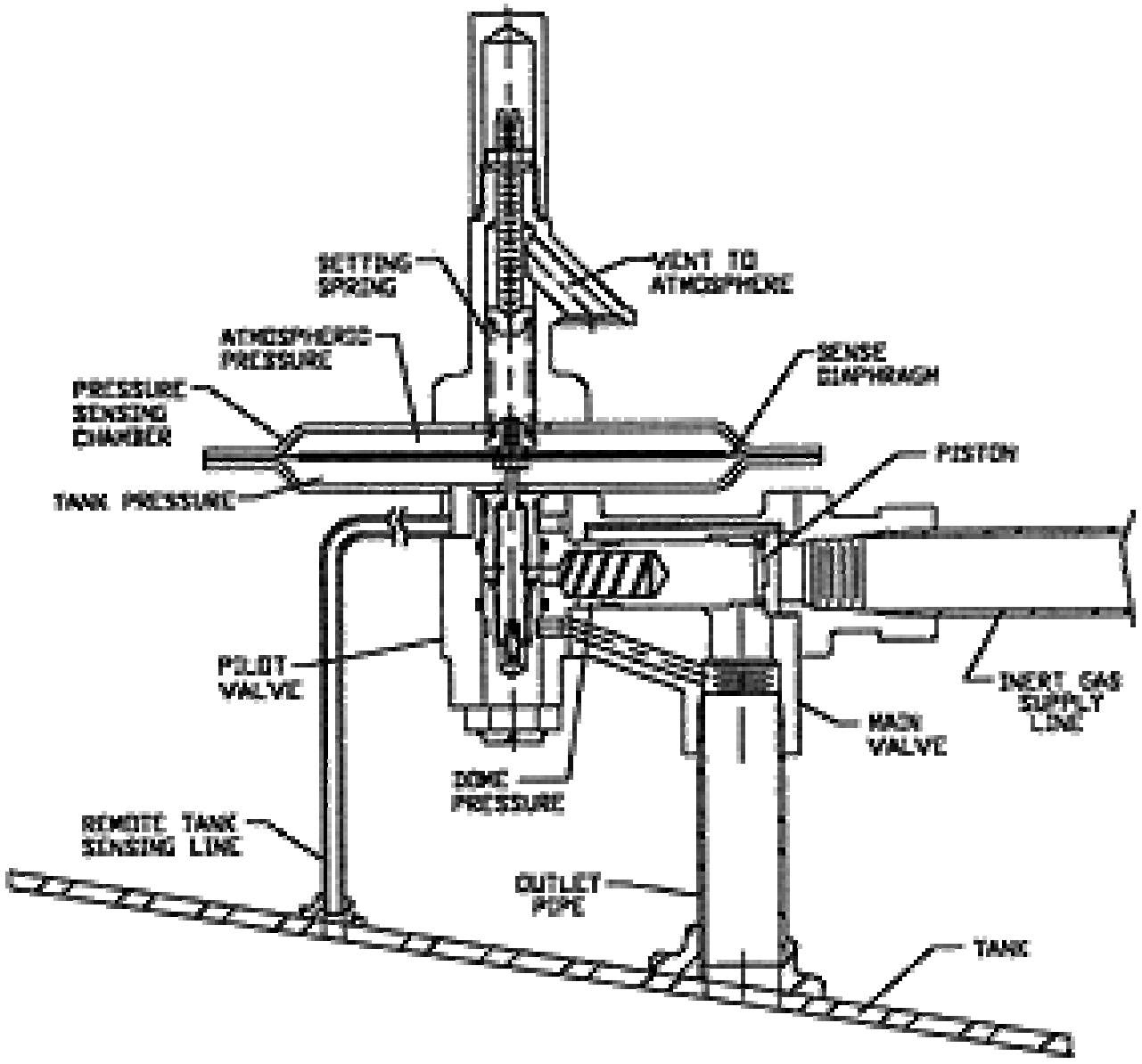

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Ethanol Tank Fire

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Explosion Prevention

- Ventilation
- Inert Gas Blanketing / Purging

- **Grounding & Bonding**
- Flame Arresters
- Control of electric equipment

- Plant Layout

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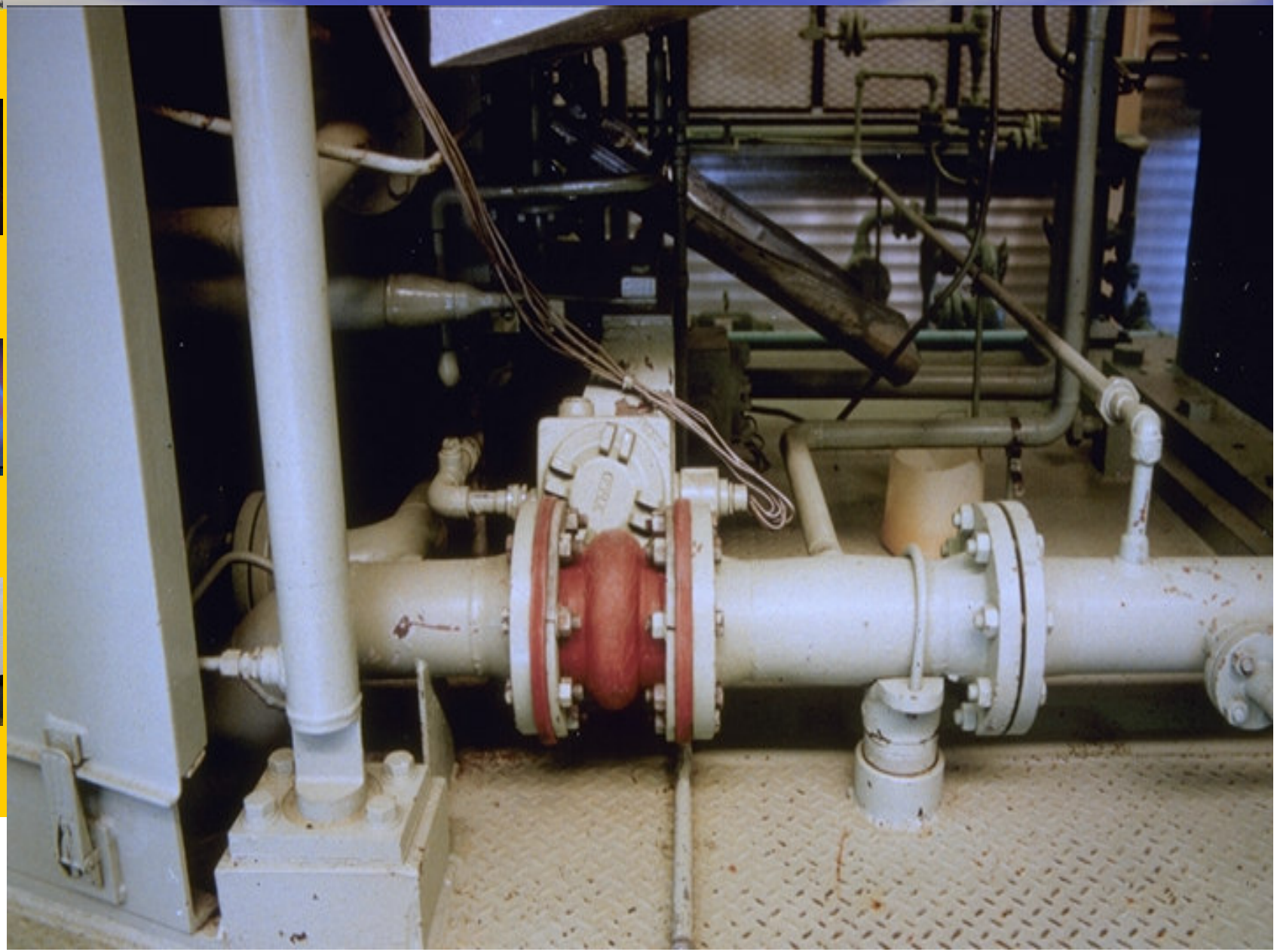
Fire/Explosion Prevention?



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Grounding Cables

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Explosion Prevention

- Ventilation
- Inert Gas Blanketing / Purging
- Grounding & Bonding

- **Flame Arresters**
- Control of electric equipment

- Plant Layout

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Flame Arresting Trash Container

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Explosion Prevention

- Ventilation
- Inert Gas Blanketing / Purging
- Grounding & Bonding

- Flame Arresters
- **Control of electric equipment**

- Plant Layout

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Loss of Electrical Integrity

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Explosion Prevention

- Ventilation
- Inert Gas Blanketing / Purging
- Grounding & Bonding

- Flame Arresters
- Control of electric equipment

- **Plant Layout**

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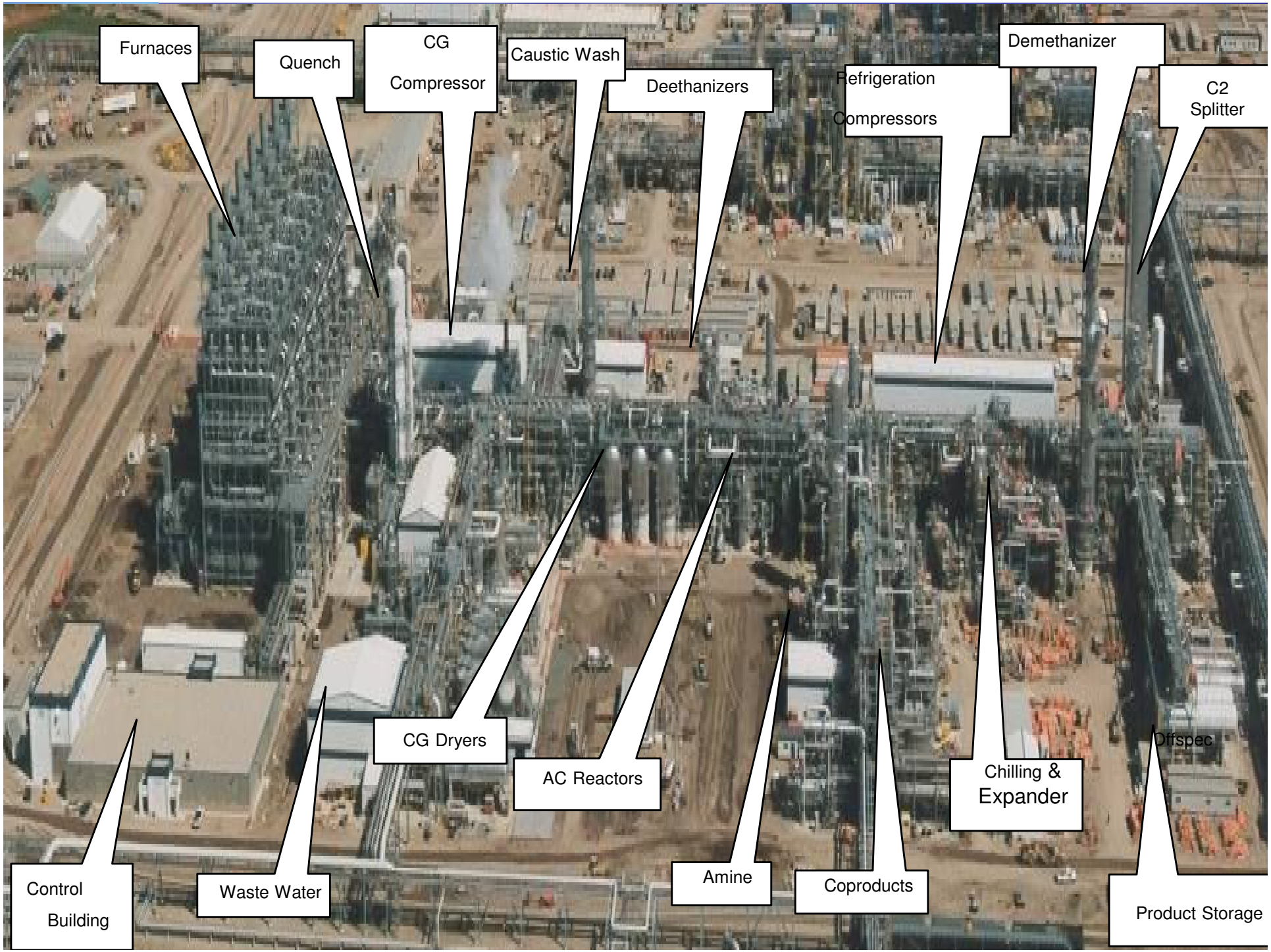
Furnaces
Quench
CG Compressor
Caustic Wash
Deethanizers
Refrigeration Compressors
Demethanizer
C2 Splitter
CG Dryers
AC Reactors
Chilling & Expander
Offspec
Control Building
Waste Water
Amine
Coproducts
Product Storage

Explosion Protection

- **Venting**
- Suppression
- Building Construction
- Building Location

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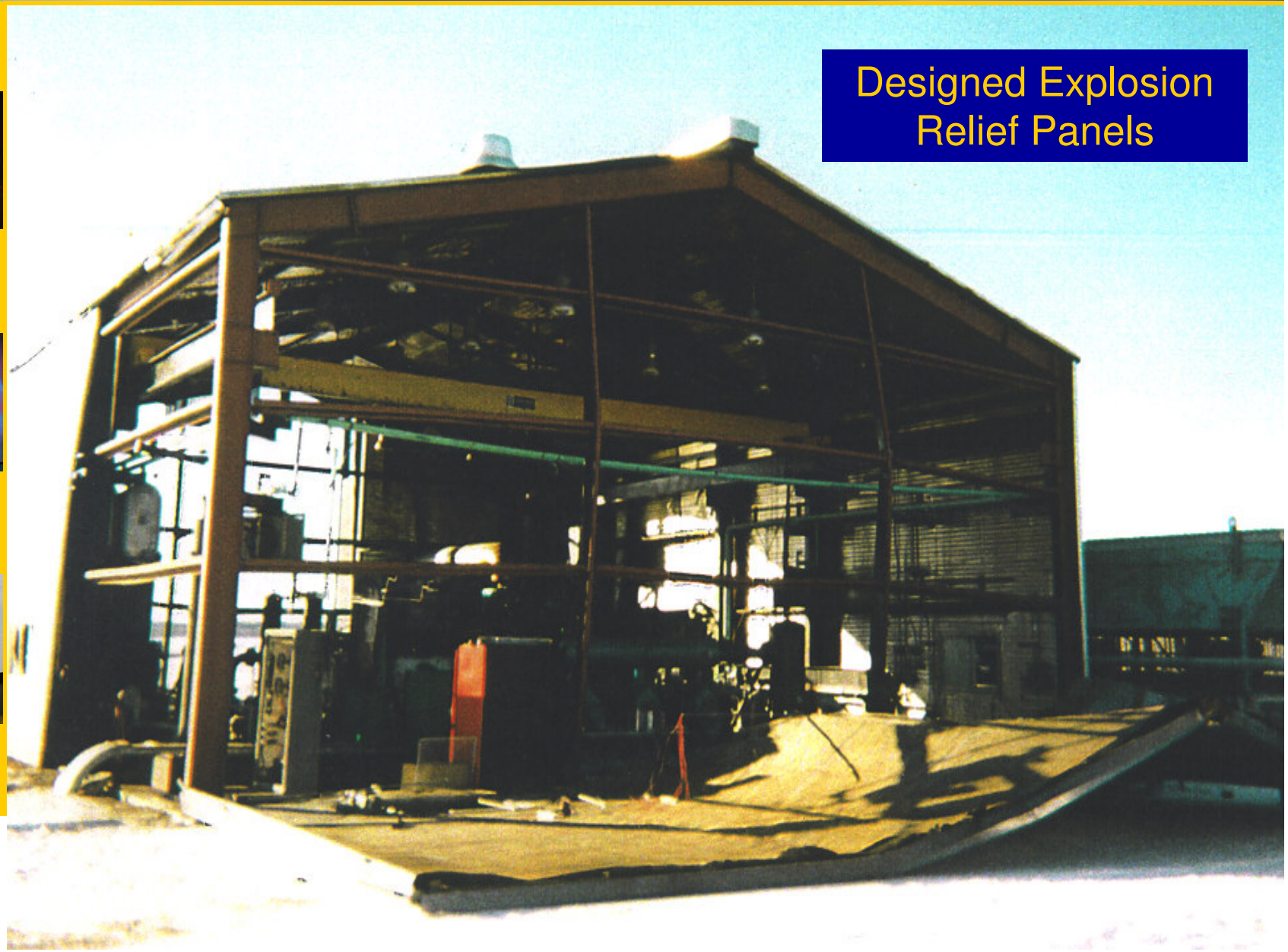
What was lacking here?

Designed Explosion Relief Panels



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Reference Material

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Knowledge Base

AIChE

OSHA

National Building Code Compliance Manual

NBC

SCOTT PARISH

NFPA

1866

IChemE

INSTITUTION OF CHEMICAL ENGINEERS

RESPONSIBLE CARE

FM Global

NACE INTERNATIONAL

THE CORROSION SOCIETY

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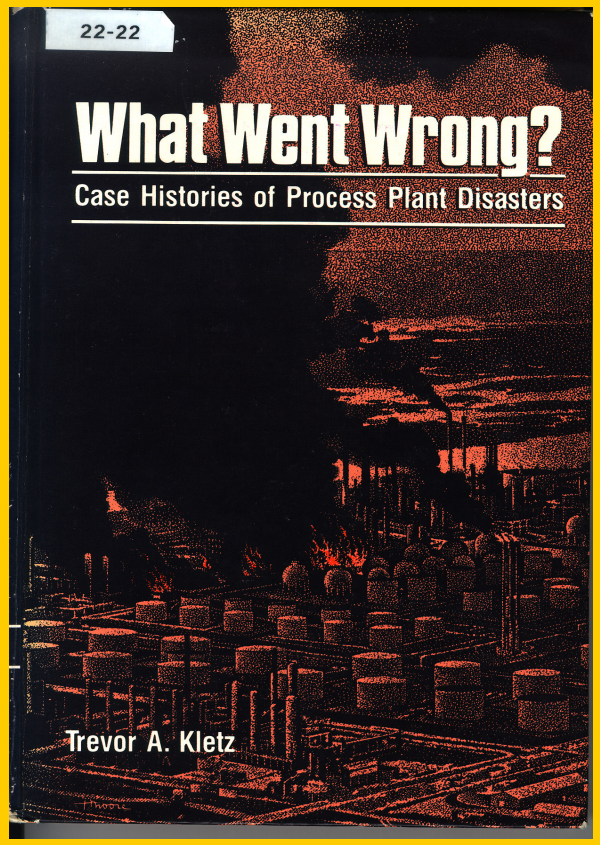
Books and Journals

"A High price has been paid for this information: people killed and billions of dollars worth of equipment destroyed. We get this information for the price of the book. It will be the best bargain ever made, if we use this information to prevent a similar incident"



Trevor Kletz from his book "What went Wrong?"

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Fires and Explosions: What You Need to Know to Prevent Them

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