2012台灣氧氣使用安全研討會

Oxygen Safety Seminar 2012 Taiwan

CLA
行政院勞工委員會

台灣區高壓氣體
工業同業公會

AIGA
Asia Industrial Gases Association

國立臺北科技大學

Introduction to Oxygen Safety

P.K. Lam – Linde Head of SHEQ, Greater China

Joined Linde in 1983
Operations (13 Yr) & Joint Venture GM (5 Yr) & SHEQ (11 Yr)

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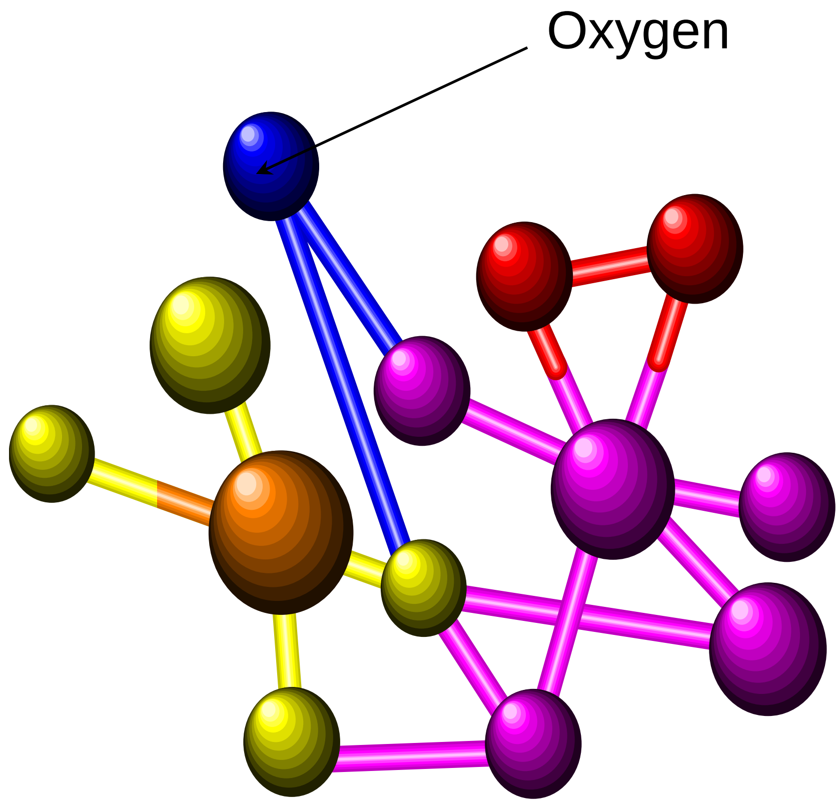
Agenda

1. **Introduction to Oxygen Safety**
2. **Materials and Oxygen Compatibility**
3. **Ignition Mechanism & Industry Incidents with Actual Cases in Asia**

Introduction to Oxygen Safety

Properties & Hazards of Oxygen

- Oxygen is essential to the maintenance of life
- Oxygen is essential for combustion
- Oxygen is a reactive gas which will form oxides with most elements



Properties & Hazards of Oxygen

What are the hazards ?

- Oxygen enhances burning of materials
  - ➢ the material burns more aggressively
  - ➢ the fire cannot be extinguished
- All materials burn in oxygen except ceramics, gold and silver
- The energy required to start an ignition can be very small
- Oxygen enrichment gives no warning

Effect of adding LOX to a charcoal fire

Necessary Conditions For A Fire

FUEL (COMBUSTIBLE MATERIAL)

- Most Items are Combustible under Favourable Conditions

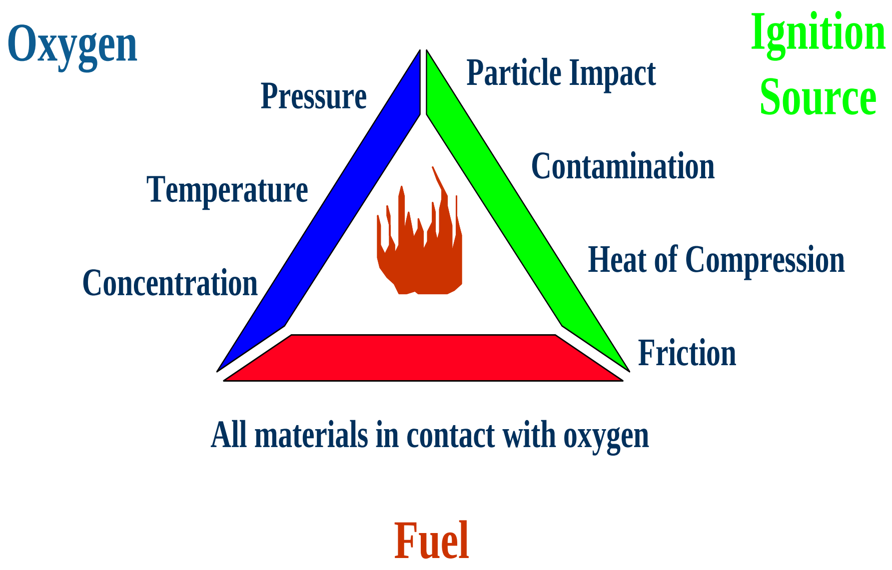
OXYGEN

- From Air
- Enriched Air or Pure Oxygen
  - Liquid
  - Gas

IGNITION SOURCE

- Flame
- Sparks
- High Energy Particles
- Adiabatic Compression
- Friction

Fire Triangle



No fire if any element is missing!

Fire Triangle: Fuel Leg

Contamination:

— Such as oil, grease, particles or fine debris from assembly are often easy to ignite and can initiate the kindling chain. Ease of contamination removal should be considered in the design

Thermal conductivity:

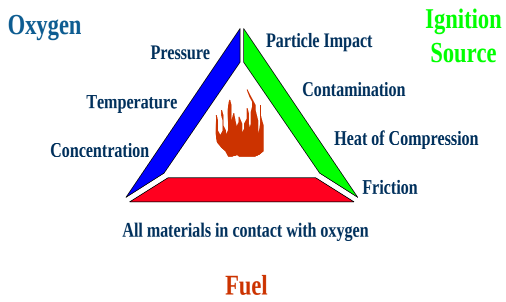
— Metals with low thermal conductivity are more easy to ignite, as hot spots cannot be dissipated before ignition occurs

Thickness:

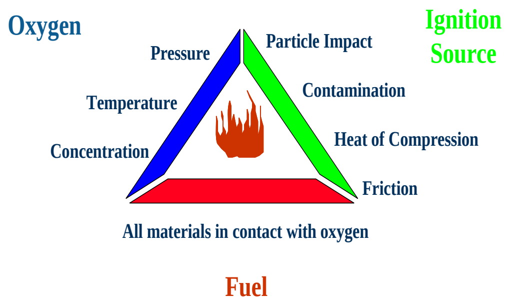
— Sharp corners and thin sections promote easier ignition, as they are heated more quickly than thicker sections

Higher heat of combustion provide more energy to promote propagation

Successful Experience with the metal in same or similar service provides a good basis for material selection



Fire Triangle: Ignition Leg



Particle impact:

- Impact from particles in a high velocity flowing oxygen stream can cause ignition of metals and non metals, particularly in impingement sites such as tees, elbows, etc.

Friction:

- The rubbing together of components generates heat that can cause ignition. Friction may also generate particles

Electrical energy:

- Electrical discharge from static energy generated by gas flow in the presence of particles can cause ignition. Similarly, electrical discharge from shorts in motors or heating elements can result in ignition

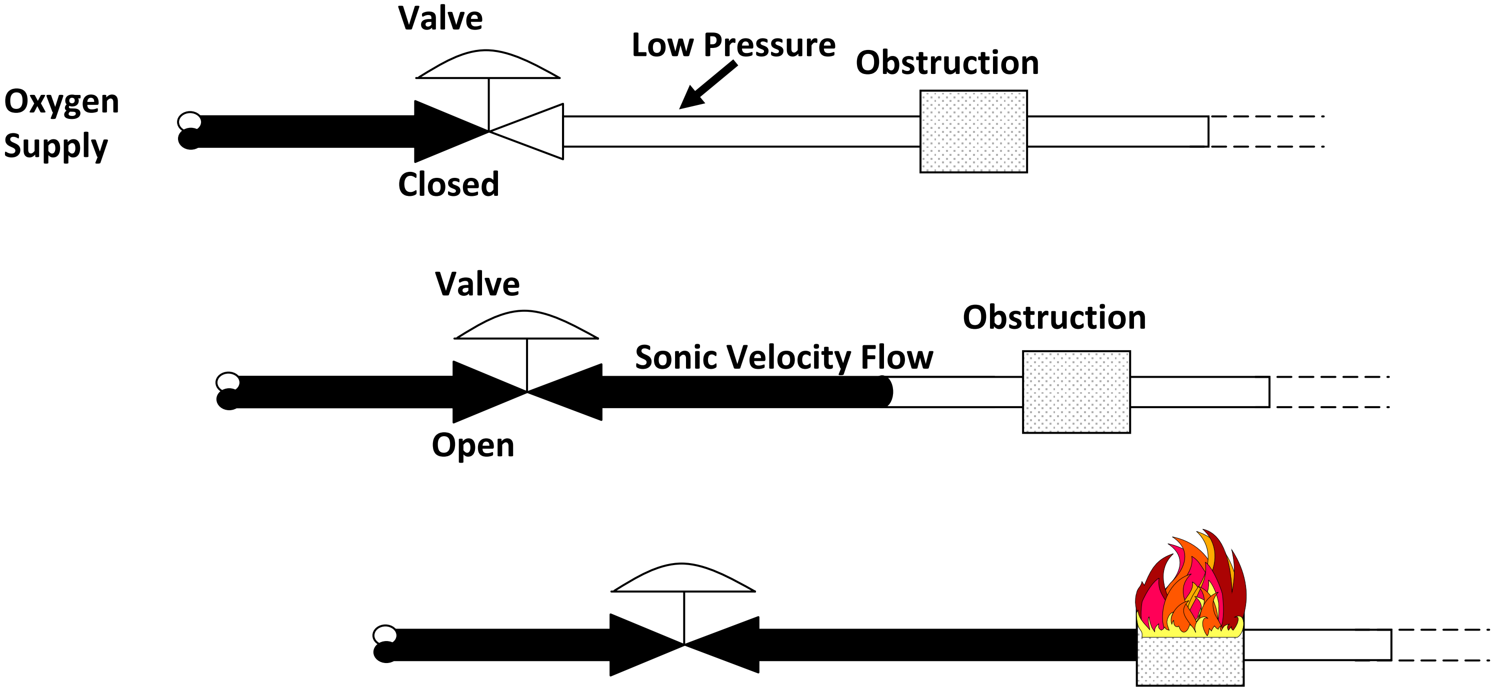
Kindling chain:

- Combustion of particles or polymers may release enough energy to ignite an adjacent metal component. Ignition of a less compatible metal such as carbon steel may cause ignition of a more compatible metal such as brass

Fire Triangle: Ignition Leg

Adiabatic compression:

- When a valve is suddenly opened, with more than 20 bar upstream, the gas downstream is compressed and the temperature in the trapped gas rises instantaneously (over 400°C)
- Polymers may be ignited when situated at dead ends. Fast opening/closing valves and dead ends must be avoided by design
- Energy adsorbing, fire resistant piping sections where temperature rise may occur is usually effective in controlling this mechanism



Fire Triangle: Oxygen Leg

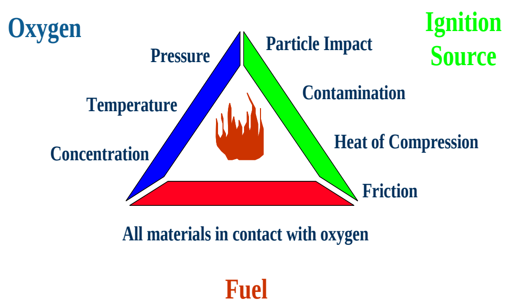
Temperature: High oxygen temperatures increase the risk of ignition of polymers. This may lead to ignition of a metal component

Pressure: Higher the pressure, higher is the ignition risk and propagation faster. Certain piping configurations provide possibilities for organ pipe heating of gases

Velocity: High velocities increase the risk of ignition from particle impact, such as in valves, restrictions, pressure regulators, filters, …

Concentration: Risks of ignition are diminished with lower oxygen concentration. Carbon steel is considered as non combustible in lower than 40% Oxygen enriched air

Phase: Gaseous form or liquid form. Fire in LOX may be explosive



Materials and Oxygen Compatibility

What is Oxygen Compatibility?

The ability of a material to coexist with both oxygen and a potential source(s) of ignition within the acceptable risk parameter of the user

— At an expected temperature, pressure and composition

As the material will most likely burn in oxygen, the level of risk that one is willing to accept must be taken into account.

Why is Oxygen Compatibility Important?

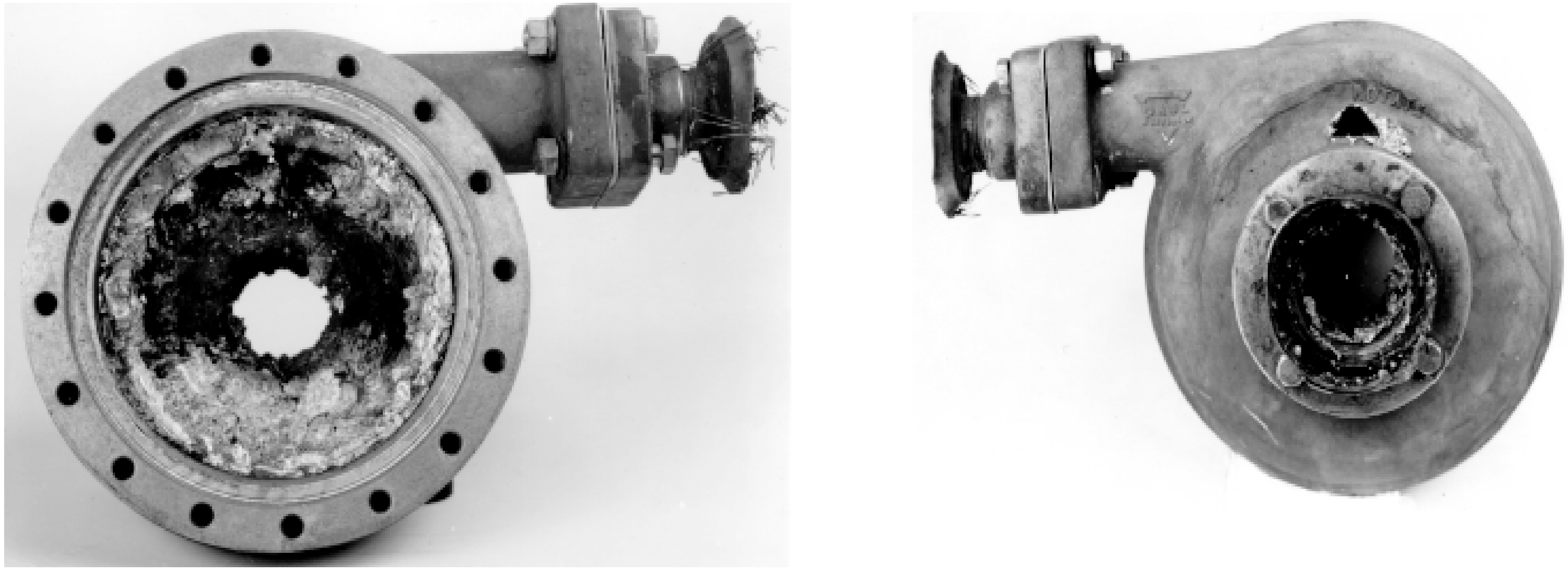
BECAUSE

FIRES

OCCUR

Why is Oxygen Compatibility Important?

During the 1970's there were numerous LOX pump fires. By replacing the aluminium bronze impeller and casing with a tin bronze material these ignitions were eliminated



ALUMINIUM PUMP

Why is Oxygen Compatibility Important?

Where do incidents occur?

- Air Separation Plants
- Cylinder filling
- Liquid oxygen pumps
- Oxygen compressors
- Oxygen pipelines & valve systems
- LOX piping and valve systems
- In areas where exposure to oxygen can occur

Agenda Part 3

Ignition Mechanism & Industry Incidents with Actual Cases in Asia

Hazard of Oxygen

So Where do Oxygen Hazards Exist?

- In atmospheric air enriched (23.5%) with oxygen
  - Venting and leaks
  - Oxygen is denser than air and so can collect in pits, ducts, trenches, etc.
  - LOX may form on contact of air with LIN, LHe etc.
- In pressurised systems containing pure oxygen greater than 1 bar
- Air compression – 30 bar partial pressure of oxygen is the limit

Hazard of Oxygen in Air

How much oxygen does it take to create a hazard?

Oxygen concentration (% in Air)	25	30	35	40
Probability of igniting clothing % Based on time to ignite denim overalls with a cigarette	5	30	50	90
Probability of a fatal or serious injury % Based on the burning rate of the material and reaction time of the victim	10	16	29	90
Combined probability of a fatal or serious injury %	0.5	4,8	14.5	81

From EIGA Position Paper PP-14

Managing Risks in Oxygen Systems

- Oxygen systems will always have oxygen and fuel (metals, gaskets, seals, lubricants etc.)
- So how do we avoid fires in oxygen systems?
- By:
  - Avoiding Ignition
  - Avoiding Propagation
  - Mitigating Consequences – (barriers)

Managing Risks in Oxygen Systems

Avoid Ignition

- Careful selection of system materials - avoid fuels with low ignition temperatures
- Good system/equipment design - avoid ignition sources
  - Good piping designs to reduce particle impact sites and using exempt materials at impingement points
- Good standards of cleanliness during construction and maintenance - avoid fuels and ignition sources
  - Absence of particulate matter and hydrocarbon oils and greases
- Good system commissioning - avoid ignition sources
- Good system maintenance - avoid fuels and ignition sources
- Operation within the system's declared safe operating limits - avoid ignition sources

Managing Risks in Oxygen Systems

Avoid Propagation

Oxygen materials compatibility is dependent on many factors, so materials compatibility in oxygen is application specific. In general acceptance criteria depends on two key factors

- Flammability – factors that determine flammability include material composition, thickness and operating conditions
- Ignitability – Ignition mechanisms include particle impact, adiabatic compression, mechanical friction, mechanical impact, thermal ignition etc.

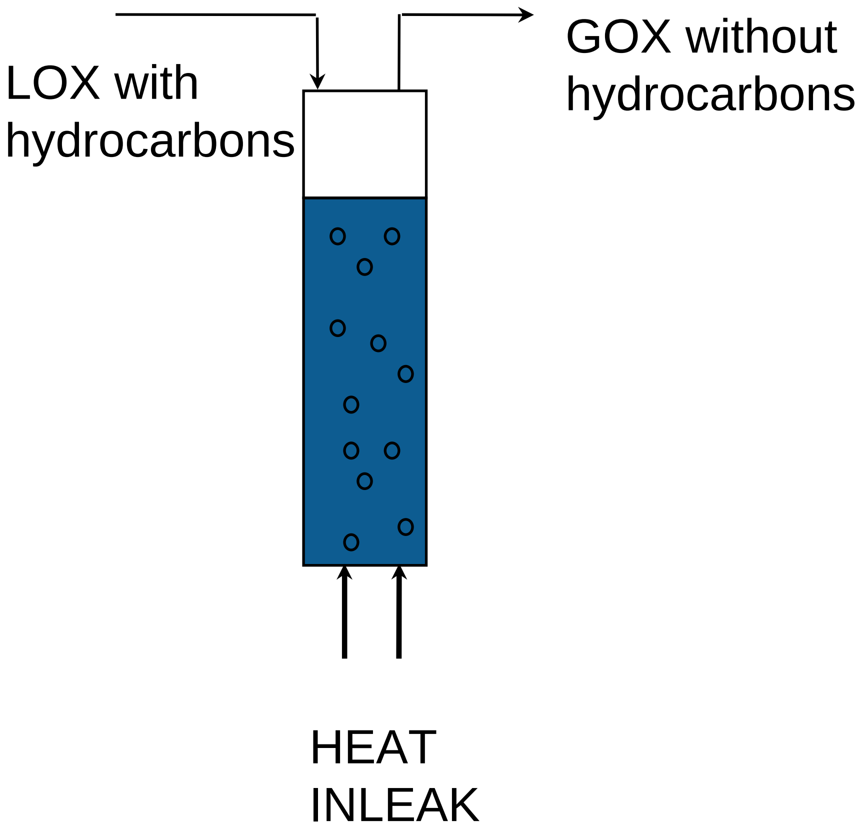
Mitigating consequences

— In some cases the best material for oxygen compatibility can not be used because there may be issues with galling, friction, high cost etc. In such cases a risk assessment should be undertaken to ensure other mitigation measures are in place to make the system as safe as possible. This could include

- Barriers around equipment and valves
- Additional cleaning of piping and equipment

Managing Risks in LOX Systems

Dead End or Pool Boiling



- Hydrocarbons and other contaminants will accumulate over time if liquid is not purged
- Solubility and flammability limits of contaminants will be exceeded
- Once Hydrocarbon levels exceed allowable limits the risk of ignition is significantly increased
- Accumulation of Hydrocarbons and other plugging contaminants must be prevented in LOX, by continuous purging of reboilers and proper routing of liquid lines to avoid low points and pockets where liquid can accumulate and boil off

The Importance of Cleanliness

What is Oxygen Clean?

— No visible evidence of:

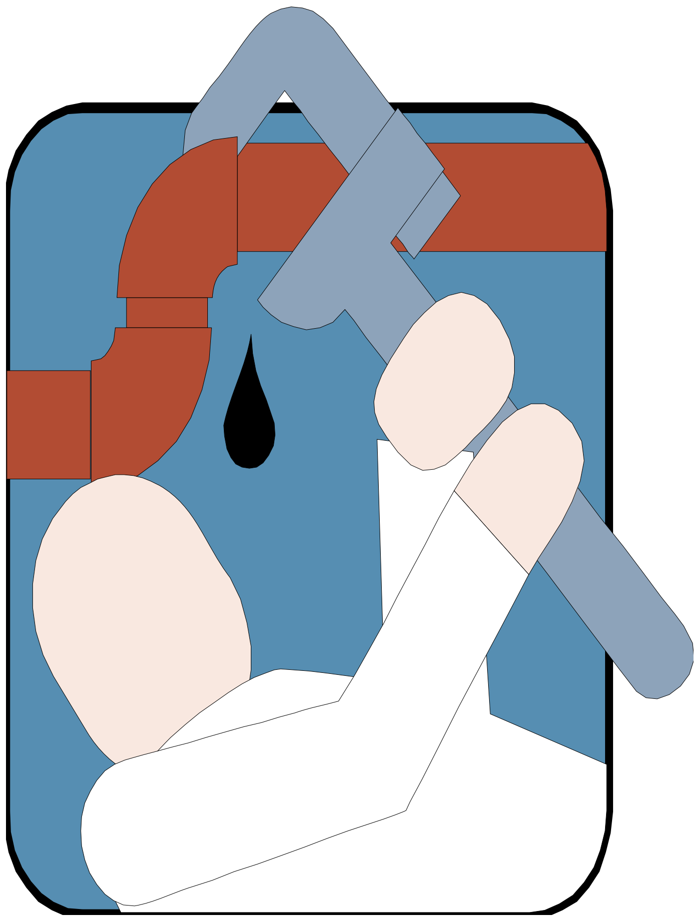
— Moisture

— Cleaning agents

— Flux residues / weld splatter

— Particulate matter

— Organic materials e.g. oil, grease, paint etc.



Cleaning for Oxygen Service

Solvent degreasing

- Wiping with a lint free cloth
- Immersion in a solvent tank
- Cold washing
- Spraying/brushing

Detergent cleaning

- Immersion
- Re-circulation
- Spraying / brushing

Steam/Hot Water Cleaning

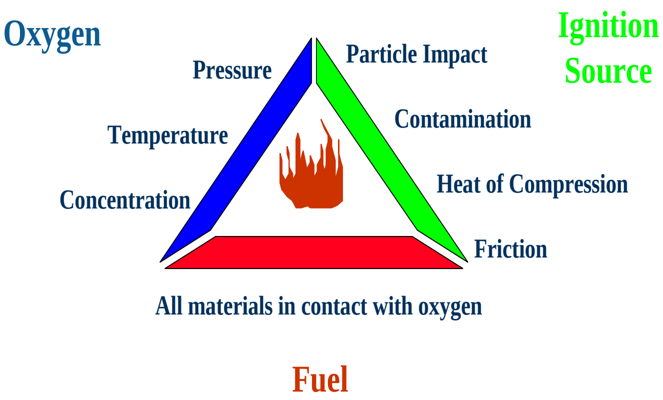
- Pressurised cleaning of major plant parts and pipes
- With or without detergent

When Things Go Wrong

When You Get Oxygen Compatibility Wrong

ASU Separation Unit (ASU) – Reboiler Explosion

An ASU reboiler exploded – why?



India - Vizag Steel Plant Blast (13 June 2012)

1. **19 people died including the General Manager**
2. **Newly extended Steel Plant under commissioning**
3. **Explosion at Oxygen Pressure Reducing Station**

Investigation still underway but what could be the issues?

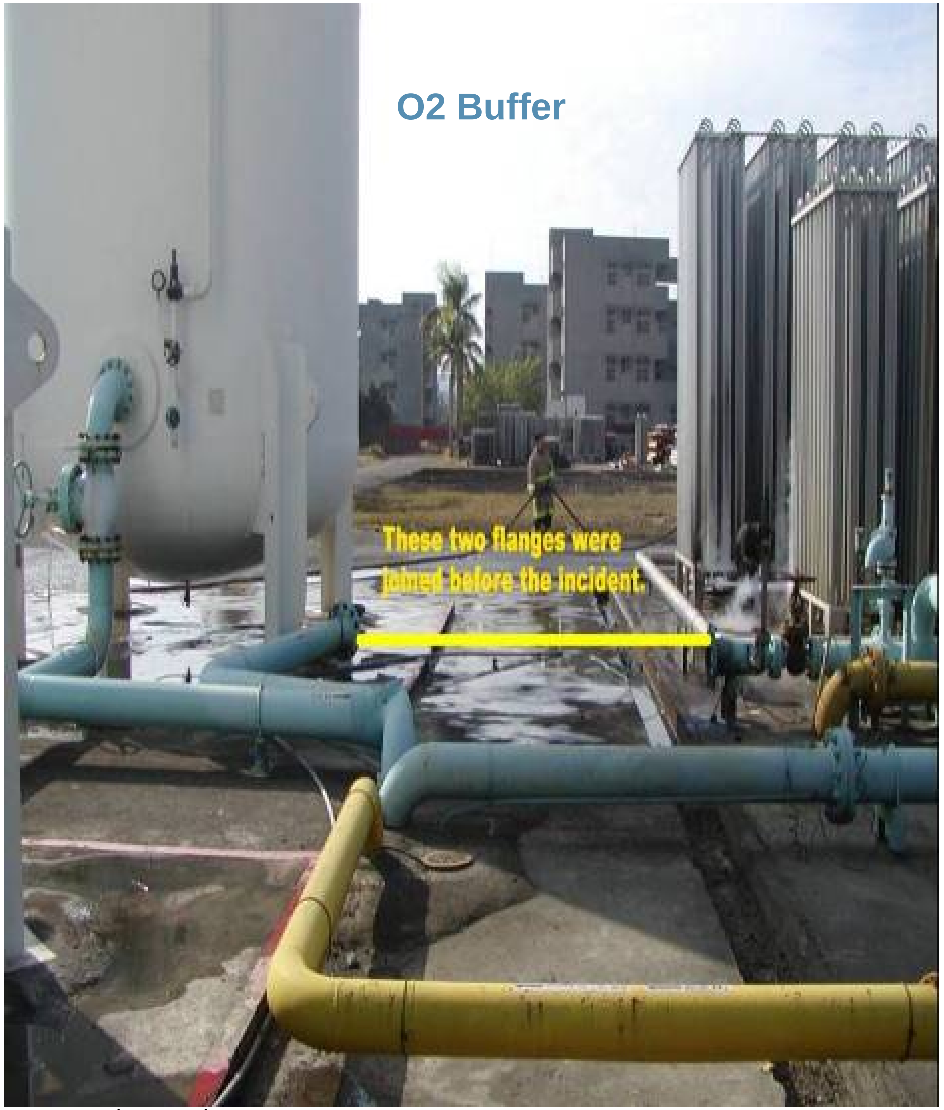
An injured employee of a steel plant is being rushed to a hospital in Visakhapatnam. (AP Photo)

hindustantimes
Mon, 18 Jun 2012
South India

Oxygen Safety Incident in Asia – ASU Pipeline Burnt

1. **Control Valve material not ideally Oxygen Compatible**
2. **Flow Rate too high**
3. **Pipeline also burnt**

Oxygen Safety Incident in Asia – Oxygen Pipeline Caught Fire



1. **Flange inner gasket irregular in shape**
2. **Minor leakage via gasket after 7 years**
3. **Incompatible grease was used on bolts & nuts**
4. **O2 leaked via gasket and caught fire with grease**

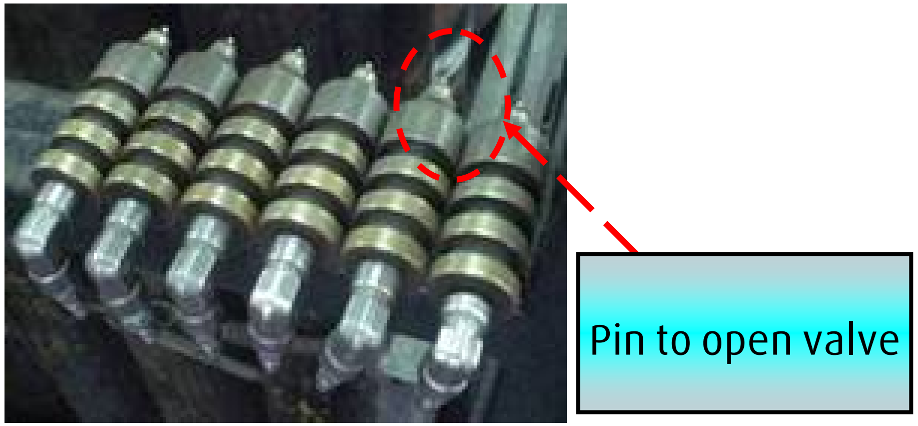
Oxygen Safety Incident in Asia – Oxygen Strainer Caught Fire

1. **28 Bar working pressure**
2. **Stainless Steel**

Oxygen Safety Incident in Asia – Oxygen Regulator On Fire

1. **150 Bar working pressure**
2. **Incompatible material of the Control Valve – aluminum bronze**

Oxygen Safety Incident in Asia – 200 Bar Oxygen Hose On Fire



1. **Incompatible material – Stainless Steel Pin vs. Monel**
2. **Vent valve wrongly opened first before main stop valve leading to too high velocity**
3. **Stainless Steel pin on fire**

Oxygen Safety Incident in Asia – Air Filter Buffer Burst

1. **Newly used system - only 4 months**
2. **11 out of 12 Paper Filters choked leading to too high a velocity via the only one in service condition**
3. **Paper Filters on fire first then Stainless Steel buffer tank**

Oxygen Valve Fire

- The valve (operating at 27 barg) had a carbon steel body with a stainless steel shaft
- It is believed that the fire started in the stem packing area, through adiabatic compression and contamination
- The kindling chain then ignited the packing and valve stem
- The valve was cleaned to an inadequate standard
- EIGA publication Doc 13* would have required exempt material for the wetted parts

The Application Determines the Material

Liquid Oxygen - Aluminium Valve Fire

Aluminium dust is one of the most highly reactive (explosive) metal dusts with oxygen

Materials need to be selected for the application

- Aluminium is suitable for ASU vessels, columns and trays. It can be used for high pressure cylinders
- Lubricants should not be applied to the internals of valves where they can collect debris
- Aluminium is not suitable for rotating machinery and valves
- Aluminium burns explosively in oxygen

Oxygen Compressor Fire

- Aluminum bronze greater than 2.5% is not allowed by modern piping standards in HP GOX system
- Aluminum content is considered flammable and is not classed as a bronze from an oxygen standpoint. It is believed that the casing inserts were aluminum bronze

Oxygen Pump Fire

- Inadequate purge to the gearbox allowed oxygen to enter the gearbox, resulting in a fire

Oxygen Barrier After Fire

— **An oxygen compressor fire is contained by the barrier**

Oxygen Compressor Fire

— **A particle impact on a carbon steel pipe bend resulted in a burn out at a reciprocating compressor**

The Importance of Cleanliness

- Silicone grease found in the threads of this cylinder
- When the cylinder was dropped the valve rubbed on the cylinder threads igniting the silicone grease in the presence of O_2 at 2000psig

The Importance of Cleanliness

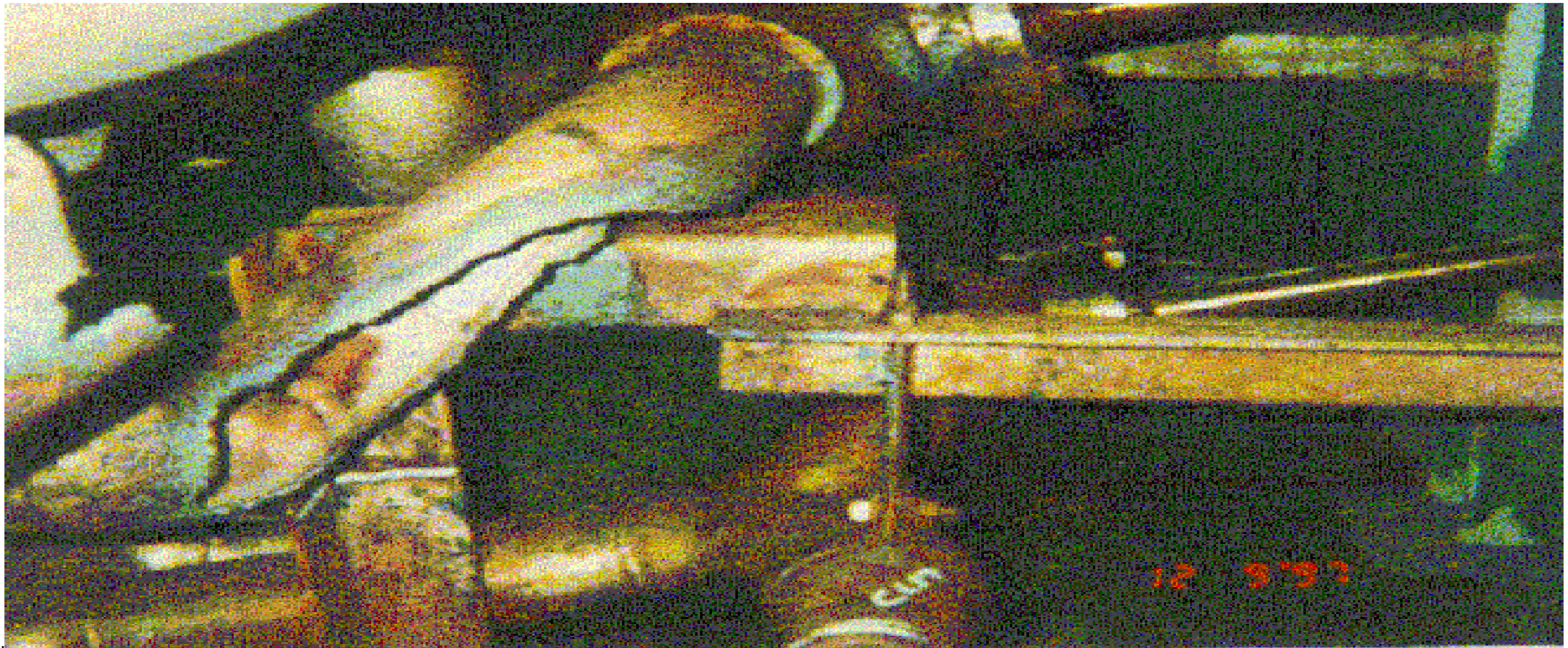
Valve Ignition Causes:

— Inadequate degreasing & blow through procedures

— Debris in the valve cage and filter

— High velocity impact or friction caused by valve movement

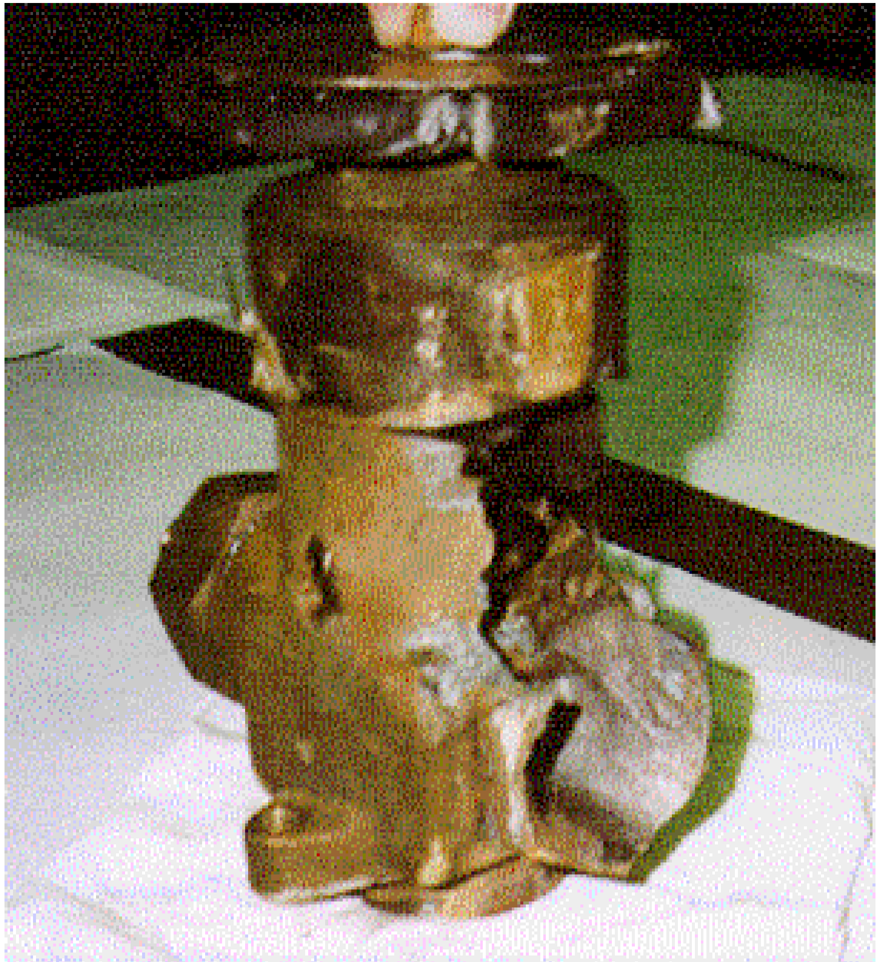
— thin sections in the valve cage



Using Improper Materials

A stainless steel filter was used in the suction line to a ground mounted LOX pump. A piece of the filter became detached and went into the pump causing an ignition

Lack of Maintenance



The non-metallics (o-rings, seals etc) of this manifold cylinder filling valve had never been replaced since the date of installation

Improper Cleaning

This is the assorted debris that can be collected on a filter during blow through of a "clean" oxygen system

Brief Summary from the above Incidents

		Design 設計	Installation 安裝	Maintenance 維修	Operation 操作
ASU Reboiler Explosion	再沸器爆炸	1			1
Iron Steel Plant Explosion	鋼鐵廠爆炸	1	1		1
Al Bronze at ASU	空分中的鋁青銅	1			1
O2 Pipeline Bended	氧氣管道被屈曲		1	1	
HP Strainer Fire	高壓過濾器著火	1			1
HP Cyl Filling Control Vlv	高壓充瓶閥	1			
HP Cyl Filling SS Pin	高壓不銹鋼針	1		1	1
Air Filter	空氣過濾器	1	1	1	1
CS Valve Packing Leaked	碳鋼閥門墊片漏	1		1	
Grease inside ASU	空分中的油脂	1	1		
Al Bronze Parts at ASU	空分中的鋁青銅	1			
Gear Box Purging	齒輪箱吹掃				1
Particle in O2 Compressor	氧壓機內的微粒	1		1	
Oil at Cyl Valve O Ring	瓶閥O型圈有油		1	1	1
Valve Strainer with Grease	閥門過濾器有油		1	1	
Particle in O2 Valve	氧閥門內的微粒	1	1		
Manifolded Cylinder Valve	匯流排閥門			1	
Strainer's Devris	過濾器的雜物		1	1	
Sub Total	分類總數	12	8	9	8

Do's and don'ts of oxygen safety

DO's

- ☑ use approved materials
- ☑ use "oxygen cleaned" materials to the appropriate level of cleanliness
- ☑ leave the bottom two threads free of PTFE tape when sealing joints
- ☑ open valves slowly to avoid sudden pressurisation
- ☑ wear clean clothes free of oil or grease
- ☑ ventilate clothing after working in oxygen enriched atmosphere
- ☑ remove all cleaning fluids from oxygen systems even where they are described as 'oxygen compatible'
- ☑ ensure that appropriate component testing is performed where required
- ☑ remember that oxygen compatibility is not a 'science'
- ☑ remember that oxygen enrichment of clothing is hazardous and clothing must be ventilated for approx. 30 minutes before approaching ignition sources

DON'Ts

- ☒ tighten leaking joints under pressure
- ☒ use oil or grease to lubricate components
- ☒ introduce contaminants into an oxygen system
- ☒ smoke in an oxygen enriched atmosphere
- ☒ misuse oxygen
- ☒ assume that below 21% oxygen there is no hazard of ignition-the environment dictates the safe concentration
- ☒ perform repairs on a 'live' oxygen system
- ☒ substitute one material for another without performing a proper review
- ☒ increase the temperature or pressure within a system without validating the materials
- ☒ assume an approved material can be used under the same operating conditions in a different configuration or thickness

Related AIGA Publications

AIGA Website: www.asiaiga.org

- AIGA 021/12 – Oxygen pipelines and piping system
- AIGA 048/08 – Reciprocating compressors for oxygen service
- AIGA 055/08 – Installation guide for stationary, electric motor driven centrifugal liquid oxygen pumps
- AIGA 071/11 – Centrifugal compressors for oxygen service

Also available in Chinese:

- AIGA 012/04 - 供氧设备的清洁
  Cleaning of equipment for oxygen service
- AIGA 056/08 - 低温空分装置安全
  Safe practice guide for cryogenic air separation plants

Thanks for your attention

Except for the section on incidents in Asia,
this presentation was originally given by
Sudhir Phakey (Linde) at the EIGA 2012 Meeting

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