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Gases Association

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Oxygen Ignition Mechanisms and Industry Incidents

Henry Liu
Air Liquide Far East

Henry Liu

Henry LIU is currently ALFE Health, Safety and Environment senior Director, responsible for HSE activities supervision and management , Risk Management and Industrial Audit.

He had previously led and supervised ALFE Industrial Operation and Project Implementation Department.

Henry graduated from Chung Yuan University with major in Mechanical Engineering. He holds the Taiwan Industrial Safety Professional Engineer Certification and is also an AL Group International expert in electronic business safety and risk management.

1. Temperature effect

- **Temperature of oxygen systems**

– Most oxygen systems operate at nearly atmospheric temperature. If an oxygen system operates at a higher temperature, an ignition is more likely to **occur**

- **Auto Ignition temperature of materials**

– The Auto Ignition Temperature (AIT) is the temperature at which a product begins to burn when placed in an oxygen atmosphere at 120 bar

– Characteristics of non metallic materials: see Excel file

– When the AIT of a product is too low, the product is not considered compatible for oxygen service as it can easily burn

AIT of plastic material

- **Use only products which are compatible with oxygen**
- **When replacing a gasket, an O-ring, never change its type**

AIT of plastic materials

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Symbol	name	P lastic or E lastomer	PRODUCTS NAMES	SPONTANEOUS IGNITION TEMPERATURE	HEAT OF COMBUSTION cal/g	OXYGEN INDEX	CHEMICAL COMPATIBILITY						Limits of Temperature °C	Hardness shore
							Data from	Oxygen	Nitrogen	Nitrous oxide	Fluorine and HF	Carbon dioxide		
PTFE	*polytetrafluoroethylene*	*P*	*Teflon - Hostaflon - Neoflon (*)*	*450 - 500 °C*	*1526*	*95-100*	CTE tests	C	C	C	C if P<1 bar and ambiant	C but permeation	*-200/+260*	*50/56 D*
PCTFE	*polytrifluoromonochloroethylene*	*P*	*Kel'F - Voltalef - Dyneon*	*420 °C*	*1476-2300*	*95-100*	CTE tests	C	C	C	C if P<1 bar and ambiant	C	*?*	*80 D*
ETFE	*ethylene tetrafluoro-ethylene*	*P*	*Tefzel*	*245°C*	*3514*	*30*	STP 1395 p98						*150*	
PVDF	*polyvinylidene fluoride*	*P*	*Kynar*	*268-294°C*	*3277-3533*	*39-44*	various	C	C				*-10/+150*	*80 D*
FFKM	*perfluoroelastomere*	*E*	*Kalrez*	*350 - 380°C*	*1565-2090*	*100*	various	C	C		type 4079 = C		*-50/200 - 316?*	*60-90 A*
FPM ou FKM	*fluoroelastomere*	*E*	*Viton*	*290 - 350 °C*	*1963-3600*	*22-80*	CTE tests + STP 1454 p25	C	C	NC		NC	*-50/+200*	*60-90 A*
PEI	**polyetherimide**	**P**	Ultem 1000	440 °C		47	CTE tests	C		increase in weight : + 9% - reduction in hardness 10%		C	-50/+170	90 D
PPS	**polyphenylene sulfide**	**P**	Ryton	438 °C	6853	46	various						-30/+220	90 D
PMMA	**polymethylmethacrylate**	**P**	Plexiglas	430°C	6000	15-21,5	PrEN 13159 + STP 1454 p25							
PSU	**polysulfone**	**P**	Ultrason S2000	404 °C		30-51	various						-100/+160	74 D
PES	**polyethersulfone**	**P**	Victrex 4100	398 °C	7521	38	CTE tests	C		reduction in hardness (6%)		reduction in hardness (7 %)	-10/+180	82 D
PI	**polyimide**	**P**	Vespel SP 1 - Kinel	350 °C	5970-7610	36-65	various						?/260	
PAI	**polyamide-imide**	**P**	Torlon 4203	324 °C		44-52	CTE tests	C		C		C	-196 ?/+230	88 D
PEEK	**polyetheretherketone**	**P**	PEEK 450 G	338 °C	7775	35	CTE tests	reduction in hardness (10%)		C		C	-65/+250	88 D
PC	**polycarbonate**	**P**	Makrolon	300-315°C	?	22,5-44	PrEN 13159							
NBR	**nitrile rubber**	**E**		173-310°C	5400-8500	17-22	PrEN 13159 + STP 1454 p25							
MQ	**silicone - polysiloxane**	**E**	Silicone	270 - 325 °C	4155	21-45	CTE tests + STP 1454 p25	C usually	C	C		C but permeation	-70/+200	30-80A
PUR	**polyurethane**	**E/P**	Vulkollan - Urethanne	181-246 °C	6510	26-29	CTE tests	C	C	C		C	-50/+90	75/95 A 51/69 D
TPE or TEEE	**thermoplastic polyester elastomer**	**E/P**	Hytrel - Lomod	data depending on type				C					data depending on type	30/82D
EPDM	**ethylene propylene**	**E**		159 - 220 °C	9220-11300	17-26	various	C	C	C		C	-40/+120	40/90 A
POM	**polyacetal - polyoxyméthylène**	**P**	Delrin	200-210°C	?	14.2	PrEN 13159							
PA 6-6	**polyamide**	**P**	Nylon / Zytel	200 - 220 °C 250 - 300°C	7500-8842	19-30	CTE tests	C	C	C risk of swelling for		C but plastifiants ???	-65/100	74/83 D
CR	**chloroprene - neoprene rubber**	**E**		175-190°C	3000-9000	17-26,3	PrEN 13159 + STP 1454 p25							
PE	**polyethylene**	**P**	numerous	181°C	11100	17,5-30,2	various							
PP	**polypropylene**	**P**	numerous	150-160°C	11000	17,4-29,2	PrEN 13159							
PPO	**polyphénylène oxyde**	**P**	Noryl			22-33	STP 1454 p25							
ABS	**Acrylonitrile Butadiène Styrène**	**P**				16-18	STP 1454 p25							

C : compatible

(*) Italic red, non suitable for "breathable use"

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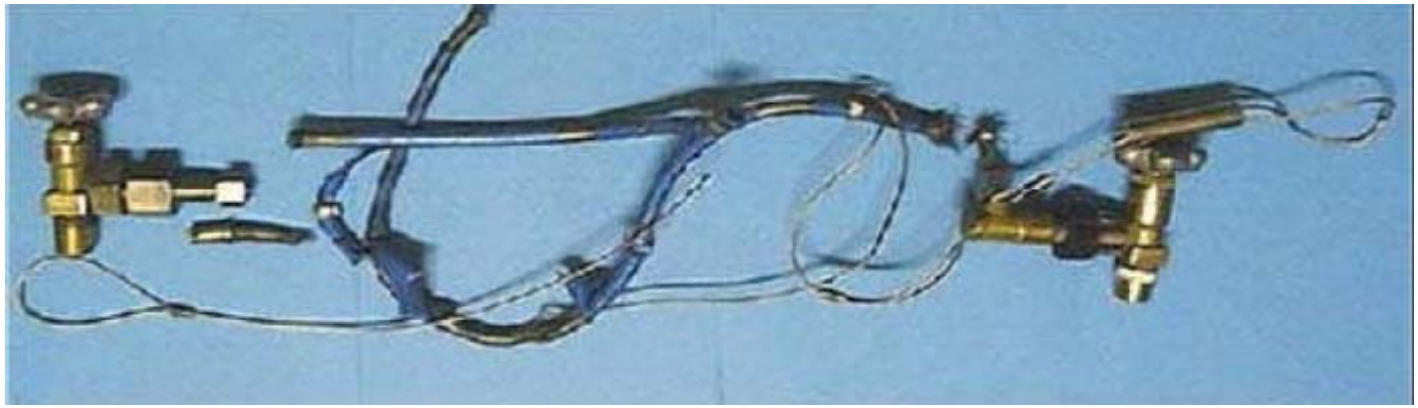
NC : not compatible

2. Adiabatic compression effect: combustion of a flexible hose



- When opening a valve, the gas downstream (if contained in a closed space) is quickly compressed. An almost adiabatic compression is created and heats the gas (like in a pump used to inflate tires)
- For a circuit passing from 1bar to 200bar, the temperature theoretically reached can be as great as 1000° C
- This temperature is above the AIT of all plastic materials

- **Always open valves slowly**
- **Use validated flexible hoses**
- **Use validated high pressure oxygen equipment**

3. Adiabatic compression effect: explosion of a pressure gauge

- The block on the picture comprises a connection to the cylinder valve, a pressure gauge and a small flow valve
- This block is used to check the pressure and analyse the gas in cylinders. It is fixed on the cylinder valve
- When the valve is opened, the pressure gauge catches fire
- The stainless steel filter burns

- **Open cylinder valves slowly**
- **Use a gauge for oxygen service**
- **Use a filter in copper or nickel alloys**
- **Keep the whole system clean**

4. Particle impact effect: fire in an elbow

- At the commissioning of a plant, when introducing oxygen in the piping, a jet fire occurred
- The main damages were apparent at an elbow
- The incident was caused by particles remaining in the pipeline after welding
- An ignition occurred in the elbow, burning the stainless steel

- **A procedure for cleaning the system from all contaminants and particles must be implemented before introducing oxygen**

5. Flow friction effect: fire at filling using a quick connector

- A leak occurs at end of filling
- The quick connector catches fire
- Velocity of gas is sound velocity and creates a friction on the damaged gasket
- The damaged gasket catches fire

- **Avoid leaks**
- **Keep gaskets in good condition**
- **More generally: Never dismount a flange of an oxygen circuit under pressure**

6. Impact and contamination effects

- A cylinder falls and hits the valve of another cylinder made of aluminium
- This last cylinder ruptures
- Its valve burns
- The aluminium burns
- The cause of the accident is the combination of a shock on a full oxygen cylinder and the presence of non compatible grease in the parallel thread of the cylinder valve

- **No grease on valve threads**
- **Avoid parallel threads for aluminium cylinders in GOX**
- **Avoid shocks on oxygen equipment**

7. Electrical energy: static electricity, electrical continuity

- **A cylinder exploded while being rolled to homogenize its oxygen rich mixture**
- **The cylinder was not corroded internally**
- **It was discovered that it was equipped with a dip tube in a plastic material**
- **It is assumed that an electrostatic spark started the violent combustion of the dip tube in the 200 bar oxygen mixture leading to the explosion of the cylinder (friction of the dip tube on the cylinder wall might also be a possible cause of the ignition)**

- **No dip tube in a plastic material**
- **For O2 and mixtures, use dip tubes in copper or Nickel alloys**
- **Mark cylinders equipped with a dip tube**
- **Ensure electrical continuity between all parts of an equipment containing O2 or O2 mixture**

8. Kindling chain effect

- **The AIT of metals is greater than 1300° C**
  - **– So, it is much more difficult to start a combustion with metals only**
  - **– An adiabatic compression is not sufficient to start burning metals**
- **Plastics have a low AIT, but don't easily dissipate heat**
- **The combustion of plastics can create enough localized heat to reach a temperature at which metals begin to burn**
- **The combustion of metals depends on the metal and on the oxygen pressure**
- **Metals may propagate a combustion initiated by plastic materials, grease, oil, dust, rust or other contaminants**
- **This effect of promoted ignition is called the kindling chain**

- **Stopping the kindling chain effect can only be done by design and material selection**
- **Use only oxygen validated equipment**
- **Use oxygen validated spare parts from the equipment supplier**

9. Concentration effect: fire on a LOX trailer :

- A leak occurs on the feed line of the pump
- A fire occurs on the electrical box located in the trailer's rear gas cabinet
- The tanker burns completely

- **Analyse the accident report**
- **Find causes of the incident**

9. Concentration effect: fire on a LOX trailer

- A leak occurs on the feed line of the pump
- A fire occurs on the electrical box located in the trailer's rear gas cabinet
- The tanker burns completely

- **Driver must stay close to the tanker during filling to be able to immediately stop the pump**
- **When possible shut-off the pump and LOX valves of the trailer and of the customer storage**
- **Do proper maintenance of LOX pumps to avoid leaks**

10. Concentration effect: fire of a homecare delivery van:

- A homecare delivery van carrying medical liquid oxygen cylinders catches fire on a highway, blocking road traffic during several hours
- The driver suffers burns to the scalp, a cylinder explodes, pin index valves are expulsed on small cylinders
- An oxygen enriched atmosphere is created in the van and material impregnated with oxygen ignites due to a spark or a flame
- A LOX cylinder had a liquid leak which had not been fixed
- The driver was smoking in the cab

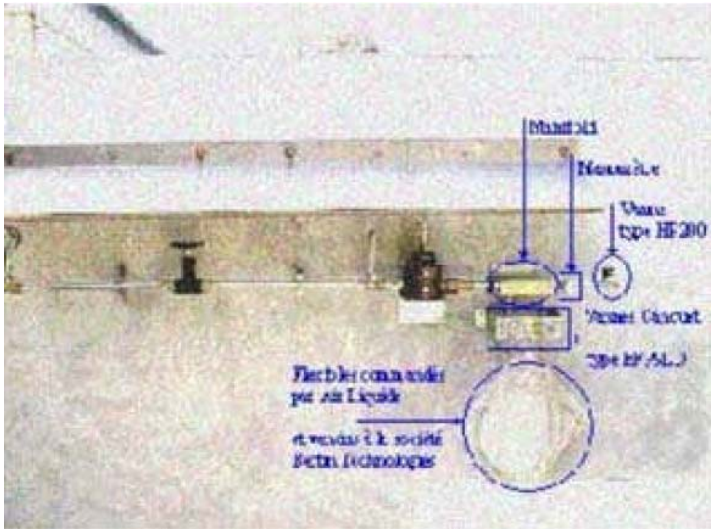
- **No smoking in presence of oxygen**
- **Use dedicated ventilated vehicles**
- **Segregate LOX and GOX containers**
- **Fix leaks**

11. Inventory effect: fire on large size compressors and stations:

- Examples of fires on a large size oxygen compressor and a let down station
- Damages are important, but limited inside barriers
- Molten metal is projected around

- **Never go inside barriers during operation (oxygen flow or pressure)**

12. Contamination effect: solvents for cleaning



- When oxygen was introduced in the installation for the first time, ignition and serious burns on equipment occurred and the flexible hose ruptured
- Cleaning had been performed using a solvent, which was vented with nitrogen
- Some degreasing agent was left in the piping and ignited at the first oxygen valve opening

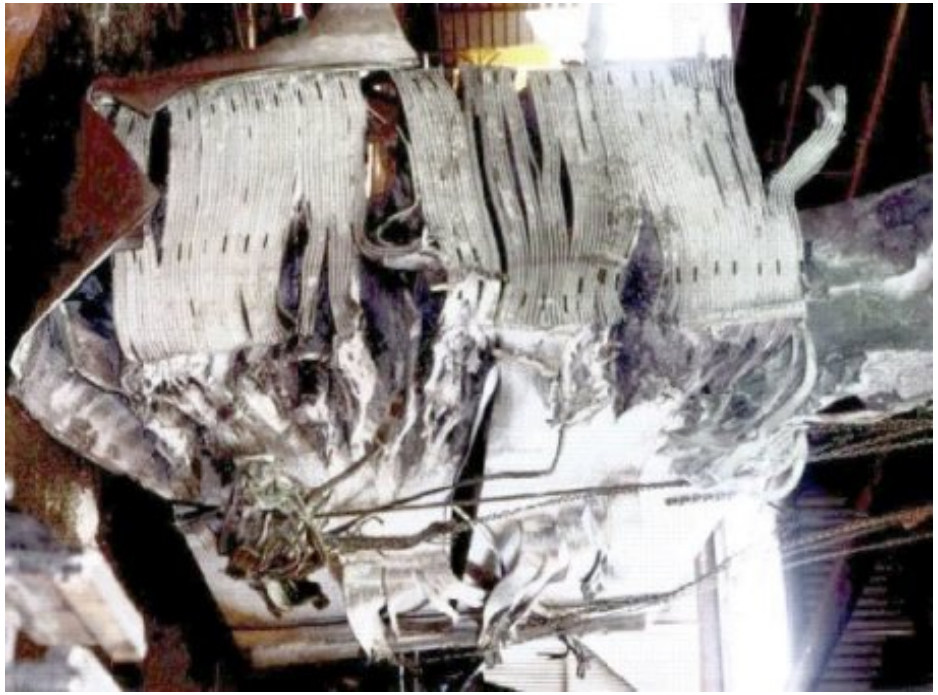
- **Use only components already cleaned for oxygen service**
- **If cleaning in place cannot be avoided, use only solvents approved for Oxygen service cleaning or water based cleaning agents**
- **Procedure for cleaning in place an oxygen system must be validated**

13. Contamination effect: Ignition during maintenance of an oxygen cylinder

- A metallic brush ignited during maintenance of the cylinder thread
- The cylinder is used in oxygen service and oxygen remained in the cylinder at atmospheric pressure
- Brush was contaminated with grease

- **Make sure that the cylinder has been vented**
- **Install a protection of the operator**

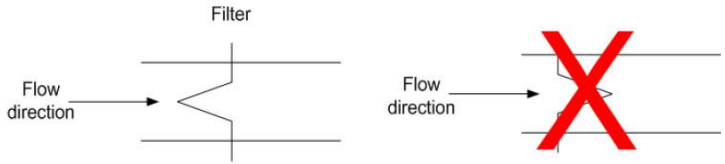
14. Contamination effect:
Explosion of the reboiler condenser of an ASU



- C_nH_m accumulated in the reboiler condenser
- They burned in presence of oxygen (LOX and GOX)
- Aluminium of the reboiler condenser also burned
- The column containing the reboiler condenser burst as well as the cold box

- **Make sure that the reboiler condenser operates according to the manufacturer‘s instruction**

15. Contamination effect: cryogenic pump fire

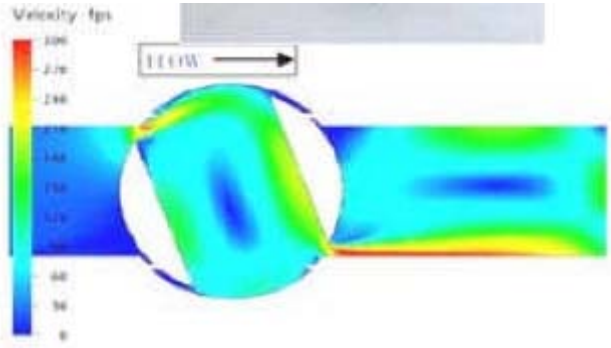


- The pumps were not continuously cooled down
- The mechanical seal had been changed several times
- Small parts of burnt mesh are found in the pump after the fire
- Stainless steel mesh particles were found in the mechanical seal, which caught fire
- The filter with stainless steel mesh was wrongly installed with the cone downstream

- **New filter mesh shall be in copper or nickel alloy whatever the pressure**
- **Narrow part of filter cone is first exposed to the upstream gas flow**

16. Velocity and flow friction effects: Ignition of ball valve

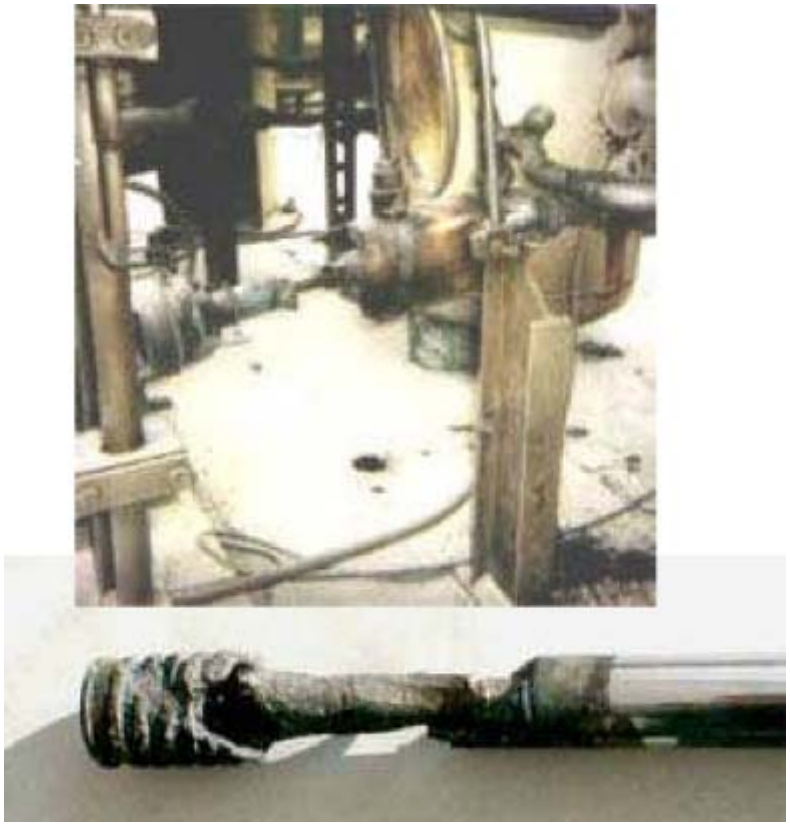
- Ball valve located on a copper pipe at 150 bar, diameter 25 mm
- Sealing gasket disappeared
- The stainless steel ball valve is partially burnt
- The valve body is also burnt
- The operator is slightly burnt on his hands



- **Limit use of manual ball valves:**
  - **– pressure limit: 25 bar**
  - **– diameter limit: ND 50 mm**

17. Mechanical friction effect:

pump running without liquid (dry running)



- The pump trips due to high temperature
- The operator restarts the pump, by-passing the safety.
- The pump catches fire
- The cause of the fire is the friction of certain internal moving parts in the pump due to the absence of liquid in it
- These parts are progressively heated and catch fire

- **A cryogenic pump must be cooled down before start**
- **Never run a pump without liquid**
- **Don’t by-pass temperature safeties**

18. Mechanical friction effect: dismounting of an oxygen cylinder valve under pressure

- In a retesting plant, the valve could not be opened by the unqualified operator
- The valve was dismounted without checking that the cylinder was empty
- The valve was ejected from the cylinder, which flew around the workshop
- The operator was burnt by burning metal and died a few hours later

- **Analyse the accident report**
- **List the facts and the possible causes**
- **Perform a root cause analysis**

18. Mechanical friction effect: dismounting of an oxygen cylinder valve under pressure

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- The valve was dismounted without checking that the cylinder was empty
- The valve was ejected from the cylinder, which flew around the worksho
- The operator was burnt by burning metal and died a few hours later
- The friction of the valve threads on the aluminium cylinder ignited the PTFE tape in the presence of oxygen remaining in the cylinder
- More than 3 kg of aluminium burnt

- **Before dismounting a cylinder valve, check that the valve is open by trying to introduce gas into the cylinder and checking that it flows out**
- **If not, put the cylinder aside so that it follows a specific and adapted treatment and inform the manager**

Thank you

Original Presentation by
Herve Barthelemy (Air Liquide) at the
EIGA 2012 Meeting

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