



SEVESO

LIST OF RELEVANT ACCIDENTS AND INCIDENTS

Doc 60.1/25

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1 Introduction

The Seveso directive (Annex II 4(c)) requires that the safety report includes a “*review of past accidents and incidents with the same substances and processes used, consideration of lessons learned from these, and explicit reference to specific measures taken to prevent such accidents*”. The intent of this appendix is to provide an industry-wide list of example accidents and incidents from which industry lessons can be identified.

For the purpose of this appendix, it is not necessary to attempt to determine retrospectively whether an accident or incident did or did not meet all the elements required for Seveso Major Accident (MA). Even if the accident or incident did not occur on a Seveso site, there is an opportunity to learn.

This Appendix is¹ mainly developed from those gas industry accidents and incidents which have been shared since 1976 within EIGA's Safety Advisory Council (SAC) and its predecessors. Note, most accidents and incidents discussed in SAC focussed on injuries and not all involved loss of containment. Under the confidentiality rules of the EIGA SAC database (see Doc 910, *SAC Data Bank*), the actual causes of any individual accident or incident may not be shared outside of SAC [1]. Only the summaries (“resumes”) which are compiled by the EIGA SAC members, may be further shared. It is important to understand that these “resumes” were often written by non-native English speakers. However, the SAC reporting agreement (see Doc 910), requires that the original wording of these resumes is not changed [1].

The overriding intent of reporting these accidents and incidents is for the subsequent SAC discussion and to ensure that relevant EIGA guidance on preventive measures is available. It is important to note that not all accidents and incidents are required to be shared at SAC, so trends or frequency assessment should not be inferred. The number of examples included in each of the following lists is not representative of quantities of accidents or incidents. These examples do not reflect all possible major accident types (see section 9, which describes how to make a comprehensive assessment of scenarios).

	SAC meeting date schedule	
	Year	Meeting Number
The 3 digits given identify the SAC meeting at which an accident or incident was reported and so give a broad indication of when it occurred. Many of the early accidents or incidents pre-date industry guidance which is under constant review and development.	1976 - 79	000 to 009
	1980 - 89	010 to 048
	1990 - 99	049 to 084
	2000 - 09	085 to 118
	2010 -2019	119 to 161
	2020 -	162 -

For each collection of accidents and incidents generic “key lessons learned” are given together with reference to relevant EIGA technical guidance.

The selected accidents and incidents were grouped by type of scenario. Where available, accidents and incidents were included to give examples of the range of possible outcomes.

Examples of relevant accidents and incidents are documented for each of the following.

- L1. Air Separation facility including storage and tanker loading
- L2. Packaged Gases cylinder filling facility
- L3. Vacuum jacketed tanks and cryogenic tanker offloading
- L4. Hydrogen tube trailers
- L5. Acetylene facility

GLOSSARY

¹ Information from one publicly available CSB accident report, as well as the YIMA ASU accident described in [TP63] have been added [2,3]. These events were not in EIGA SAC database.

The resumes often use “company vocabulary” so that different words are used in resumes for the same equipment. A brief glossary of these terms is included here:

Bundle = multiple cylinders connected to common outlet/inlet valves and fixed within a frame = pack

GOX = Gaseous Oxygen

Leads = hoses for pressurised gases

LOC = Loss of containment = release of product

LOX = Liquid Oxygen

MEGC = Multi Element Gas Container = battery vehicle or tube trailer

Pack = multiple cylinders connected to common outlet/inlet valves and fixed within a frame = bundle

Package = cylinder or bundle/pack of cylinders = receptacle

Rack = manifolded collection of fill points to allow filling of multiple cylinders together = ramp

Ramp = manifolded collection of fill points to allow filling of multiple cylinders together = rack

Receptacle = cylinder or bundle/pack of cylinders = package

RPV = Residual Pressure Valve

VIE = Vacuum Insulated Equipment = tank for storage of cryogenic liquids = VJ tank

VJ tank = Vacuum jacketed tank for storage of cryogenic liquids = VIE

Top-filling = addition of fresh gas on top of residual content in returned cylinders, i.e. filling without performing vent/vacuum steps.

Tube trailer = Multi Element Gas Container = MEGC

L.1 Air Separation facility including storage and tanker loading

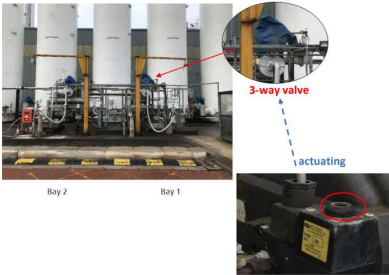
Kind of event that could happen	Example Incidents – Air Separation facility including storage and tanker loading	Key lessons learned	EIGA Doc
<u>COLDBOX</u> If excess hydrocarbons or other contaminants are allowed to accumulate inside cold box components the consequence can be a significant energy release	118.07.04 A small detonation occurred in the main condenser of the cold box resulting in damage to the column. Weld configuration in some joints resulted in a void space between the outside of the nitrogen pipe and the column head, where it passed through the head. Over time, a crack developed in the upper fillet weld, allowing liquid oxygen to migrate into the void space. This oxygen liquid would be regularly boiled by the relatively warm Nitrogen vapour at the top of the Lower Column and replenished by more Liquid oxygen. Repeating this process would selectively increase the hydrocarbon levels in this void space. 015.06.03 In a main condenser of an air separation unit a small explosion occurred probably by hydrocarbon enrichment. No damages nor injuries. 081.04.04 several detonations in the condenser reboiler caused by ignition of hydrocarbon build-up in the upper column sump resulted in severe internal damage to the column 108.05.06 A major release of LOX from bottom of the LOX adsorber occurred at the recirculating pump area. It is assumed that a hydrocarbon release at neighbouring company caused solid hydrocarbons in an aluminium pipe, which ignited. The purge rate was 1.6% but intermittently low purge rates occurred.	Plant design and safe operating procedures should be in place to prevent dry boiling and/or hydrocarbon build up.	Doc 65 Doc 145 Doc 147 Doc 04 Doc 33 SI-HF 04
<u>AIR PURIFICATION failures</u> Improper control of the front end drying and purifying systems can result in the mixture of hydrocarbons with oxygen. If air or oxygen is introduced into the Molecular sieve beds an exothermic reaction occurs, leading in extreme cases to fire or explosion.	010.03.01 The plant was restarted after a maintenance period during which a leaking valve on a hydrocarbon absorber had been repaired. The absorber had been on line for an extended period before shutdown due to leakage problem. During plant cool down the absorber was filled with liquid oxygen to test for leakage. The liquid oxygen was then drained into the disposal header. The absorber was then reactivated with nitrogen with the bottom absorber drain left open. Some short time later an explosion occurred in the 10cm dia. Line to the disposal vaporiser. 003.03.06 A fire occurred in a dust filter unit of a molecular sieve battery. The air pressure in the filter was approximately 6 bars and the fire was of sufficient intensity to burn a hole approximately 25cm by 15cm in the filter shell. 087.06.03 A failure in the logical sequence of the air dryers caused the change and gas flow into a just regenerated but not yet cooled dryer. The over 300°C heated air after dryer caused a fire probably in combination with hydrocarbons and oxygen enrichment. Air and a part of the cold box pipeline were destroyed. The cold box was damaged, and perlite released. One person suffered minor first aid injury.	Plant design and safe operating procedures should be in place to control the oxygen concentration and/or overheating in molecular sieves. Procedures for safe maintenance should be implemented, including work permit and vessel opening procedures as well as instructions for re-start after maintenance.	Doc 04 Doc 44 Doc 65 Doc 147

Kind of event that could happen	Example Incidents – Air Separation facility including storage and tanker loading	Key lessons learned	EIGA Doc
<u>DE-OXO SYSTEM</u> De-oxo process involving hydrogen is used to remove oxygen from some crude argon feeds. Under certain conditions Hydrogen can ignite, causing explosion or fire.	007.03.06 While hydrogen was being transferred from the tube trailer to a static storage installation the valve bonnet of one of the cylinder back isolating valves on the trailer blew out releasing hydrogen at a pressure of approx 200 bars to the atmosphere. The hydrogen ignited and produced a flame of approx 10 metres long. 003.03.03 An internal fire occurred in the crude argon/hydrogen gas feed line to the de-oxo unit. 076.03.04 A contractor employee suffered minor burns when a flammable mixture of hydrogen and air ignited in an absorber vessel during maintenance.	Deoxo and associated hydrogen equipment should be designed and operated as potentially flammable atmosphere areas (ATEX). Procedures for safe maintenance should be implemented, including work permit and vessel opening procedures. Operators should wear specified PPE correctly	Doc 134 Doc 147 Doc 136
<u>CRYOGENIC RELEASES AND VAPOUR CLOUDS</u> Significant release of cryogenic fluids can generate large vapour clouds and can reduce the visibility on and off-site. If liquid oxygen is released the enrichment also increases the likelihood of fire.	085.05.04 A LOX storage tank, 500 m³ capacity, in an ASU ruptured during normal operation. Severe damage at the tank and escape of liquid, no other damage, no injuries. Cause was overfilling of the tank due to malfunction of the liquid level measuring system. The whole safety feature of the tank has to be improved. 039.01.01 To speed up draining of a LOX HP pump, a worker tried to decrease the set pressure of a small safety valve on the line between tank and pump. He turned the wrong valve; the top part came loose, and LOX was spilled. Loss of 15.000 l. of LOX. 009.01.01 Plant was being shut down, discharge of liquid resulted in a cloud of fog wafting out on a public road. Three cars became involved in collisions, were damaged but nobody was injured. 064.05.01 A cryogenic vapour cloud released from an ASU caused fog on a nearby public road. A car driver disregarded the warning post and collided with another car. No injury. Cars damaged. 026.06.04 Four cars collided on the highway in a dense cloud of fog near an air separation unit after liquid oxygen run over from the total evaporator. Cause of the incident was an Inattention of the operator who did not observe on the lever meter that the vessel was full. Two persons (third party) were slightly injured.	Plant design and safe operating procedures should be in place to reliably prevent overfill. Periodic inspection and maintenance of cryogenic storage vessels should be performed. Emergency plans should recognise when spills or releases inside the plant could have off-site effects.	Doc 04 Doc 127 Doc 233 Doc 224 Doc 190 Doc 147 Doc 200 SI 33

Kind of event that could happen	Example Incidents – Air Separation facility including storage and tanker loading	Key lessons learned	EIGA Doc
	004.03.08 A liquid nitrogen storage vessel ruptured causing secondary damage to a pipeline from a liquid oxygen storage vessel. Liquid oxygen flowed from the pipeline across the facility and on to the property of a chemical company. 006.06.04 At an ASU the liquid oxygen line between the column and a storage tank burst and caused considerable material damage. A nearby street was a time closed by the produced fog. No persons injured. 155.05.01 At an ASU Plant a Flat Bottom LOX Tank failed. A pipeline customer was supplied via the Tank-Pump-Vaporizer back-up system because the ASU was offline for maintenance. An operator heard a loud bang and when he went to investigate he saw perlite and vapour coming out from a rupture at the bottom of the tank. A major loss of containment occurred (approximately 200 t of LOX as the product level in the tank was low). Emergency stops were activated, and the site was evacuated safely. [TP INC 31]		
<u>LOW TEMPERATURE EMBRITTLEMENT</u> Carbon steel equipment items can fail on exposure to cryogenic temperatures.	044.07.01 At a gas company air separation unit site, on a liquid oxygen LR tank, the bolts holding the bonnet of a liquid gate valve at the foot of the tank broke and, in 12 hours, 700 000 litres of liquid oxygen were spilt. As secondary effect a large crack affected the external carbon steel vessel and there was an emission of perlite. Also, a 1.2 m underground fire water pipe froze and ruptured. The broken bolts were made of carbon steel (should have been stainless bolts with bronze nuts). All cryogenic valves have been checked worldwide to make sure that this will not repeat elsewhere. This should have been checked before start up as required per the pre-start up inspection checklist. 050.07.08 A carbon steel pipeline installed after a steam vaporizer ruptured when an automatic air to open valve failed to close on a signal from the low temperature pipeline protection system. Underground rupture of oxygen pipeline beneath a private road, road damaged, interrupted product supply. Bi-annual check and maintenance of critical safety systems. 028.03.05 Lox was being pumped through a steam vaporizer, the instrument air-line to the steam temperature controller failed, causing the steam valve to close. The low temperature switch at the vaporizer outlet did not activate an alarm or shut down the pump. Cold gas and liquid passed through the vaporizer and into a six-inch pipeline. The carbon steel line ruptured, blowing a hole approx. fifteen feet in diameter and eight feet deep out of the ground. Lox tank retaining wall and the lox transfer line were also damaged.	Design of process equipment to protect carbon steel pipework from exposure to low temperatures. Periodic inspection and test of cold temperature protective (trip) systems should be performed. The required temperature range of all equipment items and components should be understood and specified at design. Proper cold box insulation to prevent cold spots (i.e perlite filling)	Doc 133 Doc 127 Doc 224 Doc 13 Doc 146 TP 60 Doc 200

Kind of event that could happen	Example Incidents – Air Separation facility including storage and tanker loading	Key lessons learned	EIGA Doc
	048.04.02 A section of an oxygen carbon-steel pipeline shattered as oxygen was being fed into the pipeline from a tank pump vaporizer system. Metal fragments were spread over a wide area. No injury. Plant suffered some damage. 053.03.12 During LOX vaporization the LOX pump did not trip out on low outlet temperature from the vaporizer and cryogenic product was introduced into the carbon steel GOX product line. No injury. Small crack in C.S. elbow.		
<u>OXYGEN COMPRESSOR FIRE</u> Problems with compressors in oxygen service can lead to very intense fire/explosion.	016.04.02 A 72.000 Nm³/h, 37 bar final pressure, oxygen turbo compressor ignited when in normal operation. Fragments from about 30 kg were projected to distances up to 200 m. No injury, damages to LP machine, motor, step-up gear, electric wires, lighting. 042.01.02 A violent oxygen fire broke out in the 3rd stage of the 30 bars GOX compressor probably caused by a small part of the inlet valve disc entering the cylinder and getting stuck between cylinder and piston. The "explosion" caused severe damage to 75-100 m² of the wall consisting of lightweight steel sheets and windows. 3rd stage of compressor destroyed. No injury. 043.01.01 An explosion occurred due to absence of cooling water followed by a fire which melted the cylinder line and the piston of the 3rd stage of the GOX compressor. Cylinder line and piston destroyed. 060.09.02 After maintenance, a 6 steps oxygen compressor had been coupled to the oxygen pipeline system. A few minutes after the start with oxygen, there was a flash fire in the 6th step of the turbo compressor. Damage to the compressor and gear box. 081.06.02 An oxygen compressor unit and its building were considerably damaged as the discharge line at a two piston oxygen compressor burnt out. Cause was an inadmissible pulsation-frequency of the installation initiated by the pressure-pulsation of the piston compressor. The available equipment to avoid any dangerous pulsation was insufficient designed.	Compressors in oxygen service should be specified, designed and operated correctly. Equipment for use in oxygen should be cleaned. Consideration should be given to enclosing Oxygen compressors within barriers restricting access for personnel protection.	Doc 04 Doc 10 Doc 27 Doc 147 Doc 33
<u>OXYGEN PUMP FIRE</u> Problems with pumps in liquid oxygen service can	013.00.04 Oil/oxygen explosion in a LOX piston pump. Carrier frame of the cold end destroyed. Piston rod compressed and moved out through the packing box. Cold end bulged inward, and vacuum jacket torn off. Locking device of the gear, guide of oil scraper broken.	Pumps in oxygen service should be specified, designed and operated correctly.	Doc 04 Doc 148

Kind of event that could happen	Example Incidents – Air Separation facility including storage and tanker loading	Key lessons learned	EIGA Doc
lead to very intense fire/explosion.	072.07.03 Fire occurred in an oxygen cryogenic pump because of an inadequate pump seal material (polyether ether ketone). No injuries, damaged pump.	Equipment for use in oxygen should be cleaned.	Doc 159 Doc 147 Doc 33
<u>GOX BUFFER VESSEL RUPTURE</u> If Gaseous Oxygen Buffer vessels are not properly designed, or are exposed to conditions outside the normal operating envelope, the vessel can rupture or implode	099.05.01 An oxygen gas buffer vessel imploded due to vacuum in the vessel. The vacuum was caused by wrong design and lacking procedures 107.05.01 A 30 bars, 100 m3 GOX pressure vessel ruptured suddenly causing material damage only. Fatigue cracking starting at a weld imperfection is assumed to be the cause of failure.	Pressure vessels in oxygen service should be specified, designed and operated correctly, recognising fatigue cyclic operation.	Doc 147 Doc 190 SI-HF 04
<u>TANKER FILLING/TOWAWAY</u> After tanker filling, a driver may forget to disconnect the hose before driving away - this can result in a large release of cryogenic liquid (oxygen). Failure of fill process equipment can also result in large release of cryogenic liquid (oxygen).	127.11.01 After the filling of a road tanker at the Company site, the driver (a contractor) retrieved his truck keys from the control room and started to move, without disconnecting the transfer hose from the filling equipment. The incident caused damage to the filling equipment and to the piping of the tanker. [TP INC 4] 075.04.01 A liquid driver sustained burns to his legs when his trousers caught fire after a heater cable ignited in an analyser house due to an oxygen rich atmosphere. 007.01.05 Tanker was driven away whilst still connected to storage. 3" valve and pipework pulled off tanker and considerable damage to storage tank pipework. Failure to disconnect hose. 058.07.02 A driver fell asleep in the tractor during loading of liquid oxygen at an air separation plant. The plant operator saw the large product release from the pressure relief valve and stopped the pump. Near miss. 104.05.01 The operator should load a LOX rail tank from a LOX storage tank. For reasons unknown he fainted and when the tank was overfilled, the LOX was spilled through the try cock outlet over the operator's body causing a fatal cold injury. The operator did not use the required "dead man's handle".	Written operating instructions should cover normal and abnormal (interrupted) operations Tow-away protection measures should be implemented Drivers should wear specified PPE correctly during filling Plan inspection, calibration and maintenance activities for safety systems (such as Relief valves.) Competent ADR loaders/drivers.	Doc 63 Doc 179 Doc 04 Doc 190 Doc 200 SI-HF 02 SI-HF 04 SI-TS 03 SI-TS 05

Kind of event that could happen	Example Incidents – Air Separation facility including storage and tanker loading	Key lessons learned	EIGA Doc
	167.05.01 In an ASU at one of the truck loading-bays an unintentional release of 39 t of LOX occurred from a storage tank due to a malfunctioning pneumatic valve. It had been affected by cold rainy and stormy weather. Major release of liquid oxygen. No injuries or further damage caused. [TP INC 43] 	Weather protection needs to be regularly checked/maintained.	
<u>CONTROL OF MAINTENANCE/REPAIR /MODIFICATION ACTIVITIES</u> Improperly managed modification or repair to (oxygen) process equipment can result in rupture, energy release or spill.	057.06.02 At an air separation plant a gas-return-valve of the filling pump of a low-pressure storage tank was repaired but leakage was found during the tightness test. After venting the system when unscrewing the upper part of the valve liquid oxygen splashed. Operator suffered cold burns. Lost time injury. 122.05.04 A worker left a drain valve open when completing a maintenance task on a cryogenic storage vessel. 9 tonnes of liquid oxygen was released, entering the underground sewer system. The sewer was purged with nitrogen. 116.03.01 There was a pressure release and fire from a new section of high pressure oxygen pipeline that was being brought into service as part of an upgrade project that had been installed during the recent ASU3 turnaround. 3 people working in the area at the time were affected by the pressure release, all three were referred to the medical centre with no immediate treatment required and returned to site. Subsequently two of these people have received further treatment, one scaffolder identified with a broken rib, and another Scaffolder with a badly sprained ankle. It was determined that the materials of construction for the control valve and check valve were not suitable. 111.05.01 During maintenance of the actuator of a cold box LOX valve at an ASU Site, the drive shaft was ejected from the valve body. The result was an escape of a considerable quantity of oxygen which resulted in formation of fog with severely reduced visibility. No injuries or environmental impact. The plant was put into emergency shutdown and had to be warmed up to allow examination of the damaged valve.	Leaks from process equipment and other operational issues should be addressed in a timely manner. Planned and unplanned maintenance activities should be controlled using Lockout Tagout (LOTO), Work Permit and – where relevant - Change Management procedures Equipment for use in oxygen should be clean and only suitable lubricants should be used Operators should wear specified PPE correctly	Doc 04 Doc 170 Doc 13 Doc 147 Doc 51 Doc 33 Doc 40 Doc 23 Doc 136 Doc 146 TP 60

Kind of event that could happen	Example Incidents – Air Separation facility including storage and tanker loading	Key lessons learned	EIGA Doc
	144.02.05 Rupture of a buried oxygen pipeline at 40 bar inside the plant at the inlet of the concrete casing under an internal railway due to corrosion along the length of the pipe. Soil, concrete, and water ejected over distances up to 60m from crater of 8m diameter and 3 m depth. Pipe spiral welded built in 1974, coal tar coated and modified in 1991. No injuries, no environmental damage. Material damages. 166.02.01 A worker opened up an oxygen line under 15 bar on the backup system. The line had been isolated but was not depressurised. The work permit was issued for "general works in the area" and didn't specify in detail the works being undertaken. Oxygen release. 026.06.02 After revision a cold box was damaged when a valve of the box burned. Inner parts of the valve were lubricated before with a lubrication unsuitable for liquefied oxygen. Only material damage. 069.05.01 Repair works at an intermediate cooler of an oxygen turbo compressor. Possibility of an oxygen enriched atmosphere was disregarded. Grinding sparks ignited clothing of mechanic, who was fatally burned. YIMA China 2020 : A leak in the interconnecting pipe of the coldbox valve in Air Separation Plant C. Process leakage into the perlite insulation. Over pressurization of the coldbox results in a violent blast. Support frame and coldbox plates are cold and brittle. Coldbox collapses smashing into the bulk liquid storage tank and the adjacent Liquid distribution truck's oxygen and fuel oil tanks. Liquid oxygen leaks together with available combustibles (aluminum, etc.) in the area resulting in a violent explosion. 15 deaths, 16 seriously injured and 236 hospitalized. [TP63]		
DIESEL SPILL Diesel is classified as hazardous to the aquatic environment. Spills or releases of diesel can contaminate water courses.	070.04.03 Fuel oil leaked from a broken level gauge line into the bund. A concealed hole in the bund allowed the oil into a drain and finally into a water course. Doc 113.4.9: An incident occurred at an industrial gas plant where the diesel fuel was stored in an underground storage tank. The tank was externally corroded and started to leak. The leakage went on for quite some time entailing considerable pollution of the ground.	Environmental protection measures should be implemented including spill management. Periodic inspection of diesel tanks should be considered.	Doc 113 Doc 88 Doc 94 TP 2

Kind of event that could happen	Example Incidents – Air Separation facility including storage and tanker loading	Key lessons learned	EIGA Doc
AMMONIA RELEASE Ammonia is flammable, toxic and classified as hazardous to the aquatic environment. Releases can result in harm to people or the environment.	076.01.01 The operator tried to stop a leak by adjusting the stuffing-box nut of a valve in the ammonia refrigeration system, but the leak increased. Personnel at the ASU as well as neighbouring companies were evacuated but no injuries. 077.01.04 Two maintenance workers received chemical burn injuries due to poor emptying of the ammonia in the cooling system before repair. 084.01.03 Contracted service men were asked by the plant's personnel to empty oil from the ammonia cooling system in an ASU. When opening the valve, a sudden release of 400 kg ammonia occurred causing neither injuries nor damage. No work permit was issued. 096.02.01 Rupture of a NH3 valve from a refrigeration unit with release of 1 ton of product to atmosphere.	Environmental protection measures should be implemented including spill management Specified PPE should be worn correctly Planned and unplanned maintenance activities should be controlled using Lockout Tagout (LOTO), Work Permit and – where relevant - Change Management procedures.	Doc 40 Doc 147 Doc 136
ANALYSER ROOM – GAS LEAK H₂ RELEASE Small leaks of flammable calibration gases can collect in enclosed spaces, such as an analyser room or cabinet leading to fire or explosion.	104.02.02 A minor H₂ leak took place within the GC leading to explosion of CnHm Gas Chromatograph within the control room of the air separation unit.	 Analytical equipment containing flammable gases should be assessed to prevent risk of potentially flammable atmospheres (ATEX).	Doc 134 Doc 147

L.2 Packaged Gases cylinder filling facility

Kind of event that could happen	Example Incidents – Packaged Gases cylinder filling facility (excluding Acetylene)	Key lessons learned	EIGA Doc
BURNOUT IN OXYGEN FILLING SYSTEMS Many materials will violently burn in a pure or oxygen enriched atmosphere, when an ignition occurs. Such materials include oil, grease and hydrocarbons, but also common construction materials such as plastics, used for valve seats or other sealing elements, and metals such as aluminium, carbon steel and stainless steel. When a small amount of material (e.g. an oil film or a tiny plastic element) ignites inside an oxygen system, the produced heat can rapidly set fire to more material, causing a flash fire. In pressurized systems this often results in an energy release with a potential for serious injury and damage. The most common ignition mechanisms are external heat (friction, welding, flames, etc.), particle impact and adiabatic compression. The risk of ignition increases with increasing pressure and temperature.	<u>Adiabatic compression</u> 011.03.02: Two cylinder bundles were being charged together with 24 single cylinders on a separate manifold in parallel with the bundle charging system. At 30 bar pressure the bundle charging valve (1) was closed to speed up the charging rate of the single cylinders. When the single cylinders were full, the pump was stopped and the manifold piping depressurised. The operator then opened valve (1) on the pack system. After one turn of the valve there was a loud bang from one of the pack outlet valves, followed by fire which destroyed the flexible connection. 013.05.03: When opening a master valve in order to direct oxygen from manifold 1 to manifold 2, fire broke out in the ramp. Worker suffered severe burns. 2 master valves, 4 cylinder connection valves and meters of stainless steel pipe were destroyed. 110.13.01: First burn-out on the filling rack happened because the operator decided to add an extra 10 l cylinder to the filling rack during the filling. When opening the valve, the pressure shock and extreme velocity caused that cylinder valve, connector, hose and a valve on the filling rack to be burned-out. After the fire, the filling system was not cleaned and after filling 3 more batches, the residual particles from the burn-out ignited and caused main valve burn-out. The operator suffered burns and died three days later in hospital. 118.05.02: During the rack filling of 8 oxygen cylinders the operator identified that one was not filling correctly, the shoulder not being as warm as usual when checked by touch. At the end of the fill he closed the other cylinders off and then started a new fill of the suspect cylinder on its own. An ignition occurred in the cylinder, causing damage to; cylinder neck (burnt through), to the filling rig and a first aid injury to the operator. 121.13.01: One day before the incident two oxygen 300 bar bundles were filled up to 280 bar. The next day the operator wanted to perform a top-filling to the final pressure. To pressurize the flexible hoses from the bundles he opened the bundle valves. While opening the main valve the adaptor on one bundle ignited. Nobody was injured. Damaged equipment. The cause was probably a pressure shock (adiabatic compression) due to improper work procedure.	Oxygen systems should be designed and operated to avoid adiabatic compression (such as slow-opening valves, inclusion of heat sink into fill hose). Operators who are responsible for oxygen filling, including pre-fill inspections should be competent. Specification of material compatible for use in oxygen service, at the required temperatures and pressures should be defined during design Procedures should be developed to ensure that equipment for Oxygen service is clean. Written operating instructions should cover pre-fill inspections, normal and abnormal operations as well as maintenance. Suppliers of equipment and services should be	Doc 04 Doc 33 Doc 182 Doc 136 Doc 64 Doc 236 Doc 233 SI-HF 05 SI-HF 04 SI-HF 02

Kind of event that could happen	Example Incidents – Packaged Gases cylinder filling facility (excluding Acetylene)	Key lessons learned	EIGA Doc
	143.13.01 During the filling of medical oxygen an oxygen burn out occurred on the intentionally blocked control valve at the automatic HP control valve built into the valve cabinet. [Photo TP INC 20]  173.11.01: During the preparation of a specialty mixture cylinder, after the filling of the first component (CO₂), the operator started the purging procedure of the line to prepare the filling of the second component (O₂). The purging is performed by pressurising and venting the line more than one time. After purging procedure completion, the cylinder valve was opened, scales were tared, and operator started the second component filling by opening the ball valve. Approximately 2 seconds later the ball valve got fire. The operator immediately shut off the main oxygen supply and the flames self-extinguished within few seconds. 170.02.02: The operator was performing a purge sequence on the oxygen filling ramp, when opening the third cylinder in the sequence, there was a flash fire between the connector and the flexible hose. The operator wore correct PPE including flame retardant clothing, despite this the operator received burns to 35% the body and was hospitalised. 163.14.01: The operator was filling an oxygen bundle. At the end of the filling process (ca. 190 bar) the operator recognized a leaking noise at the connection between the filling hose and the RPV adapter. He interrupted the filling process by stopping the pump, closing the bundle valve, the filling line valve and relieved the pressure. He tightened the connection between the filling hose and the RPV adapter, restarted the pump and re-opened the filling line valve. An oxygen burnout occurred at the connection between the filling hose and the RPV adapter. A darting flame and/or the filling hose hit the operator in the back (shoulder). The impact was attenuated by protective clothing (fleece & jacket), causing bruise and abrasion and light burn injuries.	subject to quality control procedures. Maintenance personnel working on oxygen systems should be competent. Design of vacuum systems should prevent oil flow into process piping. Flash fire protective Clothing (FFPC) is not certified to protect against oxygen enriched fires, but it may provide some protection. The use of backflow prevention valve can prevent contamination into cylinders. Site emergency plans should outline actions to be taken in the event of fire and product release.	