EIGA Safety Newsletter

Prepared by the Safety Advisory Group (SAG) SAG NL 87/09/E

Table of Contents

Typical oxygen incident outcome - damaged equipment.

Typical Oxygen Filling Incidents

- An operator was connecting oxygen cylinders to a filling manifold. When he **opened the valve** of one of the cylinders, the manifold ruptured explosively. A particle present at the connection between the flexible hose and the valve outlet, or a foreign particle travelling in the high-speed flow of oxygen could have been the cause of ignition.
- Once the process of O_2 filling had finished, the operator proceeded to close the cylinder valves, when he noticed that one of the cylinders was empty because the valve was closed. The operator decided to **open all cylinder valves** again to equalize the pressure. When doing so, one of the connecting hoses burst.
- A flexible hose on a four cylinder oxygen manifold failed. An ignition occurred when the operator opened one of the cylinder valves **prior to opening the manifold valve**.
- During the filling of four brand-new cylinders one cylinder suffered catastrophic failure because of extreme heat. This heat during filling was presumed to be caused by **excessive velocity** of the gas.
- When the filling of an oxygen cylinder and bundle was over, the operator closed the valves on the cylinders and on the bundle. When he **opened the vent valve**, the flexible hose burst.
- A fire occurred on the filling rack when the operator decided to **add an extra 10 litre cylinder to the filling rack during the filling. When opening the valve**, the pressure shock and extreme velocity caused the cylinder valve, connector, hose and valve on the filling rack to be burned out.
- **After the filling** of oxygen cylinders was completed and the cylinder valve closed, the operator opened the vent valve. The **vent valve** ignited, probably due to remaining particles after recent **maintenance**.

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- **After the filling** of oxygen cylinders, during the leak test a filling adapter suddenly ignited.
- After completing the filling of oxygen cylinders, the operator closed all Residual Pressure Valves (RPV) cylinder **valves but left one open**. When opening the vent valve the adaptor connected to the open cylinder valve ignited.
- An ignition occurred during filling of a 10 litre oxygen cylinder fitted with a valve with integrated pressure regulator (VIPR). The operator tried to stop a leak by **tightening** the filling adapter to the filling connector. This resulted in an ignition.

AND MANY MORE SIMILAR INCIDENTS

Oxygen Incidents in Cylinder Filling Stations

A lot has been written in recent years about oxygen hazards, incidents and safety measures. Worryingly SAG still gets repeated reports about oxygen-filling incidents. To improve safety performance SAG has examined all oxygen-related incidents from its accident database very carefully and identified the common causes of incidents, focusing on activity and type of operation when the incident happened.

The majority of all reported incidents happened in cylinder filling stations, and of these incidents, over 80% occurred during regular operation and filling. Practically all incidents are related to manual activity of the operator.

It is interesting that almost all incidents are similar in nature and are mainly caused by three **activities:**

A. **Depressurisation/venting** of the oxygen filling system after the cylinders are full.
B. Adding **extra cylinder/bundle** to the filling rack during the fill cycle OR **opening** cylinder/bundle valve which has been found closed during the filling.
C. **Tightening up connections** to eliminate leaks during filling operation, under high pressure.

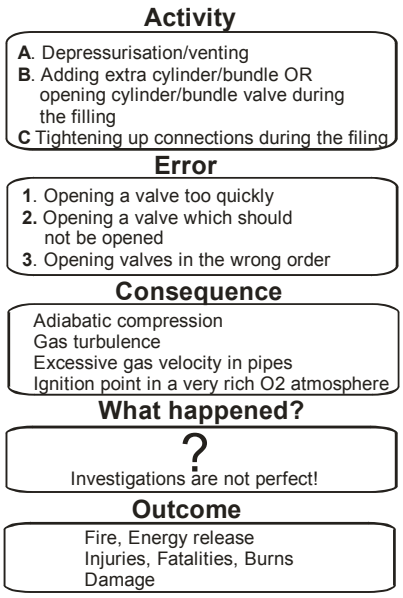
The most common errors are:

1. Opening a valve too quickly.
2. Opening a valve which should not be opened.
3. Opening valves in the wrong order.

The consequences of the above activities and errors are:

- Adiabatic compression
- Gas turbulence
- Excessive gas velocity in pipes or components
- Ignition in a very rich oxygen atmosphere.

Outcomes are usually severe burn injuries including fatalities and significant equipment damage.



Finding of the SAG Oxygen Accidents review

Incorrect activities and related human errors can cause violent pressure shock and high gas velocity which could lead to ignition caused by friction, turbulence and/or adiabatic compression. The probability of ignition is even higher in the presence of particles and/or grease.

SAG members believe that often incident investigators too easily accept the common explanations, such as adiabatic compression, particles or grease, and don't always explore all potential causes. See Safety information Sheet, Human Factors, #3 Human Factors in Incident Investigation (Safety Info HF 03/08).

A) Depressurisation/venting after the cylinders are full

Typical bundle depressurisation incident-energy release

When the filling is over the filling system is depressurised. Experience shows that usually the fire starts in the connection between the filling hose and the bundle/cylinder. The O-ring, as the weakest component ignites almost immediately. The hose ruptures with a violent energy release a few seconds later.

The cause of the incident is usually a damaged or badly positioned O-ring. In this case the gas can surround the O-ring during filling and during depressurisation the O-ring can be exposed to a large pressure shock. The O-ring can be fragmented and the resulting small pieces are pushed into the flexible hose with the flow of gas. O-ring fragments can ignite immediately in the oxygen atmosphere due to friction.

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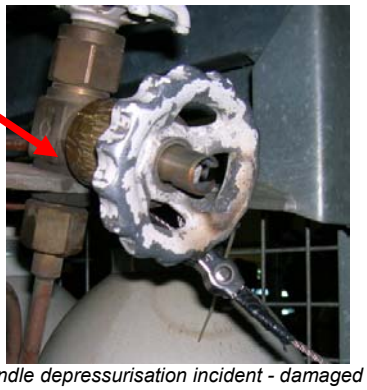
Sometimes even if the O-ring is not in the right position or is damaged, the connection is tight during the filling. So the problem is not apparent.



Typical bundle depressurisation incident - damaged equipment. Scratches behind the handwheel are evidence of use of wrench to over-tighten the valve.

Typical bundle depressurisation incident - damaged equipment. Safety cable did its job – it restrained the broken hose ends.

What actions are recommended to prevent such incidents during depressurisation?

- Check the O-ring before every fill.
- Depressurisation valve shall be opened slowly.
- After opening the depressurisation valve, the operator shall not approach the cylinder/bundle immediately.
- Operators must be well trained and operating instructions shall be available at the workplace or displayed nearby.
- Compatible, spare O-rings shall be identified as suitable for oxygen service and kept in a clean environment.

B) Adding extra cylinder/bundle to the filling rack during filling OR opening cylinder/bundle valve found closed during filling

When the filling of connected cylinders starts, the pressure begins to rise. If an extra cylinder/bundle is connected to the filling system, when that cylinder/bundle valve is opened, the high differential pressure across the valve causes an extremely high gas velocity through the valve.

Additionally, if the valve on the filling rack is opened before the cylinder/bundle valve has been opened; adiabatic compression could be caused in the filling hose.

High velocity, turbulence and adiabatic compression could generate the heat which can cause ignition of the O-ring or valve seat materials. If the pressure difference is high the" fire" is pushed into the cylinder, the upper part of the cylinder is weakened and may eventually rupture violently.

Almost the same scenario happens if the operator, during the filling, finds a cylinder with its valve closed (cold cylinder) and opens the valve during the filling.

Adding an extra cylinder to the filling rack during the filling often occurs due to business pressures.

Upper part of cylinder after the incident.
This cylinder valve burned out after the operator added an extra cylinder to the filling rack during the filling cycle.

How to prevent an incident during filling?

- Operators shall be well trained and aware of the risks
- Operating instructions, highlighting these consequences shall be available at the workplace.

C) Tightening up connections to eliminate leaks during filling operation

Gas escaping from a high pressure connection during the filling process, through a small leak path or opening, will create excessive local gas velocities.

As effort is applied to close the leak, the hole-size is reduced and the gas velocity is increased. Alternatively applying extra force to close a leak can create heat through friction between parts or damage connections. All of these can lead to ignition as described previously.

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The need to use additional tools like spanner or wrench to tighten the connection is usually the sign that something is wrong with the O-ring!

How to prevent an incident in the event of leak during fill?

- Ensure that procedures are in place so that no attempt is made to stop any leak until the filling operation has been safely stopped and the leaking section of the system is de-pressurised.

EIGA requests all member companies to highlight the particular issues described in this newsletter and ensure that managers/employees involved in oxygen filling are aware of these risks.

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