Valve Requirements for Oxygen Service

Background

For valves used in oxygen service, it is important to identify potential sources of ignition and the factors that aggravate propagation as all three elements - oxygen, fuel and heat (source of ignition) - are required to start and propagate a fire. The design and materials of construction of the valve should eliminate these factors or compensate for the presence of ignition sources. Preventing fires in oxygen and oxygen-enriched systems involves all of the following:

a) Minimizing system factors that cause fires and environments that enhance fire propagation.

b) Maximizing the use of system materials with properties that resist ignition and burning, especially where ignition mechanisms are active.

c) Using good practices during system design, assembly, operations and maintenance.

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Instances of Accidents in Oxygen service

There have been a number of accidents [1] in oxygen systems due to wrong selection of valves and valve components. The probabilities of such accidents are high during start-up and shut down. Gaseous oxygen (GOX) lines are more prone to fire than Liquid oxygen (LOX) lines as more heat is required to cause a fire in LOX lines. However in extended bonnet LOX valves, the vapor column will have gaseous oxygen (GOX), which could be a source of ignition.

Examples of accidents in oxygen systems:

1. A safety valve on a gaseous oxygen supply line was greased during repair. When the safety valve was later checked under oxygen pressure, the grease ignited and the operator was badly injured.
2. A 150-bar cylinder of 1% nitrogen in oxygen connected to analysis with a stainless steel needle valve resulted in oxygen combustion. Laboratory official stance on the valve seat material is unsuitable for extended use in oxygen and should be replaced.
3. A filling panel with ball valves was temporary, and against the standard procedure, used for the filling of oxygen mixtures. The ball valve ignited due to adiabatic compression and the operator was injured.

[1] Fire hazards of oxygen and oxygen enriched atmospheres, AIGA 005/10, Asia Industrial Gases Association

The Kindling chain

In a kindling chain (referred to as promoted ignition in Guide G94), an easily ignitable material such as flammable contamination, ignites and the energy release from this combustion ignites a more ignition-resistant material such as a plastic, which in turn ignites an even more ignition-resistant material such as a metallic component. The fire eventually leads to a breach of the system.

The primary intent is to prevent ignition of any material in the system and secondarily, is to break the kindling chain so that even if ignition does occur, it does not lead to a breach of the system. One method to accomplish this is to limit the mass of non-metallic components so that if the non-metal does ignite, it does not release sufficient energy to ignite the adjacent metal.

In an oxygen system, selection of non-metals as per ASTM Guide G63 and the careful design of components as per ASTM Guide G88 are the first line of defense. Optimum metal selection as per ASTM Guide 94 is an important second-line of defense. Oxygen system cleanliness as per ASTM G93 (Essential to prevent Kindling chain reaction) is the last line of defense as contaminants and residues that are left in oxygen systems may contribute to incidents via ignition mechanisms such as particle impact and promoted ignition-combustion (kindling chain).

Table I: Oxygen Ignition mechanisms as per ASTM Manual 36

O2 Ignition mechanisms	Detail
Particle impact	Due to Cleanliness / Sharp corners
Heat of compression	Adiabatic compression due to rapid pressurization (Quick opening to be avoided)
Flow friction	Generated when oxygen flows across or impinges upon a non-metal
Mechanical impact	Non-metals are susceptible (e.g. heat from check valve disc chattering)
Friction	Two or more rubbing surfaces, generally metal-to-metal
Fresh metal exposure	Due to rapid removal of the oxide layer
Static discharge	Discharges with enough energy to ignite the material receiving the discharge
Electrical arc	Electrical arc from a power source
Chemical reaction	Reaction between chemicals that could release sufficient heat
Thermal runaway	Accumulations of fine particles may undergo reactions that generate heat
Resonance	Heat generated by acoustic oscillations within resonant cavities
External heat	Due to lightning, explosive charges, personnel smoking, open flames etc.

Valve selection guidelines

1. Select lubricants, gland packings, gaskets and other seals that have met the BAM test for temperature-pressure requirements.
2. Avoid valves with rotating stems as rotating valve stems and seals can gall and generate particulate matter. In addition, globe valves have a tortuous path with many impingement sites
3. Isolation valves should be operated either fully open or fully closed and never in a throttling or regulating mode
4. Ball/butterfly valves are quick opening leading to concerns about adiabatic compression (Gear operation is preferred)
5. The disc of a butterfly valve is directly in the flow stream and is considered as an impingement site
6. Avoid thin walls, eliminate burrs and avoid sharp edges
7. Limit Valve-disc chatter and vibration
8. Design for component directionality: The

Particle impact ignition in a globe valve (Source - ASTM Manual 36)

severity of a globe valve, can be affected by impingement simply by changing the flow direction

Selection and testing of Non-metallic materials:
The pressure and temperature suitability of non-metals in oxygen service should be decided based on the results of the reactivity testing with oxygen. The Federal Institute for Materials Research and Testing (BAM) is an institute that conducts these reactivity tests and has published the pamphlet M034-1, which gives the list of non-metallic materials compatible with oxygen for a certain temperature and pressure.

Parameters checked in a BAM test (Annex 2 of Pamphlet M034-1)

- o Determination of the Autogenous Ignition temperature of Gaseous Oxygen: Ignition point of the test material at a certain temperature and oxygen pressure is determined. The ignition point of the tested material shall be above the intended temperature of the material.
- o Testing of materials for aging resistance: After the aging of the sealing material at a certain temperature and oxygen pressure, the sealing material and the gasket weight should remained unchanged.
- o Testing of materials for ignition sensitivity to Gaseous Oxygen impacts
- o Testing of materials for reactivity with liquid oxygen on mechanical impact: When a hammer is dropped from a height of one meter (impact energy 750 Nm) onto a test container, neither explosion nor other reactions of the material with liquid oxygen shall take place.
- o Testing of flange gaskets in Gaseous Oxygen: The flange joint shall remain gas-tight at an oxygen pressure and temperature, the material is intended for.

The non-metallic materials that are tested as per the above procedure include graphite/ PTFE packings for stems, graphite/PTFE fillers used in body joints, Elastomers & plastics used in ball valve seats/stems, lubricants used in valves internally and externally. Typically, lubricants are selected with an FOS of 100 bar over the use or design pressure.

Cleaning and Inspection as per ASTM G93
The cleaning methods recommended by ASTM G93 are mechanical cleaning, aqueous cleaning, semi-aqueous cleaning, acid cleaning, solvent cleaning and vapor degreasing. The standard is not prescriptive and one or many of these cleaning methods can be adopted to achieve the desired cleanliness level.

Valve assembly for oxygen service should be done in a clean atmosphere area or in clean Room. Parts and assembly are to be handled with lint free cloth, gloves or plastic gloves. Parts / assembly are to be protected from contamination during storage with plastic bags. Separate tools and fixtures shall be used for assembly and tools are free from oil/ Hydrocarbon Traces and dust. There are many clean room inspection methods such as Visual, UV test, wipe test, water break test etc. The UV light inspection is one of the popular inspection methods used where the components are checked using 320 – 380 nanometer ultraviolet (Black light) in a dark room. The acceptable black light shall be 50 watts or greater in power and exhibit a minimum UV light intensity of 1000 W / cm2 It is necessary to ensure that all the lubricant used on the components is detectable under UV light. Presence of any fluorescence indicates that re-cleaning is necessary.

References

1. ASTM Manual 36: Safe Use of Oxygen and Oxygen Systems - Handbook for Design, Operation, and Maintenance, Second Edition Beeson Harold, Smith Sarah, Stewart Walter

2. ASTM G63: Guide for Evaluating Non-metallic Materials for Oxygen Service

3. ASTM G88: Standard Guide for Designing Systems for Oxygen Service

4. ASTM G93: Practice for Cleaning Methods and Cleanliness Levels for Material and Equipment Used in Oxygen-Enriched Environments

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