

Oxygen Valve Safety Awareness

Mitigating Fire Risk for Oxygen Valves
Used in Chemical, Aerospace, Medical
and Other Industrial Applications



Oxygen systems present unique risks and safety concerns. Proper system design, materials selection, operation, and maintenance procedures are all critical in mitigating the risk of injury to personnel and damage to equipment and systems.

IMPORTANT NOTE: This bulletin is intended as a starting point resource for understanding some of the risks associated with valves in oxygen systems. It does not address all possible hazardous conditions and is NOT intended as a guide for the design or use of oxygen systems. Always consult a qualified professional before specifying equipment for use in oxygen service.

Oxygen is used safely around the world in a wide range of applications, from home medical to industrial chemical manufacturing to launch systems. In all of these systems, whether gaseous oxygen (GOX) or liquid oxygen (LOX), professional analysis of the application in conjunction with system and equipment design, and materials selection is critical in mitigating the risk of catastrophic oxygen fires.

The Fire Triangle

For a fire to occur, all three elements of the fire triangle are required: (1) an oxidizer; (2) a fuel; and (3) a heat source. In an oxygen system, the oxygen itself is the oxidizer and the materials of construction (pipe, valves, couplings, gaskets, filters, contaminants, etc.) are all potential fuels.

Typically, it is not possible in industrial oxygen systems to completely eliminate one of the elements of the fire triangle. Proper oxygen system design should focus on appropriate materials selection (potential fuels) and minimization of things like friction points, particle and mechanical impact, and adiabatic compression (potential heat sources).

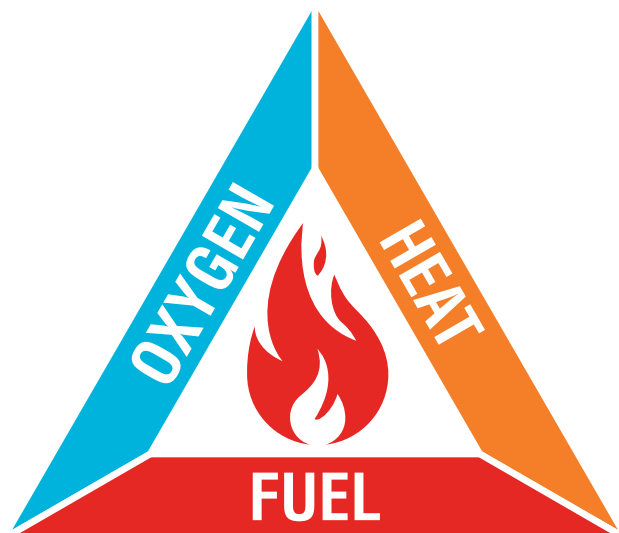


Figure 1: The fire triangle, or combustion triangle, shows the three elements required for ignition.

Kindling Chain Reactions

In a kindling chain reaction, an easily ignitable material (such as contamination in the system or a non-metallic component) burns and the energy released ignites adjacent, more burn-resistant materials.

Kindling chain reactions are a function of each material's inherent minimum ignition energy threshold, heat of combustion and heat transfer characteristics.

Risk of kindling chain reactions can be mitigated, but not eliminated, following good industry practices such as the following:

- Selecting materials that are within their combustion resistance limits
- Ensuring the system and components are cleaned for oxygen service
- Maintaining oxygen cleanliness

Industry standards have been developed to assist users in proper system design and materials selection. A list of commonly used standards has been provided in the reference section of this document.

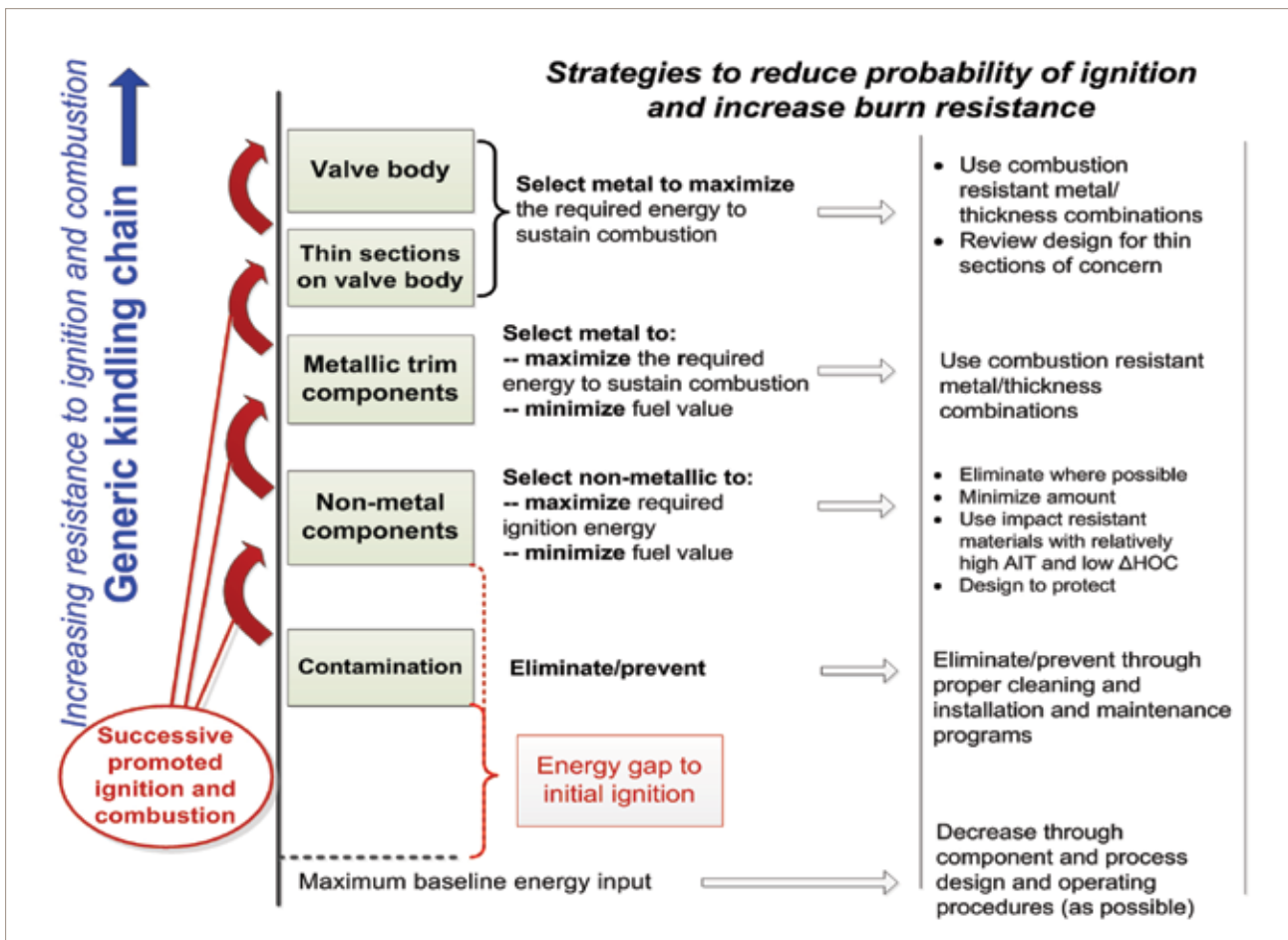


Figure 2: General approach for increasing resistance to ignition and combustion (Source: European Industrial Gases Association AISBL; Doc 200/15: The Safe Design, Manufacture, Installation, Operation and Maintenance of Valves Used in Liquid Oxygen and Cold Gaseous Oxygen Systems; 2015)

Oxidizer

As the process fluid oxygen concentration increases, it becomes a more aggressive oxidizer. At concentrations greater than 23.5%, many non-metals that typically are not combustible become flammable. At concentrations above 40%, metals become more susceptible to combustion. Oxygen also becomes a more aggressive oxidizer as the pressure and/ or temperature increases. Most materials, both metallic and non-metallic, will combust in 100% oxygen with elevated pressures.

Since it is not possible to remove the oxygen from an oxygen system, lowering the risk requires managing the other two legs of the fire triangle.



Figure 3:
Model of Argus™ FK76M ball valve that has been optimized for oxygen service

Fuels

Metals

Metals represent the largest portion of fuel in a typical oxygen system. If metals are ignited and combustion is sustained through the kindling chain, the resulting fire will likely breach pressure boundaries, potentially resulting in catastrophic damage. Metals adjacent to non-metals or in proximity to ignition sources present the greatest risk.

Copper, copper alloys and nickel alloys are preferred for pressure-containing parts and trim parts in contact with oxygen fluid streams. These materials are resistant to ignition and tend to self-extinguish if ignited when used at pressures below their highest no-burn pressure (see 13/12/E, exemption pressure). ASTM G124 test data can be used to compare the combustion resistance of various materials.

When materials are used at pressures above which they exhibit burn resistance, ignition mechanisms must be controlled to prevent potential catastrophic failure.

When materials are used at pressures above which they exhibit burn resistance, ignition mechanisms must be controlled to prevent potential catastrophic failure. System controls and/or engineered physical barriers should be used to manage the risk to personnel and equipment as a consequence of fire and/or explosion. For further information regarding metals compatibility, see relevant industry standards.

Non-Metals

Non-metals in oxygen valves include items like gaskets, packing and seals. Non-metal components require special consideration because they are easier to ignite than metals. When non-metals burn in oxygen-rich environments, the amount of energy (and the associated heat) released can be enough to ignite adjacent metals in a kindling chain reaction.

Non-metal components should be avoided where possible. When non-metals are required, they should be evaluated based on ignition mechanisms possible in the system, their oxygen compatibility based on published test data, and the properties of the adjacent materials. The goal is to minimize the risk of kindling chain fire propagation.

There are two predominant methods for determining compatibility of non-metals; these are discussed in ASTM G63 and ISO 21010 (DIN EN 1797:2002-02). The user must choose the governing standard based on regional preference, plant standards, local law or other factors. Both methods are valid and have different strengths.

The following test methods are used by ASTM and ISO to determine compatibility of non-metals:

- Autogenous Ignition Temperature (AIT)
 - See also: Spontaneous Ignition Test (SIT)
- Heat of Combustion (HOC)
- Oxygen Index (OI)
- GOX Pneumatic Impact
- LOX Mechanical Impact
- GOX Mechanical Impact

For details on how this testing is performed or to interpret the results, consult applicable industry standards.

European companies commonly require BAM-tested materials. BAM is a testing agency in Germany; evaluations are partially based on one of the approved methods in ISO 21010. Material requirements in the U.S. typically rely on ASTM G63 evaluation methods to determine compatibility.

The system designer/user is responsible for specifying the testing standards appropriate for their system.

Non-metal compatibility evaluation is a complex issue that is evolving within the industry. For GOX applications above 30 to 40 bar, selection of non-metal components is highly dependent upon the standard imposed. PTFE is common when ASTM G63 methods are imposed; PTFE or Graphite is common when using the method in ISO 21010:2014(E) Section 4.4.2.2.2. BAM ratings typically only allow Graphite-based materials at these pressures. The system designer/user is responsible for specifying the testing standards appropriate for their system.

Lubricants

Lubricants (greases) should only be used in oxygen valves when absolutely necessary. Lubrication may be needed to prevent galling, reduce friction and wear rates, assist in assembly and enhance sealing. Fluorinated lubricants are generally the best option when lubricants are required in oxygen service because they have the highest resistance to ignition. Silicone and hydrocarbon-based lubricants can be particularly hazardous due to their incompatibility in oxygen and should be avoided. When lubricant is required, it should be used sparingly.

Heat Sources

Localized sources of heat that can potentially ignite materials are ignition sources or ignition mechanisms in an oxygen system. A partial listing of some of these ignition sources follows.

In order for an ignition mechanism to be active, all characteristic elements must be present. A brief introduction to these “characteristic elements” follows in bullet-point format. For a complete summary of these elements, consult the industry references at the end of this document.

Particle Impact

Particles striking a material (typically metallic) with sufficient velocity can create localized heating of the particle and impacted material. Particle impact can be an efficient ignition mechanism for metals. Copper- and nickel-based alloys are more resistant to particle impact ignition.

- Particulate
- High velocities (> 30 m/s)
- Severe impact angles (45° to 90° are the most severe)
- Flammable target and particle

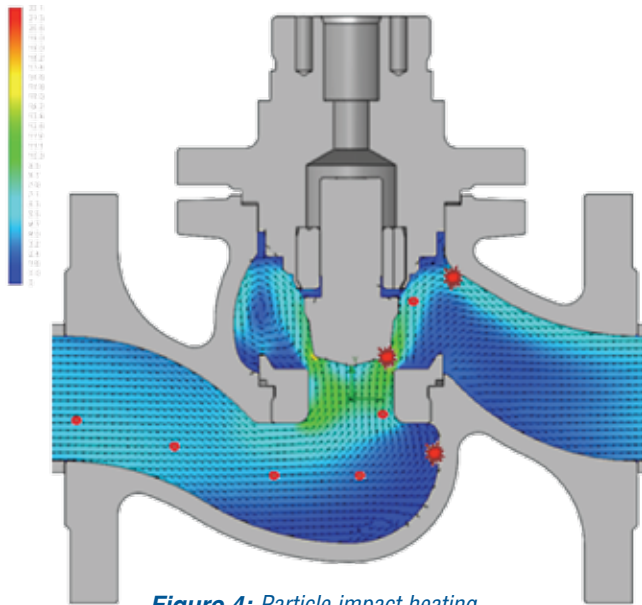


Figure 4: Particle impact heating

Mechanical Impact

Heat is generated from the transfer of kinetic energy when an object with a relatively large mass or momentum strikes a non-metal component or contaminant. The impact creates localized heating at the interface between the two impacting parts.

- Single, large impact or repeated impact loading
- Non-metal or contaminant at point of impact
- Special caution for impact on certain materials in LOX

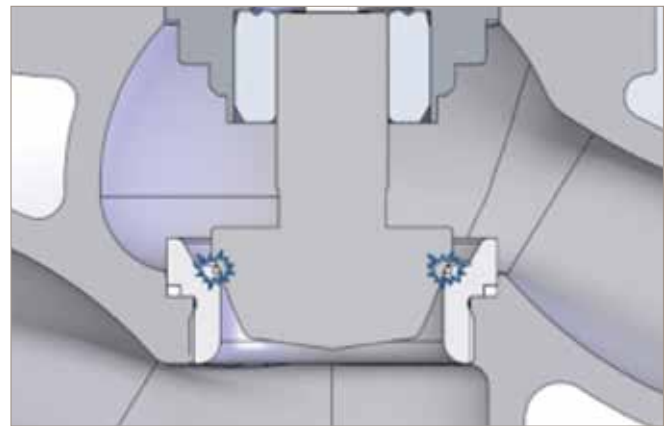


Figure 5: Example of soft seat adiabatic compression or mechanical impact heating

Galling and Friction

Adhesion between sliding surfaces or high loads with relative motion can produce an increase in localized heat. Friction affects both metallic and non-metallic materials and may occur due to improper material selection, poor design, or when gaps or clearances become reduced during operation. Particulate from the fluid stream getting jammed between close tolerance parts with relative motion can also produce galling and/or friction sufficient to cause an ignition.

- Two or more rubbing surfaces
- High speed and/or loads more severe
- One or more flammable rubbing surfaces (materials) or contaminants on these surfaces

Compression Heating

Compression heating occurs when gas is rapidly compressed from low to high pressure. Compression heating is the most efficient igniter of non-metals and contaminants.

- Pressure ratio
- Rapid pressurization
- Exposed non-metal or contaminant proximate to dead end

Example: A fast-opening valve can cause compression heating ignition when it releases high-pressure oxygen into a dead-end tube or pipe, which compresses the oxygen initially in the tube and causes heat of compression at the dead end.

Cleaning

Cleanliness is critical to safe operation of an oxygen system. The system and its components must be maintained to cleanliness levels that are consistent with the system design and potential ignition mechanisms present. See industry cleaning standards for applicable cleaning levels.

Get Expert Help

To ensure safe operation of a facility, final evaluation of the system and components should only be performed by professionals who are qualified and have knowledge of the system design, potential hazards of the system, operation of the system, and the Oxygen Hazards & Fire Risk Analysis (OHFRA or OCA) process.

When requested by the customer, applications that have been fully specified with regard to operating conditions can be reviewed by Flowserve against specified industry and/or customer standards. Applications in which the customer has not provided operating conditions cannot be reviewed by Flowserve. ASTM B16.34 or similar pressure ratings are not an indication of material oxygen compatibility. Flowserve can provide available oxygen compatibility test data upon customer request.

Material suitability and equipment design are dependent upon many factors. Knowledge of the system design, process conditions, system cleanliness, maintenance, operating procedures, etc., must be considered for a complete evaluation.

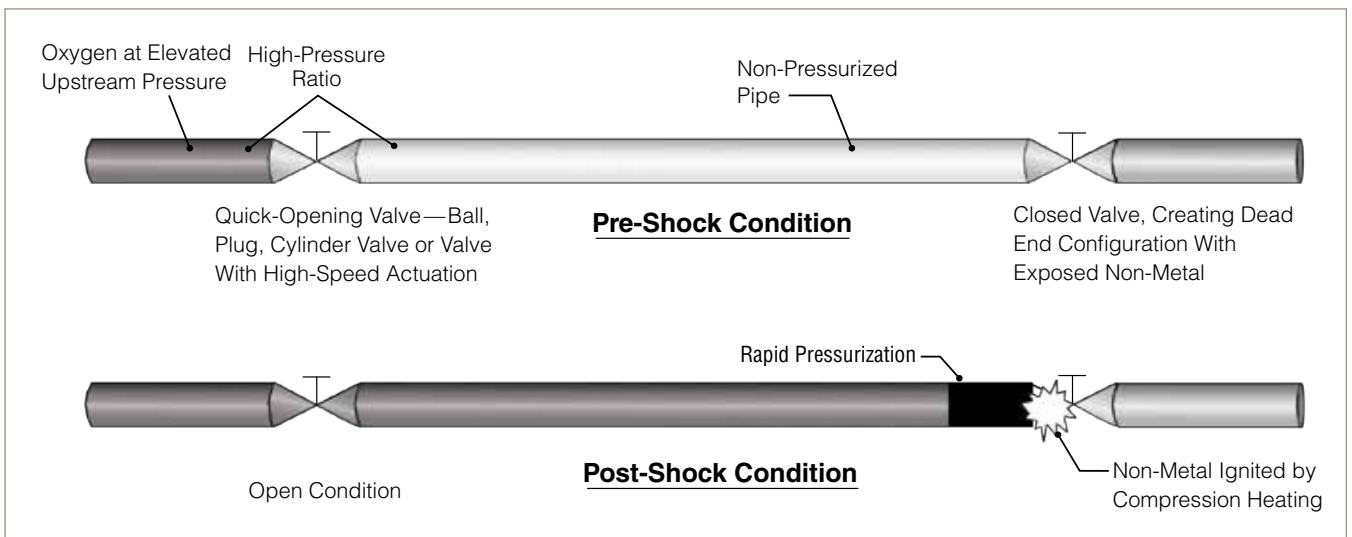


Figure 6: Compression heating of exposed non-metal

References

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 - a. ASTM MNL 36-2nd Edition Safe Use of Oxygen and Oxygen Systems: Handbook for Design, Operation, and Maintenance: 2nd Edition
 - b. ASTM G88-13 Standard Guide for Designing Systems for Oxygen Service
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 - d. EIGA/IGC DOC 200/17 Design, Manufacture, Installation, Operation, and Maintenance of Valves Used in Liquid Oxygen and Cold Gaseous Oxygen Systems
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 - b. EIGA/IGC DOC 33/06/E Cleaning of Equipment for Oxygen Service
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 - b. ASTM MNL 36-2nd Edition Safe Use of Oxygen and Oxygen Systems: Handbook for Design, Operation, and Maintenance: 2nd Edition
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 - e. ISO 10297:2006 Transportable Gas Cylinders — Cylinder Valves — Specification and Type Testing
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 - b. WHA International (575) 523-5623 <http://www.wha-international.com>
 - c. Air Liquide CTE <https://www.airliquide.com/connected-innovation/centers-expertise>
 - d. NASA
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 - c. ASTM STP 1197 “A Hazards Analysis Method for Oxygen Systems Including Several Case Studies”
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Flowserve Can Help

Still have questions? Let our Oxygen Valve Evaluation Team (OVET) help.

Flowserve's OVET refines the science of oxygen service by combining our extensive valve expertise, a long history of supplying valves for oxygen service in a variety of applications, and detailed collaboration with oxygen experts. Flowserve's globally available Oxygen Valve Evaluation Team is able to assist with valve configuration for your system design.

OVET highlights:

- Completed WHA International training; topics include:
 - Oxygen fire hazards
 - Maximize compatible materials
 - Minimize ignition mechanisms
 - Utilize best practices
 - Oxygen Hazards and Fire Risk Analysis (OHFRA)
- Industry oxygen standards and their application to our products
- Global regional expertise
- Material compatibility testing for unique materials
- Growing database of oxygen-suitable materials
- Extensive experience in air separation, aerospace, chemical and general industries

Contact Us

Flowserve is ready to collaborate with you on your next oxygen project.

To engage our OVET, contact your local Flowserve representation, which can be found by visiting <https://www.flowserve.com/en/contact-sales>



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