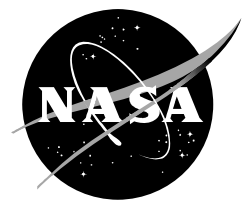


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Guide for Oxygen Compatibility Assessments on Oxygen Components and Systems

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March 2007

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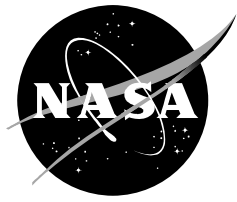
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Contents

1.0	Introduction	1
2.0	Requirement	1
3.0	Overview of Oxygen System Fire Hazards	1
3.1	Oxygen.....	1
3.2	Fuel	2
3.3	Ignition Source.....	2
4.0	Oxygen Compatibility Assessment Procedures.....	2
4.1	Determine the Worst-case Operating Conditions	2
4.2	Assess the Material Flammability.....	3
4.3	Evaluate the Presence and Probability of Ignition Mechanisms	4
4.3.1	Ignition Mechanisms	5
4.4	Determine the Kindling Chain	11
4.5	Analyze the Reaction Effect	11
4.6	Identify the History of Use.....	13
4.7	Report the Results of the Analysis.....	13
4.8	Hazard Control Table.....	13
5.0	References	17

Figures

1	Fire Triangle	1
2	Example of Cross-sectional Diagram of a Component.....	3
3	Particle Impact Ignition	5
4	Rapid Pressurization Ignition.....	6
5	Resonance Heating Ignition.....	8
6	Mechanical Impact Ignition	8
7	Friction Heating Ignition	9
8	Oxygen Compatibility Assessment Example.....	14
9	Oxygen Compatibility Assessment Example.....	15

Tables

1	Ignition Mechanisms.....	4
2	Ignition Mechanism Rating Logic	4
3	Reaction Effect Assessment.....	12
4	Hazard Control Table.....	15

ACRONYMS

ASTM	American Society for Testing and Materials
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1.0 INTRODUCTION

Understanding and preventing fire hazards is necessary when designing, maintaining, and operating oxygen systems. Ignition risks can be minimized by controlling heat sources and using materials that will not ignite or will not support burning in the end-use environment. Because certain materials are more susceptible to ignition in oxygen-enriched environments, a compatibility assessment should be performed before the component is introduced into an oxygen system. This document provides an overview of oxygen fire hazards and procedures that are consistent with the latest versions of American Society for Testing and Materials (ASTM) Standards G63 (1999) and G94 (2005) to address fire hazards associated with oxygen systems. This document supersedes the previous edition, NASA Technical Memorandum 104823, *Guide for Oxygen Hazards Analyses on Components and Systems* (1996). The step-by-step oxygen compatibility assessment method described herein (see Section 4) enables oxygen-system designers, system engineers, and facility managers to determine areas of concern with respect to oxygen compatibility and, ultimately, prevent damage to a system or injury to personnel.

2.0 REQUIREMENT

An oxygen compatibility assessment as required by NASA-STD-6001 and NASA-STD-6016 shall be performed on each component per the procedure described in Section 4 of this document.

3.0 OVERVIEW OF OXYGEN SYSTEM FIRE HAZARDS

Fires occur in oxygen systems when oxygen, fuel, and heat, combine to create a self-sustaining chemical reaction (Figure 1). Although oxygen, fuel, and ignition source are present in almost all oxygen systems, fire hazards can be mitigated by limiting the propensity for a chemical reaction to occur. Controlling the risk factors associated with the oxygen, fuel, or heat in turn, will prevent the chemical reaction.

3.1 Oxygen

Oxygen pressure and concentration have significant effects on the flammability and ignitability of materials. In general, materials are easier to ignite and burn more readily as oxygen pressure or concentration increase. Hence, oxygen systems should be operated at the lowest possible pressure and oxygen concentration. Limiting either the oxygen pressure or concentration may be sufficient to ensure that ignition and burning do not occur.

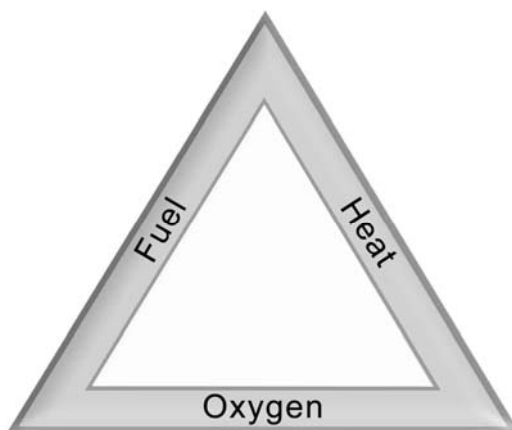


Figure 1
Fire Triangle

3.2 Fuel

Fuel sources can be reduced by appropriate materials selection. Some materials are more difficult to ignite than others. Additionally, some materials when ignited are more resistant to sustained burning than others. Materials also vary in the amount of energy they release when they burn. Selecting ignition and burn-resistant materials can, in some cases, eliminate the possibility of a fire occurring or reduce the damage caused by a fire.

3.3 Ignition Source

Despite the fact that heat sources are inherent in the operation of an oxygen system, the ability to initiate the chemical reaction between the system materials and oxygen can be limited by controlling or eliminating the ability of those heat sources to cause ignition. Carefully selected design features can limit or dissipate the heat generated within an oxygen system. If the temperatures generated by the ignition sources within the system or introduced into the system from external heat sources are below the ignition temperatures of the system materials, ignition cannot occur. The oxygen system shall also be protected from external heat sources.

4.0 OXYGEN COMPATIBILITY ASSESSMENT PROCEDURES

The oxygen compatibility assessment process provides a systematic approach for identifying and addressing the fire hazards in an oxygen system. The primary goal of the oxygen compatibility assessment process is to reduce the likelihood of a fire occurring in an oxygen system or component. The necessity for conducting an oxygen compatibility assessment is directly tied to minimizing the risk of fire and the potential effects of a fire on personnel and system. The oxygen compatibility assessment process may be used as either a design guide or as an approval process for components and systems. **The required oxygen compatibility assessment procedure is:**

1. **Determine the worst-case operating conditions**
2. **Assess the flammability of system materials**
3. **Evaluate the presence and probability of ignition mechanisms**
4. **Determine the kindling chain, which is the potential for a fire to breach the system**
5. **Analyze the reaction effect, which is the potential loss of life, mission, and system functionality as the result of a fire**
6. **Identify the history of use**
7. **Report the results of the analysis**

4.1 Determine the Worst-case Operating Conditions

The worst-case operating environment shall be determined to facilitate the evaluation of the ignition and flammability risks for a component or system. Increased oxygen concentration, temperatures, pressures, flow rates, and contamination can intensify flammability and ignition risks. Therefore, quantifying each of these conditions is a prerequisite of analyzing a system or component. **The analyst shall consult the responsible Materials and Processes organization to verify the worst-case operating environment.** Reliance on procedural controls to regulate the conditions within the oxygen systems should be minimized. A Failure Modes and Effects Analysis may be used to determine the worst-case operating conditions. **In addition, the analyst shall determine the worst-case cleanliness level of each component.**

4.2 Assess the Material Flammability

The flammability of the materials of construction shall be determined. The configuration of a system or component significantly influences the ignitability and flammability of the materials of construction. For instance, metals, including those that normally exhibit high resistance to ignition, are more flammable in oxygen when they have thin cross-sections (e.g., thin-walled tubing) or when they are finely divided (e.g., wire mesh or sintered filters). **Therefore when assessing flammability, a system flow schematic and a cross-sectional diagram (e.g., machined cut-away) of each component that shows the configuration and materials of construction (Figure 2) shall be used. The flow schematic of the system and cross-sectional diagrams of each component shall be included in the report.**

With few exceptions, materials become more flammable in oxygen as pressures increase. This includes metals, plastics, elastomers, lubricants, and contaminants. In fact, nearly all polymer materials are flammable in 100 percent oxygen at atmospheric pressure. Several test methods, such as promoted ignition and oxygen index, have been developed to determine the relative flammability of metals and nonmetals. The NASA Materials and Processes Technical Information System and latest versions of ASTM Manual 36 (2000), Standard G63 (1999), and Standard G94 (2005) provide test data for determining material flammability.

The designer of an oxygen system or component shall consult the appropriate Materials and Processes organization to ensure that the testing data used to make flammability assessments are applicable to the specific design configuration. Unfortunately, material flammability is affected by many factors and, therefore, absolute flammability thresholds are difficult to establish without testing the actual use configuration. As such, much of the oxygen compatibility assessment process focuses on the presence and probability of ignition mechanisms (see Section 4.3).

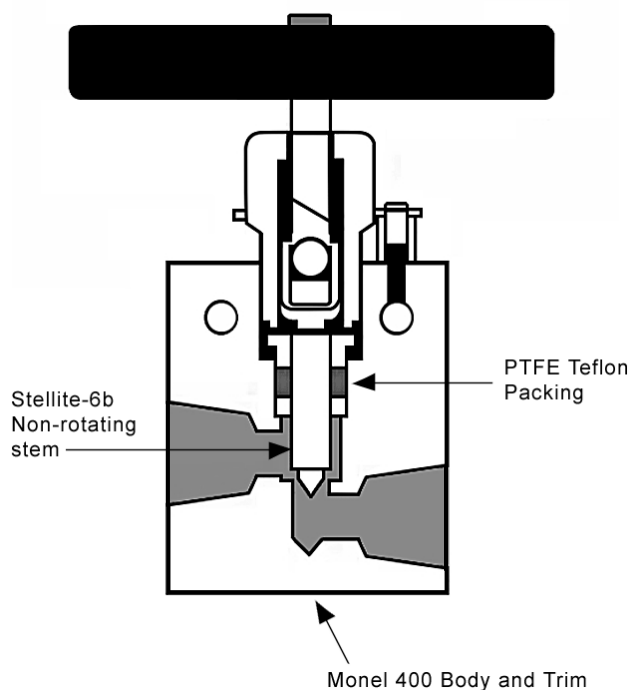


Figure 2
Example of Cross-sectional Diagram of a Component

4.3 Evaluate the Presence and Probability of Ignition Mechanisms

The presence and relative probability of ignition mechanisms shall be determined. An ignition mechanism is simply a source of heat that under the right conditions can lead to ignition of the materials of construction or contaminants in a system. The most effective way to analyze the ignition risks in a system is to methodically analyze the system for known ignition mechanisms (Table 1). **The designer of an oxygen system or component shall consult the appropriate Materials and Processes organization to ensure that the testing data used to make ignitability assessments are applicable to the specific design configuration.**

For ignition mechanisms to be effective, certain elements must be present. These characteristic elements are unique for each ignition mechanism, and each element is necessary for an ignition to occur. If any characteristic element is not present, the ignition mechanism is unlikely to occur. Conversely, if all the characteristic elements are present, ignition is possible. Ignition mechanisms are rated using the ignition mechanism rating logic in Table 2. This logic takes into consideration both the presence of a mechanism's characteristic elements and flammability of materials as discussed in section 4.2. If the flammability of a material is unknown, or the materials of construction have not been selected, then the material should be considered flammable for the purposes of assessing the ignition mechanisms.

Table 1
Ignition Mechanisms

Particle Impact	Lightning
Rapid Pressurization	Explosive Charges
Flow Friction ^a	Personnel Smoking and Open Flames
Resonance	Fragments from Bursting Vessels
Mechanical Impact	Welding
Galling and Friction	Engine Exhaust
Fresh Metal exposure	Static Discharge
Electrical Arc	Chemical Reaction
Thermal Runaway	

^a Theoretical only: No current test method exists to duplicate flow friction in the laboratory.

Table 2
Ignition Mechanism Rating Logic

Ignition Rating	Code	Criteria	
		Characteristic Elements	Material Flammability
Not Possible	0	Not all present	Nonflammable
Remotely Possible	1	All present or Not all present	Nonflammable
Possible	2	All present and active	Flammable
Probable	3	All present and some are strongly active	Flammable
Highly Probable	4	All are present and all are strongly active	Flammable

4.3.1 Ignition Mechanisms

Particle Impact — Heat generated when small particles strike a material with sufficient velocity to ignite the particle and/or the material.

Particle impact is a very effective ignition mechanism for metals, but less likely to ignite nonmetals unless they are very hard. The characteristic elements necessary for ignition by particle impact are:

- particles that can be entrained in the flowing oxygen;
- gas velocities, typically greater than approximately 30 m/s (100 ft/s) (ASTM STP 986); and
- an impact point ranging from 45 degrees to perpendicular to the path of the particle.^{a,b}

Test data show that, in most cases, the particulate must be flammable to produce ignition of the target material. However, some highly reactive materials, such as aluminum and titanium, can be ignited when impacted by inert particles.

Example: Assembly-generated particles traveling at high velocities can cause particle impact ignition by striking the body just downstream of the control element of a valve (Figure 3).

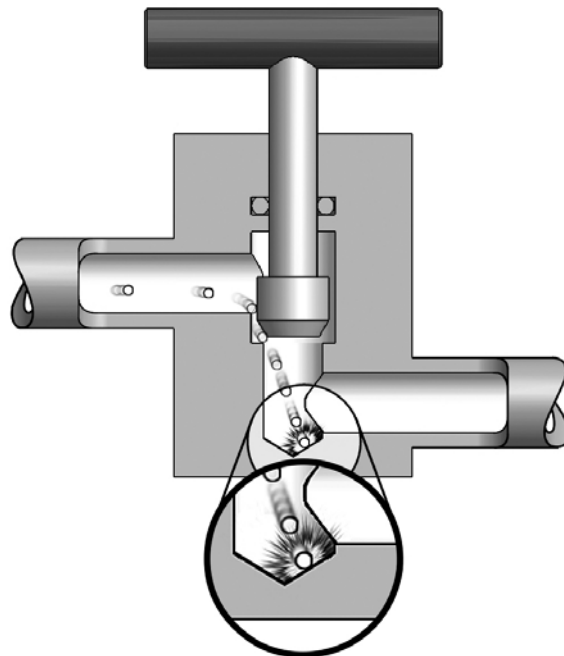


Figure 3
Particle Impact Ignition

^a This was concluded from tests conducted using test fixtures that simulated the configuration of the Space Shuttle Type II Main Propulsion System oxygen flow control valve. The Type II test fixtures were fabricated from Inconel 718 with drill points downstream the flow control orifice similar to the actual valve and with drill points removed. The tests were performed at the same conditions and using the same particle mixture that ignited and burned the Type II oxygen flow control valve during certification testing. The test conditions were as follows: 600 K oxygen temperature, 4600 psig oxygen pressure, and 10 mg of a particle mixture consisting of 26 percent Inconel 718, 29 percent 21-6-9 stainless steel, and 45 percent aluminum 2219 by weight. The Type II Inconel 718 test fixture that contained the drill point ignited and burned on the second test. The Type II Inconel 718 test fixture in which the drill points were removed resulting in an impact angle of 45 ° did not ignite or burn when subjected to 40 tests. [The Space Shuttle flow control valve was subsequently redesigned.]

^b Benz, F. *Summary of Testing on Metals and Alloys in Oxygen at the NASA White Sands Test Facility (WSTF) During the Last 6 Months*. In RF/DLPippen:kp:09/14/88:5722, *WSTF Metals Work Memo*, from David Pippen to Director of Materials and Processes Laboratory at George C. Marshall Space Flight Center, September 15, 1988.

Data: Particle impact data for metals and nonmetals are located in the latest versions of ASTM Manual 36 (2000) and Standard G94 (2005). In general, copper and nickel-based alloys are resistant to ignition by particle impact. Hard polymers have been ignited in particle impact tests, but limited data exist.

Rapid Pressurization — Heat generated when a gas is rapidly compressed from a low pressure to a high pressure. This ignition mechanism is also known as heat of compression or adiabatic compression.

Rapid pressurization ignition is the most effective igniter of nonmetals, but does not ignite bulk metals. The characteristic elements for rapid pressurization ignition are:

- rapid pressurization, generally occurring in less than 1 s;
- an exposed nonmetal close to the rapidly pressurized dead-end; and
- a pressure ratio that causes the maximum temperature from compression to exceed the situational auto-ignition temperature of the nonmetal.

The maximum theoretical temperature from compression can be calculated using the following equation:

$$\frac{T_f}{T_i} = \left(\frac{P_f}{P_i} \right)^{\frac{(n-1)}{n}}$$

Where:

T_f = final temperature (absolute),
 T_i = initial temperature (absolute),
 P_f = final pressure (absolute),
 P_i = initial pressure (absolute),
 N = ratio of specific heats (1.4 for oxygen).

The actual maximum temperature is inevitably appreciably lower than the maximum theoretical temperature.

Example: Fast-opening valve that releases high-pressure oxygen into a dead-end tube or pipe compresses the oxygen initially in the tube and causes rapid pressurization heating at the dead end (Figure 4).

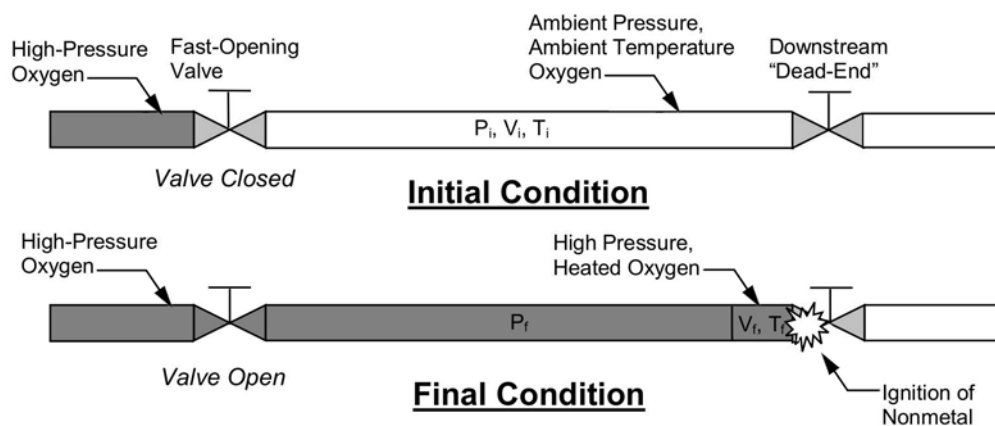


Figure 4
Rapid Pressurization Ignition

Data: Auto-ignition temperature data for nonmetals are found in the latest versions of ASTM Manual 36 (2000) and Standard G63 (1999). Extensive testing in a system consistent with ASTM G74 has demonstrated that for initial upstream pressures less than 275 psia and an initial downstream pressure of ambient or above, the actual temperature rise (with real heat loss) is too small for ignition to occur.

Flow Friction — Heat generated when oxygen flows across a polymer and produces erosion, friction, and/or vibration. Flow friction is a theoretical ignition mechanism, but current theory suggests that the characteristic elements for flow friction ignition include:

- nonmetal exposed to flow; and
- flow that produces a vibration in the nonmetal.

Note: Surfaces of nonmetals that are highly fibrous from being chafed, abraded, eroded, or plastically deformed may render flow friction heating affects more severe.

Examples: A leak past a polymer seal may cause flow friction ignition. This could occur when throttling flow through an oxygen cylinder valve with a nonmetal seat that has been damaged due to extensive cycling.

Note: Although this ignition mechanism is poorly understood, it has caused a significant number of real-life fires.

Resonance — Acoustic oscillations within resonant cavities that cause rapid temperature rise. The characteristic elements for resonance ignition include:

- a favorable system geometry, which includes a throttling device (e.g., nozzle, orifice, regulator, or valve) directing a sonic gas jet into a cavity or closed-end tube (Figure 5);
- acoustic resonance (often audible) and
- flammable materials in the area of the resonance.

The distance between the throttling device and the closed end affects the frequency of acoustic oscillations in the cavity due to the interference of incident and reflecting sound waves. The distance also affects the temperature produced in the cavity. Higher harmonic frequencies have been shown to produce higher system temperatures. The resonant frequency has been shown to be a function of pipe diameter and pressure ratio ($f(D, P/Pa)$).

Flammable materials residing at or near the closed end of the cavity can self-ignite due to the high gas temperatures produced by resonance heating. Alternatively particulate or debris can vibrate, causing collisions that generate sufficient heat to self-ignite.

Examples: A capped tee fitting downstream of a valve or orifice, similar to Figure 5, can lead to resonance ignition. Resonance is also used as an igniter for solid or liquid rocket fuel: gaseous oxygen flows through a sonic nozzle and directly into a resonance cavity, heating the gas and solid or liquid fuel. When the gas reaches the auto-ignition temperature of the fuel, ignition occurs and a flame jet is emitted from the chamber.

Mechanical Impact — Heat generated due to single or repeated impacts on a material with sufficient energy to ignite it. Most metals cannot be ignited by mechanical impact; however, nonmetals are susceptible to ignition by mechanical impact. The characteristic elements for mechanical impact ignition are:

- a single, large impact or repeated impacts; and
- a nonmetal or reactive metal at the point of impact.

Some components, such as check valves, regulators and relief valves, may become unstable and “chatter” during use. Chattering can result in multiple impacts in rapid succession on polymer poppets or seats within these components, creating a mechanical impact ignition hazard. The presence of liquid oxygen (instead of gaseous oxygen) may cause some porous materials to become dramatically more sensitive to mechanical impact.

Example: A wrench dropping onto a porous hydrocarbon (e.g., asphalt) soaked with liquid oxygen could cause mechanical impact ignition (Figure 6).

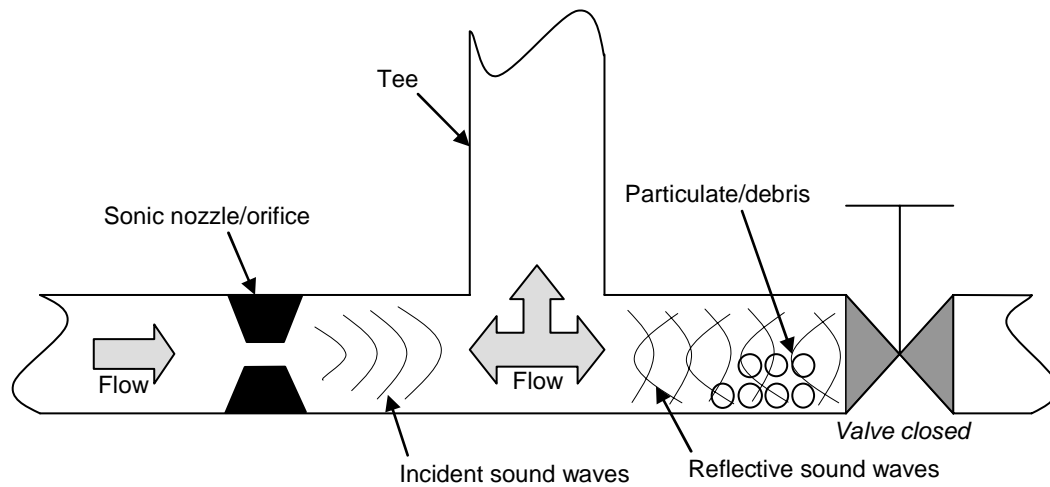


Figure 5
Resonance Heating Ignition

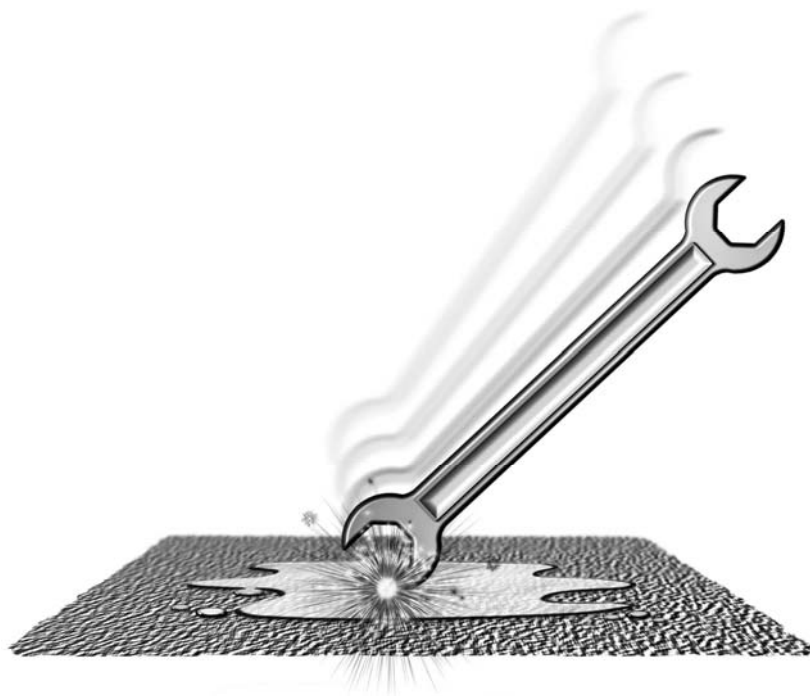


Figure 6
Mechanical Impact Ignition

Data: Most metals are not susceptible to ignition by mechanical impact. However, data has shown that aluminum, magnesium, titanium, and lithium-based alloys, as well as some lead-containing solders, can be ignited by mechanical impact. Mechanical impact ignition data for nonmetals are found in the latest versions of ASTM Manual 36 (2000) and Standard G63 (1999).

Galling and Friction — Heat generated by the rubbing of two or more parts together. The characteristic elements for frictional ignition are:

- two or more rubbing surfaces, generally metal-to-metal;
- rapid relative motion; and
- high loads pressing the rubbing parts together.

Data from ASTM Manual 36 (2000) indicate that metals, not polymers, are most susceptible to ignition by friction in the frictional heating tests currently available. Research indicates that polymers may also be susceptible to ignition in certain conditions. Some components, such as check valves, regulators, and relief valves, may become unstable and “chatter” during use. Chattering can result in rapid oscillation of the moving parts within these components, creating a frictional ignition hazard.

Example: Damaged or worn soft goods resulting in metal-to-metal rubbing between the piston and the cylinder of a reciprocating compressor (Figure 7) could lead to frictional ignition.

Data: Frictional heating data for various pairings of materials is located in the latest versions of ASTM Manual 36 (2000) and Standard G94 (2005).

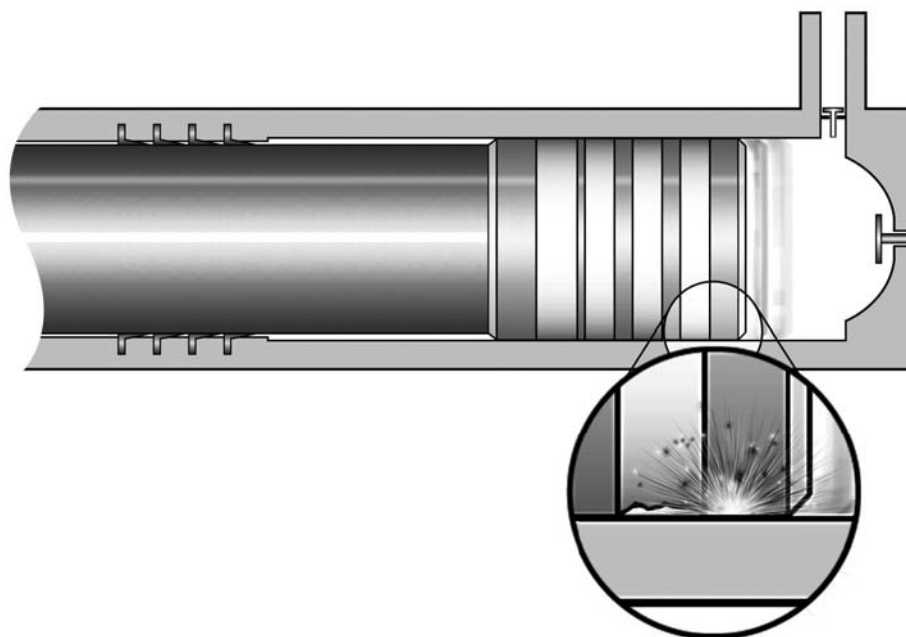


Figure 7
Friction Heating Ignition

Fresh Metal Exposure — the heat of oxidation released when unoxidized metal is exposed to an oxidizing atmosphere.

This ignition mechanism usually acts in conjunction with other ignition mechanisms, such as frictional heating or particle impact, which damage metal surfaces. This ignition mechanism may also be present with a fracture or tensile failure of an oxygen-wetted pressure vessel. The characteristic elements for fresh metal exposure ignition are:

- metal that oxidizes quickly and has a high heat of formation for its oxides, such as aluminum and titanium alloys;
- destruction or rapid removal of oxide layer; and
- configuration that minimizes heat loss.

Static Discharge — Discharge of accumulated static charge with enough energy to ignite the material receiving the charge. The characteristic elements for static discharge are:

- static charge buildup from flow or rubbing accumulated on an electrically isolated surface; and
- discharge point between materials, generally with differing electrical potentials.

Generally, two charged surfaces are not as likely to arc unless one material is conductive. Static discharge ignition is most likely to occur in dry gas environments.

Examples: Static charge accumulation due to dry oxygen flow through polymer hoses can lead to static discharge. Bed sheets in hyperbaric chambers can be ignited by static discharge.

Electrical Arc — Sufficient electrical current arcing from a power source with enough energy to ignite the material receiving the arc. The characteristic elements necessary for ignition by electrical arc are:

- an electrical power source;
- an arc with sufficient energy to melt or vaporize materials; and
- flammable material exposed to heating from the arc.

Example: A defective pressure switch could cause ignition when it arcs to a flammable material. An insulated electrical heater element undergoing a short circuit could produce ignition by arcing through its sheath to a combustible material.

Chemical Reaction — A reaction of a combination of chemicals that could release sufficient heat energy to ignite the surrounding materials.

The characteristic elements for chemical reaction ignition depend on the reactants involved. For example, some mixtures may be self-igniting while others need an external heat source. In oxygen-hydrogen mixtures, the ignition energy is so low that it is assumed that energies released from mixing will ignite the mixture.

Examples: Oxygen reacting with the palladium getter in a vacuum-jacketed vessel produces ignition. Hydrogen leaking into the oxygen section of an oxygen-hydrogen fuel cell system can produce a chemical reaction ignition. A heat-producing chemical reaction can occur when aluminum is sheared in the presence of polychlorotrifluoroethylene (PCTFE).

Thermal Runaway — some materials, notably certain accumulations of fines, porous materials, or liquids, may undergo self-sustained reactions that generate heat.

If the rate of heating compared to the rate of dissipation is unfavorable, the material will increase in temperature. In some cases, a thermal runaway may be attained and some time later the material may spontaneously ignite. Ignition and fire may occur after short time periods (seconds or minutes) or over long time periods (hours, days, or months). In the most extreme cases, the thermal runaway temperature may be near or below normal room temperature. The characteristic elements for thermal runaway ignition include:

- a material with a high surface-area-to-volume ratio (e.g., dusts, particles, foams, chars, etc.) that reacts exothermically (e.g., oxidation or decomposition) at temperatures significantly below its ignition temperature and
- an environment that does not adequately dissipate heat (e.g., an insulated or large volume vessel or an accumulation of fines).

Examples: Ignition could occur due to an accumulation of small particulate generated by rubbing and abrasion in an oxygen compressor that has been proof-tested with nitrogen gas and is then exposed to oxygen. Contaminated adsorbent or absorbent materials, such as molecular sieves (zeolites), alumina, and activated carbon, may become highly reactive in oxygen-enriched atmospheres.

Other—Potential ignition sources to consider should initially include any external heat sources. Many of the potential sources of heat are self-explanatory and include: lightning, explosive charges, personnel smoking and open flames, fragments from bursting vessels, welding, and exhaust from combustion engines.

4.4 Determine the Kindling Chain

The ability of a fire to propagate and burn through a component, i.e., the kindling chain, shall be evaluated. Kindling chain begins when a material is ignited, and the material's heat of combustion is sufficient to heat and ignite the surrounding materials leading to a burn-through of the component. A burn-through is considered unlikely when the materials are nonflammable or an unfavorable ignition configuration is present. A burn-through is considered likely when most materials (including the body) are flammable and a favorable ignition configuration is present.

An example of a component with a possible kindling chain could be a manual valve with a polysulfone seat and a stainless steel stem and body. In this configuration and at high pressures, the seat, stem and body are flammable. If the polysulfone seat were ignited (e.g., by flow friction or rapid pressurization) enough energy could be released to ignite and burn the stem, which could then ignite the body and result in a burn-through of the manual valve. The analyst should assess the kindling chain based on the presence of ignition mechanisms and the ability of the materials of construction to contain a fire. If a component could be breached, a kindling chain is present.

4.5 Analyze the Reaction Effect

The reaction effect shall be determined. The effects of a fire on personnel, mission, and system objectives are assessed by determining the reaction effect. This value is primarily assigned based on the presence of a kindling chain and the potential consequences of a fire. The potential consequences of a fire are based on the extent of fire propagation in the materials that surround the component. A guide for rating the reaction effect for a system can be found in Table 3. The example column in Table 3 demonstrates how reaction effect ratings can be applied.

Table 3
Reaction Effect Assessment

Rating	Code	Effect on Personnel Safety	System Objectives	Functional Capability	Example
Negligible	A	No injury to personnel	No unacceptable effect on production, storage, transportation, or use as applicable	No unacceptable damage to the system	There is no personnel access, kindling chain, or ignition probability greater than 0.
Marginal	B	Personnel-injuring factors can be controlled by automatic devices, or warning devices, or special operating procedures	Production, storage, transportation, or use as applicable is possible by utilizing available redundant operational options	No more than one component or subsystem damaged. This condition is either repairable or replaceable within an acceptable time frame on site	There is a kindling chain and ignition probabilities are greater than 0. In addition, access to the area is controlled in a formally documented procedure and barricades are used.
Critical	C	Personnel may be injured (1) operating the system, (2) maintaining the system, or (3) by being in the vicinity of the system	Production, storage, transportation, or use as applicable impaired seriously	Two or more major subsystems are damaged—This condition requires extensive maintenance	There is a kindling chain and ignition probabilities are greater than 0. In addition, access is limited by a shield or distance, but there are no formal access procedures or barricades used
Catastrophic	D	Personnel suffer death or multiple injuries	Production, storage, transportation, or use as applicable rendered impossible—major unit is lost	No portion of system can be salvaged—total loss	There is a kindling chain, ignition probabilities are greater than 0, and direct exposure is required for operation.

For example, a manually operated regulator constructed of nonflammable materials with a viable ignition mechanism and the absence of a kindling chain would be assigned “negligible.” The same regulator with a kindling chain would be given a higher reaction effect rating of “catastrophic” because personnel could be injured or killed if the regulator failed. Because it is difficult to conceive all possible fire scenarios resulting in injury, reaction effect ratings are often applied conservatively, which means the worst-case scenario drives the reaction effect assessment.

4.6 Identify the History of Use

The relevant history of use shall be evaluated. The history of use is determined by whether the component has experienced routine operation/cycling in similar or more severe conditions over an extended period of time. History of use is assigned a rating of either (+) successful, (-) negative, or (?) unknown. For example, if a valve has been used in similar or more severe conditions over a period of time then the component may be given a (+) to indicate a successful history of use.

4.7 Report the Results of the Analysis

The results of the compatibility assessment shall be documented. An oxygen compatibility assessment report can facilitate the communication and dissemination of the results to interested parties and record the findings for future reference. The oxygen compatibility assessment report may also recommend changes to design, materials, and procedures in order to mitigate the fire hazards identified.

Figures 8 and 9 provide an example of an oxygen compatibility assessment showing the complete analysis of a single component. Complete and thorough information is extremely beneficial in communicating the findings of the assessment. Whenever possible, references to the data used in determining the various ratings should be included. Pictures, drawings, and schematics of the component should also be referenced and included in the final report.

A system-level oxygen compatibility assessment should contain the compatibility assessment charts and drawings for each component in the system. A system description and flow schematic should also be included in the final report. A concise listing of the most severe hazards and suggested mitigations for those same hazards **shall be included in the oxygen compatibility assessment report.**

Once prepared, the report should be reviewed by other analysts to obtain consensus. Comments and feedback should be considered when finalizing the report. After a final review, the report should be archived and transmitted to the customer.

4.8 Hazard Control Table

Each component should be listed in a table in order of decreasing reaction effect rating similar to Table 4. The table records the component, schematic reference, ignition hazard, initial ignition mechanism rating, reaction effect, recommendations to control that ignition mechanism, and the resulting ignition mechanism rating after the recommendation has been implemented. Such a table is needed for displaying the hazards determined by the oxygen compatibility assessment as well as the current status of the recommendations.

Component Information**Component Type:** Manual Valve**Source:****Description:****Model:****Environment Information****Max Pressure:** 2450 psig**Max Temperature:** 115 °F**Cleanliness Spec:** NASA JPR 5322.1**Particulate Level:** 100**NVR Level:** A**Schematic Reference(s)**

HV-7AO2-23

ChemicalO₂**State**

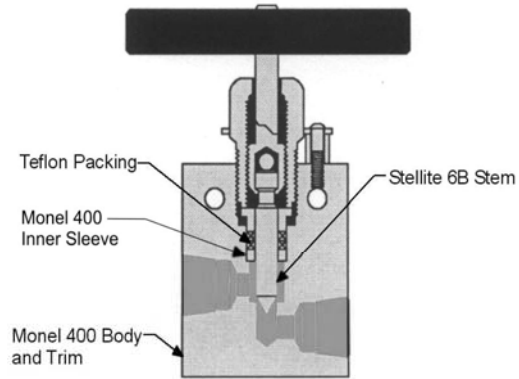
Gas

Percent

100

Notes/Recommendations:

Notes/Recommendations:

**Material Flammability**

<u>Part</u>	<u>Category</u>	<u>Material</u>	<u>Flammability</u>	<u>Notes/Recommendations</u>
Stem	Metal	Haynes 6B Stellite	F	Stellite 6B is flammable as a 1/8 in. rod in 100% oxygen at pressures above 2500 psia (ASTM STP 986, pp. 28-53). Note: the threshold pressure has not been found but is known to be between 1000 and 2500 psia.
Trim	Metal	Monel 400	F	Thin cross sections of Monel are flammable in 100% oxygen at ambient pressure (ASTM STP 1040, pp. 178-194).
Inner Sleeve	Metal	Monel 400	F	Thin cross sections of Monel are flammable in 100% oxygen at ambient pressure (ASTM STP 1040, pp. 178-194).
Packing	Soft Good	Teflon	F	Teflon (PTFE) is flammable in 100% oxygen at ambient pressure (ASTM STP 812, pp. 56-67).
Body	Metal	Monel 400	N	Monel is nonflammable as a 1/8-in. rod in 100% oxygen at pressures up to 10,000 psia (ASTM STP 1040, pp. 54-75).

Figure 8**Oxygen Compatibility Assessment Example**

(Note: Example only; data and ratings may not be accurate or current.)

Ignition Hazard

<u>Hazard Type</u>	<u>Ignition Hazard</u>	<u>Notes/Recommendations</u>
Flow Friction	1	In this component, the seals are well-supported and unlikely to be damaged. However, the pressure is high. Therefore ignition by flow friction is considered remotely possible. It is recommended to promptly repair leaks or to replace components that persistently leak.
Frictional Heating	0	Friction is present as the stem moves inside the housing. However, the frictional forces are low due to low side loads and the forces needed to produce ignition are not present. Therefore, ignition due to frictional heating is considered not possible.
Particle Impact	0	High velocities will exist in this component at the stem/seal opening. The Monel body is nonflammable; however the Stellite stem is flammable in these conditions. This valve is located downstream of a 20 micron filter, which limits the size and amount of particles that may enter this valve. In addition, any impacts on the stem would be at oblique angles. Therefore, ignition due to particle impact is considered not possible.
Rapid Pressurization	0	This valve has a metal-to-metal seat, the soft goods are well-protected, and this component is not the only dead end.

Reaction Effect

<u>Reaction Effect</u>	<u>Notes/Recommendations</u>
A	There is a credible ignition mechanism present. However, there is no kindling chain present to cause component burn through since the body material is nonflammable. Therefore, reaction effect is considered negligible.

History of Use

<u>History of Use</u>	<u>Notes/Recommendations</u>
+	Similar components have a successful history of use at WSTF.

Figure 9

Oxygen Compatibility Assessment Example

(Note: Example only; data and ratings may not be accurate or current.)

Table 4
Hazard Control Table

Component	Schematic Reference	Ignition Hazard	Probability Rating	Reaction Effect	Recommendation	Mitigated Reaction Effect	Status
Manual Valve	Dwg #	Particle Impact	4	D	Change valve body from stainless steel to Monel.	A	

0 = Not Possible

1 = Remotely Possible

2 = Possible

3 = Probable

4 = Highly Probable

5.0 REFERENCES

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13. ABSTRACT (Maximum 200 words) Understanding and preventing fire hazards is necessary when designing, maintaining, and operating oxygen systems. Ignition risks can be minimized by controlling heat sources and using materials that will not ignite or will not support burning in the end-use environment. Because certain materials are more susceptible to ignition in oxygen-enriched environments, a compatibility assessment should be performed before the component is introduced into an oxygen system. This document provides an overview of oxygen fire hazards and procedures that are consistent with the latest versions of American Society for Testing and Materials (ASTM) Standards G63 (1999) and G94 (2005) to address fire hazards associated with oxygen systems. This document supersedes the previous edition, NASA Technical Memorandum 104823, Guide for Oxygen Hazards Analyses on Components and Systems (1996). The step-by-step oxygen compatibility assessment method described herein (see Section 4) enables oxygen-system designers, system engineers, and facility managers to determine areas of concern with respect to oxygen compatibility and, ultimately, prevent damage to a system or injury to personnel.				
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