The Report of the Committee on Oxygen-Enriched Atmospheres is presented for adoption.


NFPA 53M is being redesignated NFPA53 and the word Manual is being changed to Guide in accordance with a directive of the NFPA Standards Council withdrawing Manuals.

This Report has been submitted to letter ballot of the Technical Committee on Oxygen-Enriched Atmospheres, which consists of 13 voting members: of whom 12 voted affirmatively, 1 voted negatively on one proposal (Mr. Ledoux), and 1 ballot was not returned (Mr. Chappee). The Committee member who voted negatively, and his reason for so voting follows:

Proposal 53-40 (5-3.3.8(new)) [Log #CP19]

Mr. Ledoux: Negative. New par. 5-3.3.8 on Oxygen Index (OI) needs a warning note, such as the following: "The Oxygen Index should be used as a material ranking and not an absolute number. For example, a material with an Oxygen Index of 30 will normally burn in a 30% oxygen atmosphere." There are many people who use the Oxygen Index was an absolute number. They believe that any material with an Oxygen Index equal to or greater than the oxygen concentration they are using, the material is safe. This is not the case, for example Nylon, which has an OI of 30 will burn readily in air.

I think that people would be cautioned about using the OI data. The OI is an excellent test to rank the relative flammability hazard of various material, but should not be used as an absolute number.
NFPA 53—F93TCR

53-1. (Entire document): Accept
SUBMITTER: Technical Committee on Oxygen-Enriched Atmospheres.
RECOMMENDATION: Make metric units primary, and English units secondary and place in brackets.
SUBSTANTIATION: Metric units are becoming more the standard reference units.
COMMITTEE ACTION: Accept.

53-2. (1-1): Accept
SUBMITTER: Technical Committee on Oxygen-Enriched Atmospheres.
RECOMMENDATION: In par. one, sentence one, delete "Inasmuch as", and delete the phrase "that occurs in the vapor phase". Sentence one would read as follows: "The phenomenon known as "fire" is a chemical reaction between a fuel and oxygen." Begin new sentence two with "The ignition..." [rest the same]
SUBSTANTIATION: Current statement is incorrect; phrase is too inclusive. Metals burn in a liquid stage.
COMMITTEE ACTION: Accept.

53-3. (1-2): Accept
SUBMITTER: Technical Committee on Oxygen-Enriched Atmospheres.
RECOMMENDATION: 1. Make sentence two a NOTE under definition. ("Oxygen comprises...")
2. Delete sentence three. ("When used in...")
SUBSTANTIATION: 1. Sentence two is informational only.
2. Sentence three is outside the definition of the term oxygen.
COMMITTEE ACTION: Accept.

53-4. (1-2): Accept
SUBMITTER: Technical Committee on Oxygen-Enriched Atmospheres.
RECOMMENDATION: Add new term "Oxidant", defined as follows:
Include a NOTE to read as follows: "NOTE: Examples of oxidants include nitrous oxide, nitric oxide, chlorates and chlorine."
SUBSTANTIATION: Term is used in document, but is not defined.
COMMITTEE ACTION: Accept.

53-5. (1-2): Accept
SUBMITTER: Technical Committee on Oxygen-Enriched Atmospheres.
RECOMMENDATION: In definition of term "Gas Anesthesia Apparatus," add "vaporizers, ventilators" after "control valves".
SUBSTANTIATION: Vaporizers are a standard piece of equipment incorporated in anesthesia gas apparatus.
COMMITTEE ACTION: Accept.

53-6. (1-2): Accept
SUBMITTER: Technical Committee on Oxygen-Enriched Atmospheres.
RECOMMENDATION: Add new term "Ventilator: An item of equipment used to assist or control the breathing of a patient." Include a NOTE to read: "NOTE: Ventilators are often used with an oxygen enriched atmosphere and nitrous oxide."
SUBSTANTIATION: Term is used in document, but not defined.
COMMITTEE ACTION: Accept.

53-7. (2-1: Table 2-1): Accept
SUBMITTER: Technical Committee on Oxygen-Enriched Atmospheres.
RECOMMENDATION: 1. Change "180" to "160" in heading of column 2.
2. Add a title to Table to read: "Partial pressure of oxygen in a rarefied or compressed-air atmosphere."
SUBSTANTIATION: 1. Editorial. Typographical error.
2. Editorial. No title in present text.
COMMITTEE ACTION: Accept.

53-8. (2-1.2): Accept
SUBMITTER: Technical Committee on Oxygen-Enriched Atmospheres.
RECOMMENDATION: In sentence five, change "may exhibit similar combustion supporting similar properties as ambient air..." to read "may exhibit similar combustion-supporting properties as ambient air...".
SUBSTANTIATION: Editorial. Typographical.
COMMITTEE ACTION: Accept.

53-9. (2-1.2.2; Figs. 2-1 & 2-2): Accept
SUBMITTER: Technical Committee on Oxygen-Enriched Atmospheres.
SUBSTANTIATION: There is no explanation for letters in figures. Text of referenced paper needs to be reviewed in order to understand the meaning of letters. Letters are not necessary in the present context of this document.
COMMITTEE ACTION: Accept.

53-10. (2-1.5): Accept
SUBMITTER: Technical Committee on Oxygen-Enriched Atmospheres.
RECOMMENDATION: 1. Delete last two sentences. Add a new NOTE to read as follows: "NOTE: An oxygen-enriched atmosphere may develop in situations in which nitrous oxide is employed."
2. Add new sentence three: It is also used as a combustion enhancing agent in racing vehicles.
SUBSTANTIATION: 1. To clarify that when using nitrous oxide, elevated temperatures are not required to create an oxygen enriched atmosphere.
2. Recognize other uses of nitrous oxide.
COMMITTEE ACTION: Accept.

53-11. (2-1.6 (New)): Accept
SUBMITTER: Technical Committee on Oxygen-Enriched Atmospheres.
RECOMMENDATION: Add a new 2-1.6 to read: "The use of other oxidants, such as chlorine, chlorates, nitric oxide and ozone, may result in enhanced combustion. Appropriate safety literature, such as material safety data sheets, should be reviewed."
SUBSTANTIATION: Identify other potential sources of oxygen enriched atmospheres.
COMMITTEE ACTION: Accept.

53-12. (2-2.1; 2.2.2; 2.2.5 (New)): Accept
SUBMITTER: Technical Committee on Oxygen-Enriched Atmospheres.
RECOMMENDATION: 1. In 2.2.1, add at end of paragraph the following: "Oxygen is also separated from air by adsorption and membrane-based systems."
2. Revise 2-2.2 to read as follows: "Oxygen is transported to the consumer facility as a compressed gas or as a liquid, or transmitted by pipeline."
COMMITTEE ACTION: Accept.
spheres

 advent of the NFPA Committee on Health Care Facilities, a
anesthetization of patients, and the often necessary administration
and nitrous oxide. Use of such a machine allows for both

SUBSTANTIATION: 1. to 3. Add reference to newer technology
currently in use.


COMMITTEE ACTION: Accept.

53-13. (2-3): Accept

RECOMMENDATION: 1. Revise 2-3.1 to read as follows:
"2-3.1 Oxygen-enriched atmospheres have been associated with
inhalation anesthetics since the development, in 1887, of a gas
anesthesia apparatus incorporating means of administering oxygen
and nitrogen oxide. Use of such a machine allows for both the
anesthetization of patients, and the often necessary administration
of high oxygen concentrations. The use of a flammable volatile
liquid or gaseous inhalation anesthetic agent in such an atmosphere,
however, creates severe fire and explosion hazards. Prior to the
advent of the NFPA Committee on Health Care Facilities, a
significant number of fatalities and injuries resulted from operating
room fires and explosions. Such incidents have been drastically
reduced through widespread adherence to the provisions of Section
12.4.1 of NFPA 99, Standard for Health Care Facilities.

The reduction in use of flammable anesthetics in operating rooms
has allowed for increased use of potential ignition sources (electro-
surgical units, lasers, etc.). Advances in materials-science have
introduced polymers (endotracheal tube), and fabrics (paper drapes
and gowns) that are flammable in the oxygen-enriched atmosphere
of operating rooms. Therefore, the operating room environment
continues to present fire hazards.

2. Revise sentence two in 2-3.2 to read as follows:
"In consequence, inhalation therapy, including ventilator support
of patients, is practiced widely at the present time." [addition
underlined]

3. Revise sentence one in 2-3.2.1 to read as follows:
"Since ambulatory... rent therapy equipment, oxygen cylinders,
and liquid oxygen containers for use in their homes." [addition
underlined]

4. Revise sentence one in 2-3.3 to read as follows:
"Ambulances, rescue squads... pools are often equipped with
oxygen for resuscitation and life support purposes. Use of oxygen in
an enclosed space may create a hazardous oxygen-enriched
atmosphere." [changes underlined]

Delete existing sentences 2 and 3 of 2-3.3.

SUBSTANTIATION: Existing text is outdated. Less flammable
agents are used, but new equipment and materials present new
hazards in the presence of oxygen and nitrogen oxide.

COMMITTEE ACTION: Accept.

53-14. (2-4): Accept

RECOMMENDATION: Revise 2-4 to read as follows:

2-4. Industrial Applications.

2-4.1 Oxygen, as an industrial gas, is in widespread use in a variety
of industries. Furthermore, its use continues to increase into new
applications where additional environmental or service conditions
may place severe demands on equipment, materials and systems.
Elevated temperatures, high corrosivity and reduced contamination
levels are examples of factors, in addition to flammability, which
must be considered that could limit materials selection options
for oxygen services in advanced applications.

2-4.2 In the petrochemical industry, large quantities of oxygen are
used for processes involving oxidation, and liquid oxygen as well
as coal to prepare other products. These include alcohols, polyethylenes,
and syngases. Elevated temperature stability and corrosion
resistance, in addition to oxygen compatibility that must be
considered, also limit the use of certain alloys that are resistant
to ignition and combustion in oxygen.

2.4.3 In the steel industry, oxygen is used to refine steel in the basic
oxygen furnace as well as to lance molten steel in several operations.

Oxy-fuel burners are used to reheat ingots and slabs, and to
heat ladles. Oxy-fuel burners are also used in glass furnaces.
Generally, materials selection issues and operating practices have
been well defined in these industries.

2-4.4 In the metal fabrication industry, oxy-fuel burners are used to
weld, cut, braze, silver-solder and harden various metals. This work
is done in large and small factories, automobile repair shops, and in
fabrication workshops. NFPA 51, Standard for the Design and Installa-
tion of Oxygen-Fuel Gas Systems for Welding, Cutting, and Allied
Processes; NFPA 51B, Standard for Fire Prevention in Use of Cutting
and Welding Processes, and ANSI Z49.1, Safety in Cutting and
Welding, cover such applications.

2-4.5 In the mining industry, oxygen is used to refine copper, gold,
and other metals via pressure oxidation processes where sulphurous
"refractory ores" are mined. Elevated temperatures and severe
corrosivity place severe limitations on materials selection options.

2-4.6 Oxygen, as an alternative to air, is widely used for secondary
processing in the pulp industry. Oxygen is used in kraft pulping,
which is currently in use.

2-4.7 Editorial. Sequence text in a logical order.

COMMITTEE ACTION: Accept.

(2-4.13 to 2-4.15) of NFPA 99, Standard for Care Facilities.

2-4.8 Ultra-high purity (99.999%) oxygen is used to manufacture
microchips in the semiconductor industry. The necessity to
eliminate contaminants to reduce chip defects results in ultra clean
systems which does reduce the tendency towards promoted ignition-
combustion scenarios, but the presence of oxygen can increase
flammability hazard with certain metals and nonmetals. Aluminum alloys are a prime example of materials
that show a dramatic increase in flammability when exposed to UHP oxygen (99.999+%).

2-4.9 The paper and pulp industry uses extensive amounts of
oxygen in the bleaching and delignification processes as an
alternative to chlorine. The use of ozone in this industry may also
increase fires. Materials selection issues are similar to those encountered
in various other processes where oxygen and aqueous environments
are involved.

2-4.10 As a result of new technologies, the O2 concentration of
systems originally designed for air, may be increased by a few
percent to increase efficiency. Such systems, which may not have
been cleaned initially for oxygen service or designed with oxygen
compatible or combustion resistant materials, may be individually
unique. They should be treated on a case by case basis with respect
to issues such as cleaning, filtration, degree to which the oxygen
levels are increased, etc.

2-4.11 Oxygen fireflooding is an example of a tertiary Enhanced
Oil recovery process that has been practiced. Oxygen is injected at
high pressures into heavy oil deposits which cannot be recovered by
primary or secondary oil recovery techniques. Downhole combustion
of heavy oil results in high temperatures, high corrosivity, when
water is present, but increased oil mobility allowing recovery at
collection wells.

Oxygen fireflooding requires careful system design and special operating procedures for the safe production of heavy
oils.

2-4.12 In many applications, the motivation to use oxygen is driven
by at least one of many factors. These include: higher combustion
temperatures, higher purity gaseous product (no nitrogen from air),
higher output from a given size reactor (often in conjunction with
debottlenecking a process), higher conversion efficiency, reduced
combustion emissions (NOX emissions may be reduced without the
nitrogen from air), and previously unobtainable production from
mineral or oil deposits. Service environments may limit or eliminate the
use of many materials that may be selected on the basis of
combustion resistance in oxygen-enriched atmospheres. Experimental
programs may be required to optimize materials selection and
systems design problems in advanced oxygen applications for safe
operation.

2-4.13 Large users of oxygen are generally supplied via a pipeline
from a near by oxygen plant that uses cryogenic distillation. Smaller
users’ requirements may be met by liquid oxygen that is hauled via
truck to a storage tank at the site, from a membrane or adsorption
system, or by liquid oxygen from high pressure cylinders. Requirements
for system design, materials selection, cleaning, safe
operation, etc. are well established for oxygen supply systems.

SUBSTANTIATION: Existing text is obsolete and does not address
temporary in use to future trends in technology.

COMMITTEE ACTION: Accept.
53-15 - (2-6.3): Accept
SUBMITTER: Technical Committee on Oxygen-Enriched Atmospheres
RECOMMENDATION: Replace existing 2-6.3 with the following:
2-6.3 The practice of using aviator breathing oxygen (ABO) for spacecraft life support systems has been the norm in the past and may be required in the future for long duration missions. Previous programs, such as Gemini, Mercury and Apollo, used an ABO atmosphere because life support systems were not available. An oxygen-enriched atmosphere is currently used in the Shuttle program. During normal operations, the orbiter oxygen concentration can reach as high as 25.9 percent oxygen, due to calibration margins in the control and calibration systems. Prior to each extra-vehicular activity (EVA), the orbiter atmosphere is changed to a 30 percent oxygen atmosphere at 10.2 psia (70.3 kPa). This 30 percent oxygen atmosphere is used for 6 to 10 hours prior to the actual EVA to precondition the crew for the space suit environment of 5 psia (34.5 kPa) 100 percent ABO atmosphere.
2-6.3.1 The space station is designed to operate at 10.2 psia (70.3 kPa) with a 30 percent oxygen atmosphere until it is permanently manned. The current schedule is for the space station to be manned tended (manned only when a shuttle is docked) for the first 5 to 6 years of operations. Once the space station is permanently manned, it is expected to operate at one atmosphere with up to 25 percent oxygen concentration. The space station will have a hyperbaric chamber to treat the bends if necessary. This chamber will be operated at 10.2 atmospheres at 21 percent oxygen concentration, and used only in an emergency.
2-6.3.2 The oxygen concentration on the spacecraft can be increased by leakage in the primary oxygen supply system or the emergency oxygen system. This has happened in the orbiter cabin several times over the years. A leak in one of the systems caused the cabin oxygen concentration to reach 35 percent for a few hours. Once the leaks were found and corrected, the oxygen concentration was reduced to normal limits within a short time.
SUBSTANTIATION: The existing text of 2-6.3 is out of date. Revised text reflects current and anticipated future usage of oxygen.
COMMITTEE ACTION: Accept.

53-16 - (2-7.1.1 - 2-7.2): Accept
SUBMITTER: Technical Committee on Oxygen-Enriched Atmospheres
RECOMMENDATION: 1. In 2-7.1.1, revise sentence two to read: "Where use is routine, as in military applications, proper personnel indoctrination tends to mitigate the frequency of incidents.
2. In 2-7.2, revise sentence three to read: "In general, proper personnel indoctrination and the exercise of proper precautions tends to mitigate the frequency of incidents."
SUBSTANTIATION: 1 & 2. It is not true that no hazards develop, as indicated in interviews with military and training personnel.
COMMITTEE ACTION: Accept.

53-17 - (2-8.1.4): Accept
SUBMITTER: Technical Committee on Oxygen-Enriched Atmospheres
RECOMMENDATION: Add new paragraph 2-8.1.4 to read as follows: "An inadvertent oxygen-enriched atmosphere may be created within a vented storage vessel containing liquid air due to the preferential evaporation of nitrogen."
SUBSTANTIATION: Identify a hazard associated with a new commodity.
COMMITTEE ACTION: Accept.

53-18 - (3-2.1): Accept
SUBMITTER: Technical Committee on Oxygen-Enriched Atmospheres
RECOMMENDATION: 1. Delete 3-2.1.1, 3-2.1.2 and 3-2.1.5.
2. Add the following new incidents at the end of paragraph 3-2.1:
1. There have been several incidents involving vacuum insulated liquid oxygen (LOX) tanks and pipelines. Nitrogen oxide getter packets used for vacuum maintenance have been implicated as an ignition source. The function of palladium oxide, as it is used in vacuum maintenance, is to react with offgassed hydrogen to form water. Over a period of time, the palladium oxide may be reduced to finely divided palladium metal or palladium hydride.
If LOX is suddenly introduced into a vacuum by failure of a structural joint, the reduced palladium oxide may undergo an exotherm which could ignite the superinsulation. A recommended solution is to insure that palladium oxide is suitably encapsulated within a heat sink to insure that the exotherm does not accelerate if LOX is inadvertently introduced.
2. A seismic survey vessel with an estimated cost of $1,250,000 was destroyed and three individuals were killed as a consequence of an incident involving a 2000 gallon LOX tank carried on board the ship for seismic experiments. Investigation concluded that excessive force applied to a valve stem sheared the stem collar. The internal tank pressure was approximately 60 psig.
An oxygen cloud spread over the ship. There was no shortage of containments. Steel deck vapor were engulfed and cracked. Several flashes preceded an explosion. The precise ignition source is unknown. Questions during the post accident investigation were raised about the system maintenance, awareness of personnel about oxygen hazards and the failure of safety valves.
3. A 1500 gallon aluminum LOX tank truck exploded shortly after a delivery to a customer's tank. Two individuals were killed. Explosion occurred shortly after one of the individuals reported that a subsequent transfer pump was not working properly. Improper bearing lubrication and pump reversal due to improper maintenance procedures were possible causes of the pump failure.
 Appropriately eight pounds of aluminum from the pump were consumed. All submerged pumps were removed from service and replaced with external pumps.
4. A LOX tank truck exploded after making a delivery to a hospital. Two individuals were killed. Approximately 162 pounds of aluminum were consumed and contributed to the intensity of the explosion. The definitive cause of the accident was not firmly established. It is believed that various factors contributed to a condition of aluminum in the scenario.
SUBSTANTIATION: 1. Dated incidents.
2. Add new incidents.
1. from T/C member file.
COMMITTEE ACTION: Accept.

53-19 - (3-2.2): Accept
SUBMITTER: Technical Committee on Oxygen-Enriched Atmospheres
RECOMMENDATION: 1. Delete 3-2.2.1, 3-2.2.2 and 3-2.2.6.
2. Insert the following seven incidents at the end of 3-2.2:
1. A tracheotomy was being performed on a thirty-three year old ventilator-dependent woman with multiple medical problems, anesthetized with intravenous agents, and ventilated with 100% oxygen at 10.2 psia (70.3 kPa) 100 percent ABO atmosphere. Investigation concluded that excessive force applied to a valve stem sheared the stem collar. The internal tank pressure was approximately 60 psig.
An oxygen cloud spread over the ship. There was no shortage of containments. Steel deck vapor were engulfed and cracked. Several flashes preceded an explosion. The precise ignition source is unknown. Questions during the post accident investigation were raised about the system maintenance, awareness of personnel about oxygen hazards and the failure of safety valves.
3. A 1500 gallon aluminum LOX tank truck exploded shortly after a delivery to a customer's tank. Two individuals were killed. Explosion occurred shortly after one of the individuals reported that a subsequent transfer pump was not working properly. Improper bearing lubrication and pump reversal due to improper maintenance procedures were possible causes of the pump failure.
4. NTSB Report #HAR-72-74/900.
5. During the performance of a tonsillectomy on a four year old boy under approximately 50% oxygen, 50% nitrous oxide and 1% halothane general anesthesia, fire "blow-torched" from the mouth due to an inadvertent oxygen enriched atmosphere. The fire was extinguished by a combination of deluge with saline solution, axad a cessation of the flow of oxidant enriched atmosphere into the anesthetic circuit. The anesthetic gases were administered via an endotracheal tube
specifically manufactured for CO2 laser surgery, consisting of a silicone rubber shaft externally coated with a silicone rubber layer containing metal particles. After excision of the polyprop and during control of vocal cord bleeding using the laser, smoke emerged from the mouth, flames emerged from the endotracheal tube, and flames were noted within the tubing of the anesthesia breathing circuit. The flames were extinguished with saline solution and the burned endotracheal tube was replaced. The patient suffered extensive burns of the trachea and bronchi, from which he eventually recovered.

Examination of the burned endotracheal tube revealed combustion of the cuff, which had been filled with saline solution to isolate the anesthetic gases within the breathing circuit and lung, and combustion of the tubal shaft. The CO2 laser had most likely perforated the cuff and then ignited the silicone rubber in the oxygen and nitrous oxide-enriched atmosphere.


4. The use of a dry gauze pad in an oxygen-enriched atmosphere led to a fire in the incision site. A gauze pad was placed in the incision site during a lung resection. The dry pad was being used to blot blood from the tissues. At the time when the fire occurred, an electrosurgical unit (ESU) was being used to cauterize a bleeder immediately next to the gauze. The lung lobe had already been resected and oxygen was flowing out of the resected area, enriching the operative site. The oxygen enriched the gauze and allowed it to be easily ignited by the ESU. The burning gauze pad was thrown to the floor and extinguished without any apparent injury to the patient.

Footnote Reference: Incident Report, ECRI, Plymouth Meeting, PA.

5. The creation of an oxygen-enriched atmosphere, caused by an open oxygen source, allowed this fire to occur. A patient requiring oxygen therapy was at home using an oxygen concentrator with a nasal cannulae. While grinding metal in his shop, grinding sparks ignited the nasal cannulae. He pulled the tubing from his face and was slightly burned in the incident.

Footnote Reference: Incident Report, ECRI, Plymouth Meeting, PA.

6. An oxygen-enriched atmosphere, created by the presence of oxygen and nitrous oxide, allowed easy ignition of facial hair. A patient was undergoing oral surgery with general anesthesia maintained through a nose mask with a concentration of 25% oxygen, 75% nitrous oxide, and a small percentage of halogenated anesthetic. The patient had a mustache. As the surgeon was grinding a filling with a tungsten-carbide bur, an incandescent spark flew from the bar and arced out of the patient's mouth, over his upper lip, and landed in his moustache. Because of the oxygen- and nitrous oxide-enriched atmosphere, the moustache immediately burst into flame and ignited the nasal mask. The fire then flashed back toward the anesthesia machine along the gas delivery hoses. As soon as the fire was noticed, the nasal mask was removed from the patient's face, but not before significant burning of his nose and upper lip had occurred.

Footnote Reference: Incident Report, ECRI, Plymouth Meeting, PA.

7. Improper use of an oxygen concentrator caused this face fire. A patient requiring oxygen therapy was at home using an oxygen concentrator with a nasal cannulae. While grinding metal in his shop, grinding sparks ignited the nasal cannulae. He pulled the tubing from his face and was slightly burned in the incident.

Footnote Reference: Incident Report, ECRI, Plymouth Meeting, PA.

3. Revise 3.2.2.2 to read as follows: "Improper maintenance of a device used with oxygen lead to this fire. A humidifier was used alongside a two year old child's crib fitted with an oxygen tent. There were indications of low water in the humidifier, failure of its thermal safety feature, and of fire originating in the inflow, feeding the flames. The flames were blown into the oxygen tent, where the little girl was burned to death."
532-2. (3.6): Accept

SUBMITTER: Technical Committee on Oxygen-Enriched Atmospheres

RECOMMENDATION: 1. In 3-2.6.8, paragraph six, change 2590 feet to 282 feet.
2. Add the following incident at the end of 3-2.6:
   "A space shuttle extra-vehicular mobility unit (spacesuit and life-support backpack) was destroyed in a flash fire during a functional test in the Johnson Space Center's Crew Systems Laboratory. (See Figure 3-XX.) A technician, who was standing next to the suit, received second-degree burns over his upper body in the accident. It was determined that the fire originated in an aluminum-bodied regulator/valve assembly when 41 MPa (6000 psi) oxygen was released through the valve into the regulator. It was postulated that the fire was caused by: a) the rupture of a thin, internal section of the aluminum body, b) the ignition of a silicone o-ring by compression heating of the oxygen or, c) particle impact. As a result of this fire, the practice of performing a vigorous inert gas purge was implemented to remove assembly generated contaminants prior to pressurization of a system with oxygen.

SUBSTANTIATION: 1. Not a good description of an incident.
2. More appropriate location for this incident.
3. These are incidents that have occurred at the White Sands, NM, Test Facilities. Incidents update 3-2.5. Incidents are on file at WSTF.

COMMITTEE ACTION: Accept.

532-24. (3-2.7.3): Accept

SUBMITTER: Technical Committee on Oxygen-Enriched Atmospheres

RECOMMENDATION: 1. Delete text of 3-2.7.5, and replace with following incident:
   "3-2.7.3 In January of 1984, the Royal Australian Air Force experienced a ground fire that destroyed a six million dollar P35 Orion aircraft. The incident occurred during removal of an onboard oxygen cylinder, one of three that supplied the flight crew. Examination of the aircraft's oxygen system revealed that the fire had initiated in an oxygen manifold check valve assembly. The primary cause of the incident was a leaking poppet valve, which allowed oxygen stored at 12 MPa (1800 psi) to escape to the atmosphere. Deterioration of the silicone rubber seal and galvanic corrosion are believed responsible for the valve failure. Contributory causes to the fire were system contamination and failure to bleed the oxygen system before cylinder disconnection. A thermit reaction involving the aluminum check valve housing, metal particles, and metal oxides was thought to be the most likely cause of ignition. Investigators findings indicate the need to consider using materials other than silicone rubber in oxygen systems. It was also determined that further investigation into the ignition of aluminum and other materials by metal particle impingement in the presence of metal oxides in a high-pressure oxygen environment is required." (F.N. 1)


SUBSTANTIATION: Existing incident is out of date. Recommended one is a recent incident.

COMMITTEE ACTION: Accept.

532-25. (3-2.7.9 (New)): Accept

SUBMITTER: Technical Committee on Oxygen-Enriched Atmospheres

RECOMMENDATION: 1. Add new aircraft incident to read as follows:
   3-2.7.9 A commercial aircraft fire occurred during servicing of the passenger oxygen system. Three crew members, four flight attendants, and 12 passengers were on board the plane when the fire erupted. All passengers and crew were evacuated safely. Shortly after the preboarding of passengers had begun, a sound, described as a muffled "bang" or "boom," came from an area near the forward galley. Within seconds, thick black smoke started to fill the cabin, and flames began to burn through the forward right side of the fuselage. Witnesses stated that they saw a three- to four-foot flame extending sideways from the fuselage on the forward right side of the airplane. A hole, several feet in diameter, burned through the fuselage, just behind the right, forward-galley service door.

The passenger oxygen system is located in the forward right side of the airplane. The system is composed of two oxygen cylinders, each charged initially to a pressure of 12.8 MPa (1,850 psi). The cylinders supply oxygen through steel tubing to the flow control unit, which reduces the pressure of the oxygen and then controls its flow to the passenger masks. During a preflight inspection of the airplane, a mechanic found that the quantity of oxygen in the cylinders was below the acceptable level, and therefore changed the cylinders. He said that as he was about to leave the area, he saw a flash of white light that enveloped the oxygen system flow control unit.

The inspection team from the National Transportation Safety Board concluded that the fire originated in the passenger oxygen system's flow control unit.
Recent incident in airline industry that involved OEA.


COMMITTEE ACTION: Accept.

SUBMISSION: Technical Committee on Oxygen-Enriched Atmospheres

RECOMMENDATION: Revise 4-3.3 as follows:
1. Add new section 4-3.3.3 to read as follows:
   "4.3.3.3 Once ignited, the likelihood of flame propagation and the rate of propagation of a combustible are primarily dependent upon the stoichiometry of the fuel and oxygen, the concentrations of oxygen with the inert gas present, and the velocity of the gas mixture. In general, inert gases vary in their ability to render a mixture non-flammable, with tritatomic gases (e.g., CO2, H2O) turn more effective than diatomic gases (e.g., N2) which are, in turn, more effective than monatomic gases (e.g., Ar). This trend has been correlated with the heat capacity of the gas which increases with the structure of the inert gas molecule. Helium is an exception to this trend. Due to its very high thermal conductivity, the flame propagation rate in helium dilution is higher than would be expected by examining heat capacity ranking alone."

SUBMISSION: Clarification and expansion to include flammability limits.

COMMITTEE ACTION: Accept.

SUBMISSION: Technical Committee on Oxygen-Enriched Atmospheres

RECOMMENDATION: Add new section 4-3.3.3 to read as follows:
1. Add new section 4-3.3.3 to read as follows:
   "4.3.3.3 Once ignited, the likelihood of flame propagation and the rate of propagation of a combustible are primarily dependent upon the stoichiometry of the fuel and oxygen, the concentrations of oxygen with the inert gas present, and the velocity of the gas mixture. In general, inert gases vary in their ability to render a mixture non-flammable, with tritatomic gases (e.g., CO2, H2O) turn more effective than diatomic gases (e.g., N2) which are, in turn, more effective than monatomic gases (e.g., Ar). This trend has been correlated with the heat capacity of the gas which increases with the structure of the inert gas molecule. Helium is an exception to this trend. Due to its very high thermal conductivity, the flame propagation rate in helium dilution is higher than would be expected by examining heat capacity ranking alone."

SUBMISSION: Clarification and expansion to include flammability limits.

COMMITTEE ACTION: Accept.


2. Committee is separating metals and nonmetals because metals and their properties are not currently addressed in 4-5.3.

COMMITTEE ACTION: Accept.

53-32 - (5-2.2.1; Table 5-1): Accept
SUBMITTER: Technical Committee on Oxygen-Enriched Atmospheres
RECOMMENDATION: In Table 5-1, add the following combustibles in the Anesthetic Agents category, after chloroform:

<table>
<thead>
<tr>
<th>Combustible</th>
<th>Flash point</th>
<th>Air</th>
<th>LFL</th>
<th>UFL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enflurane</td>
<td>&gt;200(93)</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Isoflurane</td>
<td>&gt;200(93)</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Desflurane</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>17.2</td>
</tr>
</tbody>
</table>

451

SUBSTANTIATION: Add currently used anesthetics not previously listed in table.
COMMITTEE ACTION: Accept.

53-33 - (5-2.3.1): Accept
SUBMITTER: Technical Committee on Oxygen-Enriched Atmospheres
RECOMMENDATION: 1. Add title to 5-2.5.1 to read: "Nonmetals"
2. Add new section 5-2.3.2 to read as follows:
"5-2.3.2 Nonmetals. As with nonmetals, the extent of combustion or flame propagation for metals will depend upon a number of factors including the absolute pressure, ambient temperature, fuel and oxidizer composition, geometric shape and temperature of the fuel sample and, direction of combustion front. Depending upon these factors, the combustion front in metals can propagate at greatly varying rates. For example, a 3.2 mm (0.13 in) diameter 316 stainless steel rod burning upward in 6.9 MPa (1000 psia) oxygen will propagate at about 11 mm/s (0.43 in/sec), whereas a 3.2 mm (0.13 in) diameter 6061 aluminum rod will burn at 64 mm/s (2.5 in/s) [ref. F.N.1]. Since most metals have 3.2 mm (0.13 in) diameter normally has little effect upon the combustion front propagation rate, once a minimum chamber diameter is reached which allows adequate amounts of oxidizer to surround the fuel to enable combustion providing the system is sufficiently pressurized (less than 5% reduction of oxidizer). In general, combustion front propagation rate increases with increasing ambient pressure, oxidizer concentration, ambient temperature, and decreasing sample dimensions [ref. F.N. 2-5]."

Reference Footnotes:


SUBSTANTIATION: Address subject not previously covered in text.
COMMITTEE ACTION: Accept.

53-34 - (5-2.4-5.2.5 (new)): Accept
SUBMITTER: Technical Committee on Oxygen-Enriched Atmospheres
RECOMMENDATION: 1. Change title of 5-2.4 to read: "Limits of flammability of nonmetallic materials."
2. Add new section 5-2.5 "Limits of flammability of metallic materials" to read as follows:
"5-2.5 Limits of Flammability — Metals
5-2.5.1 Flammability limits, per se, do not exist for most structural metal alloys since they burn in the liquid rather than the vapor phase. However, two measures of the relative flammability of metals exist which are of practical value. They are the minimum oxygen pressure required to support combustion of a standard sample (threshold pressure) and the minimum oxygen concentration required to support combustion of a standard sample at some elevated temperature and pressure (oxygen index). Data regarding the threshold pressures and oxygen indices of metals and alloys are provided in 5-3.4."
COMMITTEE ACTION: Address subject not previously covered in text.
COMMITTEE ACTION: Accept.

53-35 - (5-3.2.6; 5-3.2.7; 5-3.2.10): Accept
SUBMITTER: Technical Committee on Oxygen-Enriched Atmospheres
RECOMMENDATION: 1.Revise 5-3.2.6 to read as follows:
"5-3.2.6 All metals with the possible exception of the noble metals — gold and platinum — can be expected to ignite in oxygen at some elevated temperature and pressure. Metals most liable to ignition hazards are those configured with high surface-to-volume ratios such as dusts, thin sheets, wires, and wire meshes. When these bulkier structural elements of systems containing pressurized oxygen ignite and burn, the results are often catastrophic, due to the explosion-like release of high pressure gases and ejection of burning debris. Ignition mechanisms include mechanical impact, particulate impact, friction, electrical arc and spark, resonance, rupture, exposure of fresh metal surfaces, and promoted ignition. The most ignitable common metals are titanium, magnesium, and lithium, the least ignitable are nickel, copper, and cobalt. Increase in pressure and content promote the ignition of metals at lower temperatures. [ref 1]

2. Add new section 5-3.2.10 to read as follows:
"5-3.2.10 Ignition of metals by frictional heat is a commonly recognized hazard in rotating machinery for oxygen service [ref. 2-5]. Frictional ignition is controlled by two factors: the resistance of the material to ignition and combustion due to its chemical composition (chemical kinetics) and the ability of the material to generate heat by friction. The combined effect of these factors is reflected in the product of the contact pressure (P — test specimen contact pressure at ignition [loading force divided by initial contact area]) and the velocity (v — relative velocity between the rubbing components) required to initiate material test specimens tests in standard configuration and conditions. Table 5-xx shows the PV product required for ignition of 2.5 mm (1 in) diameter x 0.25 cm (0.1 in) wall x 2 cm (0.8 in.) long specimens rotated axially with a sliding friction coefficient of 0.5. Tests were conducted by keeping v constant at 22 m/s (72.4 ft/s) and increasing P at a rate of 35 N/s (7.5 lbf/s) until ignition."

Table 5-xx [ref. 2-5, 6, and 7] Ignition Test Data for Similar Pairs of Test Specimens.
where increasing or decreasing pressure produces increases in the
required to ignite the stainless steel, thereby degrading the
performance of the Monel® 400 [ref. 8].

For example, when Monel® 400 and 316 stainless steel are rubbed
by friction, the ignition tends to control the ignition threshold [ref. 7].

In Figure 5-xy gives the Pv products required for the frictional
ignition of three alloys as a function of oxygen pressure. In the case
of carbon steel 1015 and 316 stainless steel, there exists a pressure
where increasing or decreasing pressure produces increases in the
Pv products required for ignition. At the pressure where the
minimum Pv product occurs, it is believed that the heat rate
produced by the oxidation process is equal to the heat loss rate. The
ignition process at pressures lower than this minimum are dominated
due to oxidation kinetics whereas at pressures above this minimum, the
ignition process is dominated by heat loss from the material [ref. 5].

Caption to Figure 5-xy to read as follows: Results of supersonic
impact of single 2000 micron (0.08 inch) diameter aluminum
particles impacting various alloys in 27 MPa (3900 psia) oxygen [ref. 2].

Reference Footnotes:
   Report 224, Defense Metals Information Center, Battelle Memorial
   Institute, Columbus, Ohio, February 1966.
2. Stoltzfus, J.M., Gunaji, M.V., "Test Methods for Determining the
   Suitability of Metal Alloys for Use in Oxygen-Enriched Environ-
   ments," Technology 2001, The Second National Technology
   Transfer Conference and Exposition, Conference Proceedings.
   NASA Conference Publication 3136, Volume 1. National Aeronau-
3. Jenny, R., and Wysannan, H., "Friction-Induced Ignition in
   Oxygen." Flammability and Sensitivity of Materials in Oxygen-
   Enriched Atmospheres, ASTM STP 812, B.L. Werley, Ed., American
   Evaluation for Oxygen Centrifugal Compressors," SORIEAS-78-590,
   final report, Southern Research Institute, Birmingham, Ala., Sept.
   1978.
   Gaseous Oxygen by Friction Heating," Flammability and Sensitivity
   of Materials in Oxygen-Enriched Atmospheres: Second Volume,
   ASTM STP 910, M.A. Benning, Ed., American Society for Testing
   Required for the Frictional Ignition of Alloys," Flammability and
   Sensitivity of Materials in Oxygen-Enriched Atmospheres: Fourth
   Volume, ASTM STP 1040, Joel M. Stoltzfus, Frank J. Benz, and Jack
   S. Stradling, Editors, American Society for Testing and Materials,
   Committee G-4 Metals Flammability Test Program: Data and
   Discussion," Flammability and Sensitivity of Materials in Oxygen-

Table 5-xy [ref. 2,5,6, and 7] Friction Ignition Test Data
for Similar Pairs of Test Specimens

<table>
<thead>
<tr>
<th>Test Materials</th>
<th>( W/m^2 \times 10^8 ) (( \text{lbf/in}^2 \times \text{ft/min} \times 10^6 ))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inconel MA 754</td>
<td>5.96 - 4.12</td>
</tr>
<tr>
<td>Inconel MA 758</td>
<td>5.34 - 6.42</td>
</tr>
<tr>
<td>Nickel 200</td>
<td>2.29 - 3.19</td>
</tr>
<tr>
<td>Inconel 600</td>
<td>2.80 - 2.21</td>
</tr>
<tr>
<td>Inconel 625</td>
<td>1.63 - 1.75</td>
</tr>
<tr>
<td>Monel 400</td>
<td>1.44 - 1.50</td>
</tr>
<tr>
<td>Monel K500</td>
<td>1.37 - 1.48</td>
</tr>
<tr>
<td>Inconel 718</td>
<td>1.10 - 1.19</td>
</tr>
<tr>
<td>17-4 PH (H 900)</td>
<td>1.00 - 1.21</td>
</tr>
<tr>
<td>304 SS</td>
<td>0.85 - 1.00</td>
</tr>
<tr>
<td>Brass CDA 360</td>
<td>0.70 - 0.80</td>
</tr>
<tr>
<td>17-4 PH (Good. A)</td>
<td>0.61 - 0.80</td>
</tr>
<tr>
<td>316 SS</td>
<td>0.55 - 0.65</td>
</tr>
<tr>
<td>Aluminum 6061-T6</td>
<td>0.061</td>
</tr>
<tr>
<td>Ti-6AI-IV</td>
<td>0.0035</td>
</tr>
</tbody>
</table>

Note: All unreferenced data is from previously unpublished
Frictional Heating Tests performed at NASA White Sands Test
Facility.

This material did not ignite at these Pv products
(a) When frictional ignition test specimens made from different
metals are rubbed together, the metal that is least resistant to
ignition by friction tends to control the ignition threshold [ref. 7].
For example, when Monel® 400 and 316 stainless steel are rubbed
together, the pair ignites within the range of the Pv products
required to ignite the stainless steel, thereby degrading the
performance of the Monel® 400 [ref. 8].

(b) Figure 5-xy gives the Pv products required for the frictional
ignition of three alloys as a function of oxygen pressure. In the case
of carbon steel 1015 and 316 stainless steel, there exists a pressure
where increasing or decreasing pressure produces increases in the
Pv products required for ignition. At the pressure where the
minimum Pv product occurs, it is believed that the heat rate
produced by the oxidation process is equal to the heat loss rate. The
ignition process at pressures lower than this minimum are dominated
due to oxidation kinetics whereas at pressures above this minimum, the
ignition process is dominated by heat loss from the material [ref. 5].

Caption to Figure 5-xy to read as follows: Effect of oxygen pressure
on the Pv products required for the frictional ignition of Monel 400,
316 stainless steel, and carbon steel 1015 [ref. 5].

5.2.6.2 The impact of high-velocity particles on surfaces has been
suspected for many years to be the cause of fires in oxygen-enriched
atmospheres (OEA) [ref 9-12]. Pressure, temperature, particle size,
quantity, and type, target material and configuration, and oxygen
concentration all affect the likelihood of particle impact ignition.
Generally, likelihood of particle impact ignition increases with
increasing particle velocity, target temperature, and oxygen
concentration. The ignition/no ignition response of five structural
alloys subjected to supersonic impact of single 2000 micron (0.08 in)
diameter aluminum particles in 27 MPa (3900 psia) oxygen is shown
in Figure 5-xy [ref. 2].

<table>
<thead>
<tr>
<th></th>
<th>( \text{Pv Product at ignition} )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( W/m^2 \times 10^8 ) (( \text{lbf/in}^2 \times \text{ft/min} \times 10^6 ))</td>
</tr>
<tr>
<td>Inconel 718</td>
<td>5.96 - 4.12</td>
</tr>
<tr>
<td>Inconel 758</td>
<td>5.34 - 6.42</td>
</tr>
<tr>
<td>Nickel 200</td>
<td>2.29 - 3.19</td>
</tr>
<tr>
<td>Inconel 600</td>
<td>2.80 - 2.21</td>
</tr>
<tr>
<td>Inconel 625</td>
<td>1.63 - 1.75</td>
</tr>
<tr>
<td>Monel 400</td>
<td>1.44 - 1.50</td>
</tr>
<tr>
<td>Monel K500</td>
<td>1.37 - 1.48</td>
</tr>
<tr>
<td>Inconel 718</td>
<td>1.10 - 1.19</td>
</tr>
<tr>
<td>17-4 PH (H 900)</td>
<td>1.00 - 1.21</td>
</tr>
<tr>
<td>304 SS</td>
<td>0.85 - 1.00</td>
</tr>
<tr>
<td>Brass CDA 360</td>
<td>0.70 - 0.80</td>
</tr>
<tr>
<td>17-4 PH (Good. A)</td>
<td>0.61 - 0.80</td>
</tr>
<tr>
<td>316 SS</td>
<td>0.55 - 0.65</td>
</tr>
<tr>
<td>Aluminum 6061-T6</td>
<td>0.061</td>
</tr>
<tr>
<td>Ti-6AI-IV</td>
<td>0.0035</td>
</tr>
</tbody>
</table>

In Figure 5-xy gives the Pv products required for the frictional
ignition of three alloys as a function of oxygen pressure. In the case
of carbon steel 1015 and 316 stainless steel, there exists a pressure
where increasing or decreasing pressure produces increases in the
Pv products required for ignition. At the pressure where the
minimum Pv product occurs, it is believed that the heat rate
produced by the oxidation process is equal to the heat loss rate. The
ignition process at pressures lower than this minimum are dominated
due to oxidation kinetics whereas at pressures above this minimum, the
ignition process is dominated by heat loss from the material [ref. 5].

Caption to Figure 5-xy to read as follows: Results of supersonic
impact of single 2000 micron (0.08 inch) diameter aluminum
particles impacting various alloys in 27 MPa (3900 psia) oxygen [ref. 2].


2. In 5-3.2.7, sentence one, delete "", which are generally considered to be noncombustible.

3. In 5-3.2.10, sentence one, change "solid materials" to read "nonmetallic materials".

SUBSTANTIATION: 1. To include new information and data on the ignition of metals.

2. Not consistent with current technology.


COMMITTEE ACTION: Accept.

(Log # CP35)

55-36 - (5.5-3; 5.3.4(new)): Accept

SUBMITTER: Technical Committee on Oxygen-Enriched Atmospheres

RECOMMENDATION: 1. Change title of section 5-3.3 to read: "Combustion - nonmetallic materials."

3. In 5-3.3.1, sentence one, change "solid materials" to read: "nonmetallic materials"

2. Add new section 5-3.4, Combustion - metallic materials, to read as follows:

"5-3.4 Combustion of Metals

5-3.4.1 General agreement exists that metals are more flammable in oxygen-enriched environments than in air. For example, a 3.2 mm (0.13 in) diameter rod of Ti-6Al-4V burned completely when ignited at the bottom in commercially pure oxygen at 0.14 MPa (20 psia), whereas it did not burn at all in air at 34.5 MPa (5000 psi) even though the partial pressure of oxygen was 7.2 MPa (1045 psia) [ref. 1]. This leads to the general conclusion that commercially pure oxygen at low pressures is more hazardous than air at relatively higher pressures. Whereas small increases in oxygen concentration at atmospheric pressure render nonmetallic materials dramatically more flammable (5-3.3.1), relatively large increases in oxygen concentration and increase in total pressure are required to render most structural metals flammable. Two measures of the relative flammability of metals exist which are of practical value. They are the minimum oxygen pressure required to support complete combustion of a standard sample (threshold pressure) and the minimum oxygen concentration required to support combustion of a standard sample at a given pressure (oxygen index).

NOTE: Combustion is considered "complete" when the sample burns up to the point where the sample holder influences the combustion process.

5-3.4.2 The threshold pressures of several alloys configured as 3.2 mm (0.13 in) diameter rods burning in the upward direction are shown in Table 5-7 [refs. 2-7]. Because the results of combustion tests are highly configuration dependent, it must be noted that these threshold pressures are not absolute flammability limits. Changing the configuration of the test samples can dramatically affect the threshold pressures. Table 5-8 shows the threshold pressures of several metal alloys configured as 60 x 60 wire meshes with a wire diameter of 0.18 mm (0.007 in). The wire mesh test samples were rolled into 6.4 mm (0.25 in) diameter cylinders, mounted vertically, and ignited at the bottom [ref 8]. Comparing the threshold pressures for 3.2 mm (0.13 in) diameter rods and the wire meshes, the dramatic effect of configuration becomes evident.

### Table 5-7
<table>
<thead>
<tr>
<th>Material</th>
<th>Threshold Pressure A (MPa)</th>
<th>Threshold Pressure A (psia)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monel K-500</td>
<td>&gt;68.9</td>
<td>&gt;10,000</td>
</tr>
<tr>
<td>Inconel MA754</td>
<td>&gt;68.9</td>
<td>&gt;10,000</td>
</tr>
<tr>
<td>Monel 400</td>
<td>&gt;68.9</td>
<td>&gt;10,000</td>
</tr>
<tr>
<td>Brass 360 CDA</td>
<td>&gt;68.9</td>
<td>&gt;10,000</td>
</tr>
<tr>
<td>Nickel 200</td>
<td>&gt;55.2</td>
<td>&gt;8,000</td>
</tr>
<tr>
<td>Copper 102</td>
<td>&gt;55.2</td>
<td>&gt;8,000</td>
</tr>
<tr>
<td>Hastelloy C276</td>
<td>20.7</td>
<td>3,000</td>
</tr>
<tr>
<td>Inconel 600</td>
<td>17.2</td>
<td>2,500</td>
</tr>
<tr>
<td>Inconel 625</td>
<td>17.2</td>
<td>2,500</td>
</tr>
<tr>
<td>Hastelloy C22</td>
<td>15.8</td>
<td>2,000</td>
</tr>
<tr>
<td>Inconel 718</td>
<td>6.9</td>
<td>1,000</td>
</tr>
<tr>
<td>440C SS</td>
<td>6.9</td>
<td>1,000</td>
</tr>
<tr>
<td>316 SS</td>
<td>6.9</td>
<td>1,000</td>
</tr>
<tr>
<td>304 SS</td>
<td>6.9</td>
<td>1,000</td>
</tr>
<tr>
<td>17-4 PH SS</td>
<td>6.9</td>
<td>1,000</td>
</tr>
<tr>
<td>Weldalite 049</td>
<td>2.1</td>
<td>300</td>
</tr>
<tr>
<td>Aluminum 8090</td>
<td>2.1</td>
<td>300</td>
</tr>
<tr>
<td>Aluminum 2219</td>
<td>0.2</td>
<td>35</td>
</tr>
<tr>
<td>HSLA steel</td>
<td>0.17</td>
<td>25</td>
</tr>
<tr>
<td>Aluminum 99.9%</td>
<td>0.17</td>
<td>25</td>
</tr>
<tr>
<td>Ti-6Al-4V</td>
<td>0.007</td>
<td>1</td>
</tr>
</tbody>
</table>

A Threshold pressure is the minimum test pressure required to support complete combustion of the test sample. (See NOTE in 5-3.4.1.)

B Denotes "high strength low alloy" steel.

### Table 5-8
<table>
<thead>
<tr>
<th>Material</th>
<th>Threshold Pressure A (MPa)</th>
<th>Threshold Pressure A (psia)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nickel 200</td>
<td>&gt;69</td>
<td>&gt;10,000</td>
</tr>
<tr>
<td>Copper 100</td>
<td>0.3</td>
<td>47</td>
</tr>
<tr>
<td>Monel 400</td>
<td>≤0.085</td>
<td>12.4</td>
</tr>
<tr>
<td>316 stainless steel</td>
<td>≤0.085</td>
<td>12.4</td>
</tr>
<tr>
<td>304 stainless steel</td>
<td>≤0.085</td>
<td>12.4</td>
</tr>
<tr>
<td>Carbon steel</td>
<td>≤0.085</td>
<td>12.4</td>
</tr>
</tbody>
</table>

A Threshold pressure is the minimum test pressure required to support complete combustion of the test sample. (See NOTE in 5-3.4.1.)

5.3.4.5 The minimum oxygen concentration required to support combustion of a standard sample (oxygen index) is another important measure of the flammability of metals. The oxygen indices for C-1018 carbon steel tube (25.4 mm [1 in] outside diameter and 4.8 mm [0.19 in] wall) are shown in Figure 5-xz [ref. 9]. For most structural alloys, the oxygen index decreases with increasing pressure [refs. 5, 10-14]. The oxygen indices for several alloys configured as 3.2 mm (0.13 in) diameter rods are provided in Figure 5-yy [ref. 11]. The oxygen indices of several alloys configured as rods and tubes are given in Fig. 5-zz [ref. 12].
Caption to read: "Figure 5-xz [ref. 9]. Effect of pressure on the mole percent of oxygen in nitrogen required to support upward combustion of C-1018 carbon steel tubes (25.4 mm [1 in] outside diameter and 4.8 mm [0.19 in] wall)."

Caption to read: "Figure 5-yy [ref. 11]. Summary of flammability data showing boundaries between burn and no burn zones for several engineering alloys configured as 3.2 mm (0.13 in) diameter rods burning in the upward direction."

Caption to read: "Figure 5-zz [ref. 12]. Oxygen Index of Some Alloys in Various Configurations."

5-3.4.4 The oxygen indices of aluminum alloys are affected by the diluent gas used with oxygen. Figure 5-yz shows the threshold pressures of two aluminum alloys configured as 6.4 mm (0.25 in) diameter rods burning upward in downward flowing gas as a function of the mole percent of nitrogen and argon in oxygen [ref. 10].
Reference footnotes:

COMMITTEE ACTION: (Log # CP36)
53-57 - (5-3.3.1): Accept
SUBMITTER: Technical Committee on Oxygen-Enriched Atmospheres
RECOMMENDATION: This recommendation three to read as follows:
"It is also recognized that material in 100 percent oxygen at 5 psia (258 mm Hg) are more flammable than in normal air at 1 atm."
SUBSTANTIATION: Existing statement is incorrect: oxygen is not flammable. Text reworded to reflect affect of increased oxygen in an atmosphere.
COMMITTEE ACTION: Accept.

( Log # CP38)
53-58 - (5-3.3.1; 5-3.3.4; Tables 5-3 and 5-4): Accept
SUBMITTER: Technical Committee on Oxygen-Enriched Atmospheres
RECOMMENDATION: 1. Delete sentence four of 5-3.3.1 ("As shown in Tables . . . oxygen atmosphere.9"). Delete existing Tables 5-3 and 5-4.
2. In 5-3.3.4, at end of sentence one, insert the following:
"(See Table 5-3."
3. Insert new Table 5-3 to read as follows:

<table>
<thead>
<tr>
<th>Material</th>
<th>Flame spread rate (mm/sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>In air</td>
</tr>
<tr>
<td></td>
<td>In 258 mm Hg Oxygen</td>
</tr>
<tr>
<td>Aluminized Mylar tape</td>
<td>45.53</td>
</tr>
<tr>
<td>Aluminized vinyl tape</td>
<td>NI</td>
</tr>
<tr>
<td>Asbestos insulating tape</td>
<td>2.05</td>
</tr>
<tr>
<td>Butyl rubber</td>
<td>0.12</td>
</tr>
<tr>
<td>Canvas duck</td>
<td>6.35</td>
</tr>
<tr>
<td>Cellulose acetate</td>
<td>0.305</td>
</tr>
<tr>
<td>Chaptick</td>
<td>46.23</td>
</tr>
<tr>
<td>Cotton shirt fabric</td>
<td>NI</td>
</tr>
<tr>
<td>Cotton cloth fabric</td>
<td>38.1:1.27</td>
</tr>
<tr>
<td>Electrical insulating resin</td>
<td>6.68</td>
</tr>
<tr>
<td>Electrical terminal board</td>
<td>1.52±0.24</td>
</tr>
<tr>
<td>Fiberglass insulating tape</td>
<td>NI</td>
</tr>
<tr>
<td>Foam cushion material</td>
<td>5.14</td>
</tr>
<tr>
<td>Foamed insulation</td>
<td>0.051</td>
</tr>
<tr>
<td>Food packet, aluminized paper</td>
<td>7.11±2.72</td>
</tr>
<tr>
<td>Food packet, brown aluminum</td>
<td>17.7±7.02</td>
</tr>
<tr>
<td>Food packet, plastic</td>
<td>8.38</td>
</tr>
<tr>
<td>Glass wool</td>
<td>NI</td>
</tr>
<tr>
<td>Kev-F</td>
<td>NI</td>
</tr>
<tr>
<td>Masking tape</td>
<td>4.32</td>
</tr>
<tr>
<td>Natural rubber</td>
<td>0.254</td>
</tr>
<tr>
<td>Neoprene rubber</td>
<td>(8.1±0.1)</td>
</tr>
<tr>
<td>Nylon 101</td>
<td>(8.8±0.2)</td>
</tr>
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<td>Paint Capon ivory</td>
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</tr>
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<td>Solder, resin core</td>
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<tr>
<td>Sponge, washing</td>
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<td>Tygon A</td>
<td>14.47±1.27</td>
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</tr>
<tr>
<td>Wire, Mil W76B, blue</td>
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</tr>
<tr>
<td>Wire, Mil W76B, yellow</td>
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<td>Wire, Mil W16878, green</td>
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<tr>
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<td>Wire, misc., yellow, 5/32</td>
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NP - No sustained propagation of flame.
NI - No ignition of material.
SUBSTANTIATION: 1. and 2. Reference to Tables 5-3 and 5-4 in 5-3.3.1 is not correct. Issue of flame spread is discussed in 5-3.3.4.
3. New Table 5-3 is existing Table 5-4 without reference to “After 30-day storage” because this subject is not discussed in document. Reference to English units has been deleted because they are not relevant to issue.
COMMITTEE ACTION: Accept.
Table A: Oxygen Index for Selected Materials

<table>
<thead>
<tr>
<th>Material</th>
<th>Description</th>
<th>OIa</th>
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<td>Polyacetal</td>
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<td>Locite pipe sealant</td>
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<td>user-added 50% glass</td>
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<td>CTFE Lubricants</td>
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<td>Fluorolube GR562 grease</td>
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<td>Halocarbon 25-20 oil</td>
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<tr>
<td>Silica gel</td>
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<td>DNI</td>
</tr>
</tbody>
</table>
Material | Description | OR
--- | --- | ---
Blue Drierite | cup test$^a$ | DNI
Kawool Insulation | alumina-silica | DNI
Cerawool paper | DNI | DNI
Fiberglass/cement board | cup test$^b$ | DNI
Kwik Flux #54$^a$ | DNI | DNI
Asbestos cement board | DNI | DNI
Transite® | DNI | DNI
Siandoys G51® | DNI | DNI
Turmalite TI 150® | DNI | DNI
Asbestos paper | 32 lb/100 ft$^2$ | DNI

$^a$ DNP (Did not propagate), DNI (Did not ignite).

Reference Footnote:

53-45.-(6.3.1.10) Accept
SUBMITTER: Technical Committee on Oxygen-Enriched Atmospheres
RECOMMENDATION: Add new section 6-3.1.10 to read as follows: 6-3.1.10 Guidelines for the design of systems for oxygen or oxygen-enriched service are provided in ASTM Guide G 88 [ref. 1]. The basic intent of the document is to reduce the severity of the environment by avoiding or minimizing the factors that cause ignition and enhance propagation. It does not address the selection of materials of construction for which ASTM Guides G 63 and G 94 are available.

Reference Footnote:

53-47.-(6.3.3) Accept
SUBMITTER: Technical Committee on Oxygen-Enriched Atmospheres
RECOMMENDATION: In NOTE, change reference from "5-3.2.6" to "5-3.4."

53-48.-(6.4 (New)) Accept
SUBMITTER: Technical Committee on Oxygen-Enriched Atmospheres
RECOMMENDATION: Insert new section 6-4 on cleaning to read as follows (Renumber existing 6-4 to new 6-5):
6-4.1 All materials which contact oxygen should be cleaned to remove all foreign material. Of particular importance is the removal of lint, dust, and organic matter such as oil and greases. The latter includes fingerprints. These foreign materials are relatively easily ignited in oxygen and oxygen-enriched atmospheres and could result in an explosion or a fire. A fire could, in turn, ignite the oxygen container or piping. (Ignition mechanisms are listed in 4.3.1.4 and 5.3.2.6).
6-4.2 A variety of cleaning methods is used in practice including: caustic or acid solutions, steam (with or without detergents), hot water (with or without detergent), solvents (with or without vapor degreasing equipment), supercritical fluids, electropolishing, and sand or shot blasting. The method selected depends upon the equipment available, foreign materials present, undesirable side reactions (acid attack of metals, solvent attack of non-metals, etc.), level of cleanliness desired, ability to dispose of spent cleaning agents, worker exposure to the cleaning agents, as well as other factors. The solvent or detergent should not leave a residual material on the cleaned surface.
6-4.3 The level of cleanliness required typically increases with the pressure of gaseous oxygen, and the required level of cleanliness is always high in liquid oxygen systems. A typical cleaning specification used in industrial gaseous oxygen systems is for the remaining organics to not exceed 500 mg/m$^2$ (of oxygen contacted surfaces). Some organizations, including military and NASA, have specifications that can be many times lower than this.
6-4.4 Verification of cleanliness is generally accomplished indirectly via one of several methods:
1) direct visual inspection with white light;
2) direct visual inspection with UV or black light;
3) inspection of a wipe-sample using a clean lint-free cotton or linen cloth, or a white filter paper (examine under white light or UV light);
4) solvent extraction to determine the level of extractable contaminants (non-volatile residue analysis, volume of residue analysis, spectroscopic technique).
6-4.4.1 The reported level of residual organics may be misleading since it is an average level over the surface examined. The organic may actually be concentrated in one area.
6-4.4.2 Such shapes as bellows tubing, Bourdon tubes (in pressure gauges), small diameter piping, dead-legs in piping, and crevices such as in mated pipe threads are difficult to clean. Explosions from residual cleaning agents have occurred within these shapes. It is always desirable to disassemble components fully for cleaning as this mitigates the hazard of remaining solvent. Adequate rinsing and drying time are important. Cleaned parts should not be handled with bare hands. Cleaned parts should be placed in sealed non-contaminating bags (or otherwise sealed with plugs in the case of long piping runs), and labeled as "Cleaned for Oxygen Service."

Reference Footnote:


SUBSTANTIATION: Include guidance on subject not currently addressed in document, and for which a problem exists if not properly done.

COMMITTEE ACTION: Accept.

7-2.5 Metal fire extinguishing agents.

Little data exists on the extinguishing of metal fires in oxygen-enriched environments. Most metal fire extinguishing agents work by forming a barrier between the burning metal and the surrounding environment (OEA), and thus should be somewhat effective on metal fires in an atmospheric pressure OEA. A review of metal fire extinguishing agents can be found in Ref Tapscott et al.¹. Agents commonly used on metal fires that should be avoided in OEA include trimethoxy boroxine (TMB) based agents (additional hazards exist because of the secondary methanol fire and halon additives) and sand (the barrier formed by the sand is permeable to oxygen). Agents that may be effective include copper powder based agents as well as other Class D powders.¹

Reference Footnotes:


COMMITTEE ACTION: Accept.