Oxygen (Compressed Gas) Cylinder Hazard Summary

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Scope

This summary, though developed in 2002, is still relevant and addresses portable medical grade oxygen cylinders (also called tanks or bottles).

It is a SUPPLEMENT and **DOES NOT** replace existing guidelines and directives for proper handling, storage, and operation of medical oxygen (e.g., Joint Commission guidance on storage of "E" cylinders).

Audience

- Patient and occupational safety personnel (e.g., patient safety managers, industrial hygienists)
- Respiratory technicians
- Nurses and technicians who handle oxygen (especially in high use areas like OR & Urgent Care)
- Physicians who direct the usage of oxygen and other gases (interventional radiologists)
- Biomedical Engineers, physical plant personnel, and medical system maintenance personnel

Background/Rationale

- Close calls and adverse events have occurred at VA facilities and private hospitals.
- Human factors engineering design problems have been identified by NCPS through RCAs and the SPOT data base.
- Case studies and "alerts" involving adverse events with oxygen cylinders have been issued from:
    - FDA's Center for Devices and Radiological Health (see the Appendix below this summary) *†
    - ECRI: Case Study*†
      Use of Wrong Gas in Laparoscopic Insufflator Causes Fire Medical Gas Cylinders[Health Devices Jan-Feb 1994;23(1-2):55-6]
    - Compressed Gas Association (CGA) *†

Vulnerabilities

Fire

Materials that are slow to ignite or that will not burn in air will ignite and burn in an oxygen rich environment. This environment is created by oxygen flowing during treatment and the inadvertent releases. 100 percent O2 saturates into surgical drapes, bed sheets, clothing, etc. Ignition sources could include eleculosurgical instruments (e.g., ESU devices - Bovie or cautery pencil), defibrillators, cigarette lighter, matches, outdoor grills, or any other spark or heat-producing appliance. Recent fires have included a patient on O2 who's hair and clothing started on fire while grilling (Hibachi) in his back yard; a patient in the OR who was burned when surgical drapes ignited due to oxygen and use of an ESU.

Rapidly opening a valve on a compressed gas cylinder can cause particle impact ignition resulting in a fire (this is why aluminum regulators are not permitted - aluminum is a combustible metal).

Mix-ups

CO2 and O2: A grayish green cylinder was confused for a greenish gray cylinder that resulted in a patient inhaling CO_2 during transport instead of oxygen. The use of universal adaptors (universal adaptors override the pin indexing system on the cylinder) contributed to this event.

CO2/O2 and CO2**:** Insufflation of the body cavity for arthroscopy is done with CO2 as the gas will not sustain combustion and is easily absorbed by the body. A gray and green CO2/O2 cylinder was confused with the gray CO2 cylinder that resulted in an internal body cavity fire when a surgical laser was used. The CO2/O2 gas will support combustion.

Oxygen not available

It isn't always apparent whether an oxygen cylinder is full, partially full, or empty. In cases where the cylinder valve is closed and the regulator valve is open (see photograph; click on photo for larger view), no pressure will register on the pressure gauge. Staff in a hurry has assumed the cylinder is empty when in fact it is full.<

In some cases the O2 cylinder is believed to be empty when trapped pressure in regulator is bled off by opening the flow meter/regulator valve when the cylinder valve is in the closed position.

You can't always tell by just looking at the valve if it's open or closed. Valves controlling the oxygen flow are not indicating type valves. What's an indicating valve? See: A Brief History of Indicating Valves for Fire Protection*† for further information on this topic.

Cylinder goes ballistic

Ferromagnetic O_2 cylinders introduced into the MRI environment can inadvertently be turned into missiles when they are drawn into the magnet. For more information on projectile hazards in and around MRI's see the MR Hazard Summary*† available in this section of our website.

A second way a cylinder can be turned into a missile is to fracture the cylinder. Escaping gas will propel the cylinder with enough force to penetrate cinder block walls.

Case Studies

From FDA Manufacturer and User Facility Device Experience Database (MAUDE), ECRI, and VA databases

- An "E" cylinder containing CO2 was mistaken for O2 and was used during patient transport - he died. The modified O regulator had been modified to fit "grayish" O2 cylinder that really contained CO2. This event emphasizes the point that cylinder color alone cannot be used to confirm the content of the cylinder (see Appendix, case 1)
- A gray "E" cylinder (usually indicating CO2) was used for insufflating a uterus for endoscopic laser surgery. Instead, it contained a 20% CO2 - 80% O2 mixture normally used by anesthesiologists to induce breathing. Use of the laser resulted in an internal fire. This event again emphasizes the point that cylinder color may not be used as the primary indicator for the type of gas the cylinder contains (see Appendix, case 2).
- Misunderstanding of the dangers of using O2 near ignition sources have resulted in minor fires and burns while: a) patient using a Hibachi grill on home O2 therapy; b) hospital team used a defibrillator during cardioversion; and c) operating room team used electro-surgery (see Appendix, case 3).
- Empty O2 cylinders have been inadvertently stored in code (crash) carts. During ACLS, the empty cylinder either contributed to difficulties in resuscitation, or caused undue commotion and diversion.

Root Causes and Other Factors

- The most obvious cue for staff on the contents of a gas cylinder is the cylinder color, however, the color may be misleading or misunderstood. The cylinder label is the primary means of identifying the cylinder content. Follow directions and labels first - not color or other cues (e.g., storage location) … To be truly effective, CGA/ECRI recommends that the label be overwhelming in size.
- If there is a mismatch between the color of the cylinder and the cylinder content, for example a gray cylinder that contains oxygen or a green cylinder that contains nitrogen,

this is a guarantee that future problems will occur. For more information on color mismatch confusion and how humans cannot ignored conflicting inputs see the "Stroop Effect" exercises.*† Provide as many cues that a cylinder does not contain 100% O2 as possible for mixed and non-O2 gas cylinders (e.g., store separately, transport in "odd-shaped" wheel cart).

- Text labels on cylinder can be damaged or for some reason may be illegible; if the label cannot be reliably read the cylinder should not be used.
- Cylinder tags (Full/In-use/Empty) are often misused and misunderstood and are a relic from systems used for compressed gases found in industry (welding torches, etc). Relying upon the pressure gauge reading is the most effective method of determining how much gas is left in the cylinder.
- Improved cues are needed to signify to non-experts when cylinders are "empty" (like the empty cylinder warning light on your dashboard). For example, caution labels stating which valves need to be open.
- The regulator pressure gauge appears to be direct measure of gas available in the cylinder - however it can be isolated from the cylinder by closing the cylinder valve. If this occurs the gauge is only reading pressure trapped between the cylinder valve and the flow meter/regulator valve.
- Compressed gas pin indexing systems should not be overridden or defeated under any circumstances.
- To prevent ballistic missile type injury all cylinders, even empty ones, should be handled as if they are pressurized (all guns are "loaded").

Next Steps

- Color-coding may be misleading and is not ideal for use in identifying medical gases., NCPS will work with CGA and FDA to determine optimal labeling without use of color for coding on cylinders.

References

- FDA: "Avoiding The Hazards Of Medical Gases" July/August 2000 FDA Consumer Magazine
- FDA Med watch Alert March 2001 - on mix-up of oxygen and other gases
- CGA/USP/AGA/ISO: "Standard color marking of compressed gas containers intended for medical use" 1988, reaffirmed Sept 1993. Compressed Gas Association, Inc. 1235 Jefferson Davis Highway, Arlington, VA 22202 (see summary of content*†).

Appendix

Three case studies from FDA CDRH databases

1. FDA's MAUDE Database -- Case study from searching on "CO2 Cylinder"

Report Date: 07/20/1999
MDR Text Key: 783215
Patient Sequence Number: 1

At approximately 12:30 pm, July 12, 1999, a vascular shut was placed in a pt. for the purpose of dialysis. The procedure was successful and the pt. was prepared to return to the nursing unit. The oxygen connection was removed from the wall oxygen source and attached to a portable cylinder. The oxygen cannula was then attached to the pt.'s existing tracheostomy. The pt. was then transported by bed to the ICU. On arrival to the ICU, the pt. was noted to be in a ventricular fibrillation. The pt. then became apneic and sustained a cardiac arrest. Cardio-pulmonary resuscitation was implemented, including medication (calcium and sodium bicarbonate) and intravenous fluids. The pt. failed to respond and was pronounced dead after approximately 10 minutes. At this time, it was discovered that the portable cylinder used to transport the pt. was a carbon dioxide cylinder. The physician involved in the case concluded that the CO2 had probably contributed to the pt.'s cardiopulmonary arrest. On examination, it was noted that the original tank used for transport was an aluminum O2 tank with green paint near the top and the CO2 tank was a steel container that was similar in color to the O2 tank that was originally used for transport to the OR. The gunmetal gray color of the CO2 tank was significantly distorted by rust. In addition, the CO2 tank contained a standardized (DOT) green label that read "Non-flammable." The standard green label was located near the top of the tank where green paint was located on the original aluminum O2 cylinder. In addition to this, the CO2 tank was equipped with a flow meter and a green nipple adapter that was similar in appearance to the flow meter used for oxygen. The regulators on the two canisters looked identical, with the exception of the words, "Carbon dioxide," written in small print on the flow meter portion. In essence, the pin indexing system that was designed to constrain this type of event was over-ridden by a look-alike product. Further review revealed that the color and type of oxygen tanks located in the facility were inconsistent. Tanks could be steel, painted in light or dark green. They might also be aluminum (gray) in color with a green painted band at the top. The CO2 tanks had a greenish hue, with rust marks and scratches on them. Both had DOT labels, which have a green background. The vendor was notified.

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2. FDA's MAUDE Database -- Case study from searching on "CO2 Tank"

Report Date: 01/30/2001
MDR Text Key: 1084430

The CO product's polybag instructs the user for oxygen connection location. Section H.3: Device evaluation summary … The MedWatch report filed by the user facility, dated 12/2000, indicated that a hospital staff member accidentally obtained a CO2 tank instead of an O2 tank and connected the tubing to the CO2 flow meter connection on the tank regulator. The report also indicated that as a result of this, the pt. had a cardiac arrest. CPR was administered, the pt. was reconnected to the 02, and the pt. had a good recovery. The staff member later recognized the error. Although the account did not report the finished product code number, the did provide a component part number. No sample was returned to VIS for investigation. A document investigation revealed that the CO shipped two orders of code blue II resuscitator, 7552K, lot number A042, to this account. Based on this the CO believes that this may be the product code and lot number involved in this incident. The CO document investigation revealed that the tubing used in this lot number had a green connector on the end of the tubing. The green color is used to alert the end-user that the tubing is used for oxygen supply. Based on this investigation, the CO believes that this incident is the result of user error, not product malfunction or performance

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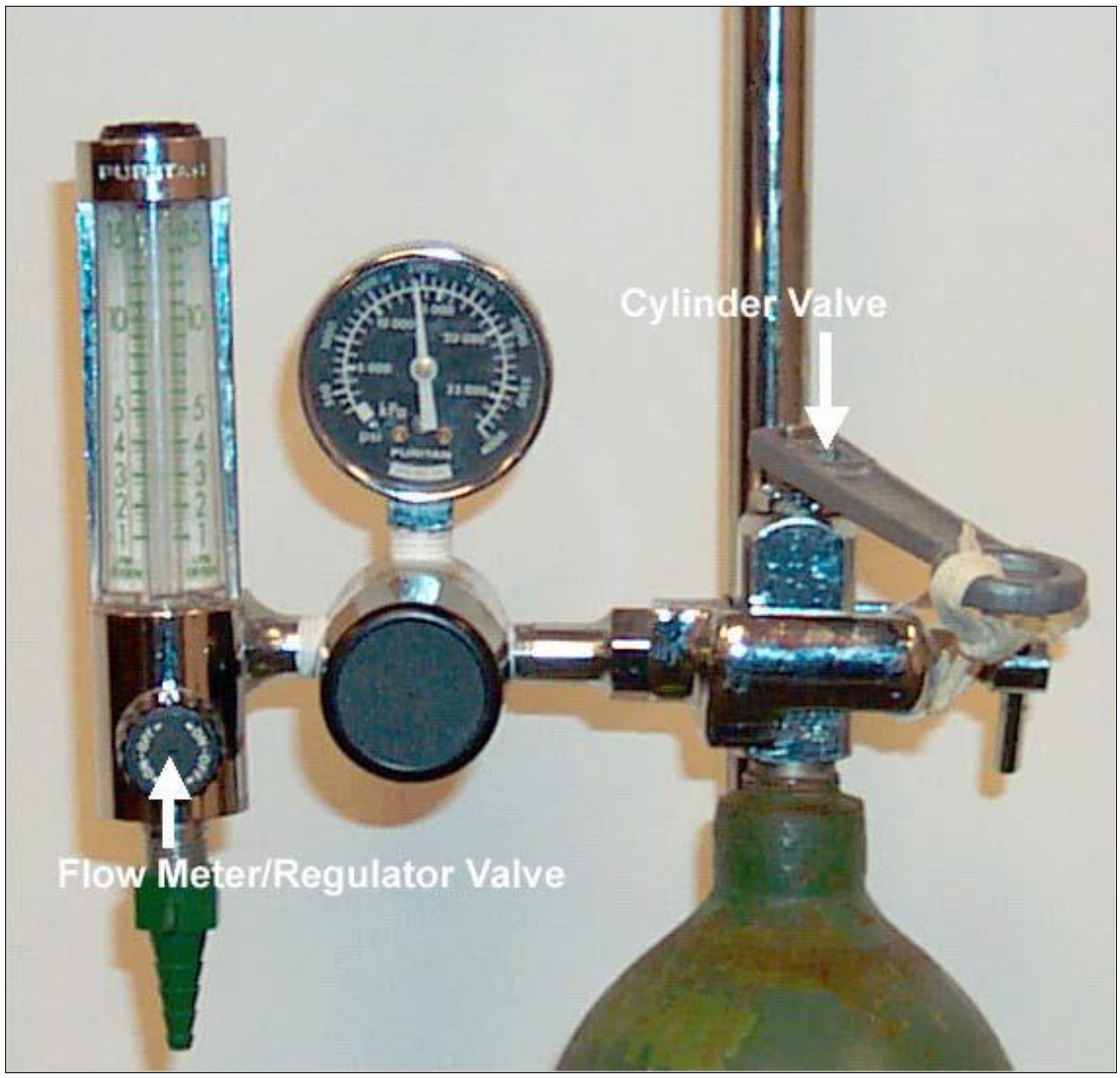
3. FDA's MDR database -- Case study from searching on "O2 and CO2"

Access Number: M331912
Date Received: 11/20/92
Product Description: LAPAROFLATOR

Event Description: Although this unit is specified to be used with CO2 only, the hospital hooked the Laparoflator up with a CO2/02 mixed gas by mistake (14% CO2 and 86% O2). While the laparoscopic cholecystectomy procedure was about 95% completed, an explosion occurred inside the pt. The doctor opened the pt. to verify any damage and found no injury to the pt.



O2 cylinder appears empty, after initially being full (main valve open, inter-valve area pressurized, gauge now reading full, then main valve re-closed).