

Potential Hazards of Compressed Gas Cylinders:

A Review

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Hospital personnel must be familiar with potential problems arising from medical compressed gases in order to recognize and reject unsafe cylinders.¹ The present report describes the problems we have experienced with compressed gas cylinders.

METHODS

The Beth Israel Hospital uses "H" cylinders to supply oxygen and compressed air to some patient rooms, and to supply nitrogen to the operating rooms. "E" cylinders of oxygen are used for patient transportation, cardiac arrest, and as back-up supply on all anesthesia machines. "E" cylinders of nitrous oxide are the only supply of that gas. Cylinders also provide the reserve system for our bulk oxygen supply. All of the cylinders come from two suppliers. All of the "H" cylinders come from one supplier, while all of the "E" cylinders come from the other. All cylinders delivered are carefully inspected. The results of these inspections form the basis of this report. Gas chromatographic analysis was performed on those tanks suspected of being contaminated.

RESULTS

Over the four-year period 1972-1975, 14,000 tanks of medical compressed gas were delivered to the Beth Israel Hospital. Irregularities were recorded for 120 cylinders (1.2 per cent). Irregularities occurred in five major areas:

1) *Cylinder contents*: Six "H" cylinders labeled "compressed air" were noticed to have an unusual

odor to the "air." Gas chromatography revealed contamination with several fluorinated and chlorinated hydrocarbons in concentrations of 6-8 ppm. Partially filled and empty cylinders of oxygen were delivered labeled full on numerous occasions, accounting for 33 per cent of all incidents. Overfilled tanks of oxygen with pressures as high as 4,000 psig were found on two occasions. A cylinder of nitrous oxide was overfilled to a pressure of 1,500 psig.

2) *Cylinder identification*: A label indicating the contained gas was missing from 30 cylinders. Many cylinders had their markings painted over so that they could not be read without scraping off the paint. Caps were also painted into place. On four occasions cylinders labeled "compressed air" arrived painted colors other than their standard yellow.

3) *Cylinder valves*: Five cylinders were delivered with compressed air labels and contained compressed air; however, the cylinder outlet utilized oxygen threading. The valve assemblies were loose on two cylinders of oxygen and 12 cylinders of nitrous oxide. The valve assemblies were inoperable on four cylinders.

4) *Cylinder testing*: Many cylinders arrived without evidence of inspection within the required ten-year period. In many of the instances there was paint over the stamps so that evidence of testing could not be ascertained.

5) *Cylinder storage*: Cylinders of oxygen were found to be stored with cyclopropane on one occasion. All oxygen "E" and "H" cylinders were stored in wooden flammable racks. Improper securing of cylinders was also seen. On one occasion a patient was receiving oxygen by face mask from an "E" cylinder which had been left unsecured, standing upright. The cylinder tipped over, the regulator snapped off, and the tank was propelled about 30 feet down the corridor. On another occasion two improperly secured "H" cylinders of oxygen tipped over and opened, partially causing them to roll about from the force of the oxygen stream. In a third instance, a respiratory therapist entered a patient's room to find the patient hoisting himself out of bed by pulling on an "H" cylinder cart, in the process nearly tipping over the cylinder. No patient was injured.

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DISCUSSION

The regulations pertaining to compressed gas containers, in general, are well thought out and have been summarized elsewhere.² All of the problems we encountered should not have occurred if the supplier and the hospital had adhered to National Fire Protection Association (NFPA) regulations and Compressed Gas Association (CGA) guidelines. A similar pattern of poor compliance was also found when we investigated bulk gas delivery systems.^{3,4}

Hydrocarbon contamination of compressed air is a potentially serious hazard. This possibly occurred at some stage during filling of the cylinders. Gross contamination such as this can be detected by the practice of "cracking" a cylinder before use. CGA guidelines state that there should be no odor from the contents of either oxygen or compressed air cylinders, however, trace quantities (<5 ppm) of hydrocarbons may not be in violation of existing standards.^{5,6}

The fact that some tanks were found to have oxygen at pressures of 4,000 psi suggests that the safety relief valve of the cylinder valve may not have been functional. The bursting pressure of the cylinder in question is about 5,700 psi. The safety relief valve is required to relieve excess pressures that might occur in circumstances such as intense heat. If the valve used were a combination frangible disc-fusible metal safety device it would not vent excessive pressure unless heat was also present. If the valve were a frangible disc safety device it should have vented the excess pressure. Such a failure could occur if two discs were placed instead of one.⁷

The lack of labeling, the mislabeling, and the painting over the labels of cylinders was in violation of Department of Transportation (DOT) regulations.⁸⁻¹⁰ All medical gases should be marked in several ways. The cylinder is stamped with the type of cylinder and its service pressure. This is followed by a serial number and an identifying mark of the original owner or the manufacturer. There is then the date of the most recent cylinder testing. Each cylinder is also labeled stating the gas which is contained. A tag also is affixed to each tank which states the gas contained and indicates whether the tank is full, in use, or empty. The color coding of cylinders is established by the CGA, and most manufacturers adhere to this code.¹¹ This code is not mandatory in the United States at the present time, so the best guide to the cylinder contents is the label and not the color.² Absolute identification can be assured only by gas analysis.

Finding oxygen threading on the valves of compressed air cylinders should not occur. Valve threads are standardized so that gas connections cannot be interchanged.¹² The use of appropriate threading or

pin index systems is covered by CGA standards; however, this is not mandatory by any government regulation. Loose or leaking valve assemblies are obviously hazardous. Inoperable valves should not be tampered with; the cylinder should be returned to the supplier.

All cylinders should be tested every ten years. The cylinder is tested to 1.66 times its normal service pressure. The date of testing is stamped on the cylinder.² Outdated cylinders such as the ones we found should be returned to the supplier.

The violations regarding cylinder storage resulted from neglect on the part of hospital personnel. Improperly secured cylinders that fall are a tremendous hazard, and can act as missiles, as one of ours did. All cylinders should be stored in a well-ventilated room, and not in areas with flammable materials or other flammable gases. All cylinders should be secured in a carrier or be chained to a fixed object. Storage racks and carriers should be constructed of nonflammable material. The valve should be protected, since it is the most vulnerable portion of the cylinder.¹³⁻¹⁵

The difficulties we have encountered with medical gas cylinders developed because of lack of compliance by suppliers and the hospital with existing NFPA, CGA, and DOT guidelines. The Joint Commission on Accreditation of Hospitals requires compliance with these regulations for accreditation. Users of gas cylinders are frequently unaware of regulations governing use and storage. Few users are aware of the appropriate mechanism for correcting problems encountered with infractions caused by manufacturers or suppliers. Although the Department of Transportation is charged with enforcing regulations governing some aspects of gas cylinders, several commonly encountered problems are not covered by DOT regulations. Cylinders with valves stuck closed, improper outlet indexing, improper color coding, or contaminants in the cylinder of a noncorrosive nature are not regulated by the DOT. There is no formal mechanism within the DOT through which the user can report problems with cylinders. After it has been determined that the DOT indeed has jurisdiction over a particular problem, the appropriate agency within the DOT must be contacted with the complaint. That agency will vary according to the means used to transport the cylinder to the user institution.

The most efficient method available for reporting problems encountered with cylinder gases is through the United States Pharmacopeia (USP) Problem Reporting Program. Forms are available from the USP.¶

¶ United States Pharmacopeia, Inc., 12601 Twinbrook Parkway, Rockville, Maryland 20852. Attn: Dr. J. G. Valentino.

Information sent to the USP will be forwarded to the appropriate regulating group and the manufacturer or vendor of the cylinder in question.

Compressed gas cylinders are potential hazards to patients and hospital personnel. In our survey, 120 (1.2 per cent) of 14,500 cylinders delivered to us had potentially hazardous irregularities. The hazards of medical gas delivery systems are not the result of a lack of regulations, but are the result of lack of compliance with existing regulations by gas suppliers and hospitals. All personnel involved with supplying and administering medical gases should be aware of the existing regulations to minimize accidental harm. Occupational Safety and Health Act (OSHA) standards require that each hospital determine that compressed gas cylinders used in that institution are safe (Section 1910.166).¹ Experience in cylinder inspection is therefore important. OSHA recommends that users lacking experience in cylinder inspection should return any doubtful cylinders that do not have: 1) a label or tag indicating gas content, 2) the proper valve outlet, or 3) the proper color on the tank for the gas contained. Additionally, all problems with medical gas delivery systems should be reported, so that problems can be analyzed and regulations updated if necessary.

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REFERENCES

1. Federal Register, Vol 37, #202, Oct 18, 1972, p. 22248
2. Dorsch JA, Dorsch SE: Understanding Anesthesia Equipment. Baltimore, Williams and Wilkins 1975, pp 1-14

3. Feeley TW, Hedley-Whyte J: Bulk oxygen and nitrous oxide delivery systems: Design and dangers. *ANESTHESIOLOGY* 44:301-305, 1976
4. Feeley TW, McClelland KJ, Malhotra IV: The hazards of bulk oxygen delivery systems. *Lancet* 1:1416-1417, 1975
5. Commodity specifications for oxygen, Pamphlet G-4.3, Compressed Gas Association, 500 Fifth Avenue, New York, New York 10036, 1966
6. Commodity specifications for air, Pamphlet G-7.1, Compressed Gas Association, 500 Fifth Avenue, New York, New York 10036, 1973
7. Safety relief device standards, Pamphlet S-1.1, Compressed Gas Association, 500 Fifth Avenue, New York, New York 10036, 1969
8. A guide to the preparation of labels for compressed gas containers, Pamphlet C-7, Compressed Gas Association, 500 Fifth Avenue, New York, New York 10036, 1960
9. American standard method of marking portable compressed gas containers to identify the material contained, Pamphlet C-4, Compressed Gas Association, 500 Fifth Avenue, New York, New York 10036, 1954
10. Characteristics and safe handling of medical gases, Pamphlet P-2, Compressed Gas Association, 500 Fifth Avenue, New York, New York 10036, 1971
11. Standard color-marking of compressed gas cylinders intended for medical use in the United States, Pamphlet C-9, Compressed Gas Association, 500 Fifth Avenue, New York, New York, 10036, 1973
12. American standard compressed gas cylinder valve outlet and inlet connections, Pamphlet V-1, Compressed Gas Association, 500 Fifth Avenue, New York, New York 10036, 1965
13. Safe handling of compressed gases, Pamphlet P-1, Compressed Gas Association, 500 Fifth Avenue, New York, New York 10036, 1965
14. Standard for the use of inhalation anesthetics, NFPA 56A, National Fire Protection Association, 470 Atlantic Avenue, Boston, Massachusetts 1973
15. Inhalation therapy, NFPA 56B, National Fire Protection Association, 470 Atlantic Avenue, Boston, Massachusetts 1968

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Gas Embolism during Laparoscopy

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Surgeons and anesthesiologists involved with laparoscopic procedures are aware of the potentially dangerous complication of gas embolism, although the exact incidence is unknown. Bruhl reviewed

63,845 laparoscopies for diagnostic procedures other than tubal sterilization and found only one case of gas embolism among 1,594 serious complications.¹ Since laparoscopy is performed frequently all over the world for tubal sterilization and various diagnostic procedures, we decided to monitor 100 patients with Doppler ultrasonic instrument.

METHOD

All patients undergoing laparoscopic procedures irrespective of age, color or prior disease, were included in the study.

The protocol included:

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