

Hyperbaric Chamber Fires: Lessons Learnt

Dick Clarke, CHT

Hyperbaric Chamber Fires

Lessons Learnt

Primary Training in Hyperbaric Medicine
Columbia, South Carolina

Factors Precipitating Chamber Fires

- Absence of design/manufacturing codes; code non-compliance
- Lack of a formal fire safety plan
- Inadequate fire safety plan
- Apparently adequate fire safety plan not adhered to
- Unanticipated factors

Absence of design/manufacturing codes: code non-compliance



Steel monoplace at 2.4 ATA
air compressed, mask O₂; inboard dump
no analyzer so unknown O₂ concentration

Flash fire
structural integrity maintained
hot gases melted door seal, cut through concrete floor, blew out building windows

Cause of ignition: non-intrinsically safe communication system



Intrinsically safe

- keeping level of electrical energy too low to cause ignition
thereby preventing sparks & keeping temperatures low
- device designs that exclude oxygen
plus, purging device with inert gas
- device strong enough to contain explosion
- moving device outside hazardous (chamber) area

No chamber design/construction codes & standards in Peru *some such countries adopt authoritative standards*

Lack of adequate operational safety procedures

- no overboard O₂ dump*
- unknown chamber O₂ concentration*
- no pt. grounding*
- oil lubricated air compressor ? filtration*

**Monoplace Chamber Fire
Lima, Peru, 2006
Incident Report**

Glenn J. Butler,
President & CEO

R.W. "Bill" Hamilton, Ph.D
Hamilton Research

Michael W. Allen,
Senior Vice President – Operations & Safety

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 10000 W. Higgins Road, Chicago, Illinois 60631
 1-800-955-7273 • 773-439-8800

Life Support Technologies group
200 W. Main Street, Suite 100 • 1990
 Northampton, Massachusetts

Lack of a formal fire safety plan



Lauderdale-by-the-Sea, Florida, May 2009
 fire engulfed chamber & 2 occupants at 1.75 ATA O₂
 ~ 4 yo CP pt., 62 yo grandmother
 ~ his txs started 7 months earlier!
 operator (trainee) didn't know procedure for
 emergent decompression
 ~ tried several times to open door while pressurized
 both occupants succumbed

Vickers "clam shell" manufactured in 1967
 Burn pattern again suggested internal speaker as source
 Legal proceedings:
 Adult "reached to adjust cushion, static discharge from her clothing jumped to earphone jack"
 Adult "banged on chamber for five minutes to attract attention"
 "Nobody was monitoring them and when fire started victims were required to scream and bang on glass (sic) dome to get the attention of a bystander who in turn notified staff of the fire, which caused a delay in decompressing the chamber and freeing the victims before the flash fire occurred. When police deputies arrived, the victims were still in the chamber and on fire"



Numerous pages of safety violations
 Most damning, set up fictitious inspection company
 "Certified Hyperbarics" for federal facility certification application
 Medical Director & CHT "exhibited gross lack of competency, gross inattention, criminal indifference to pt. safety"
 Both guilty of "aggravated manslaughter of a child & manslaughter by reckless disregard of human life & safety of persons exposed to dangerous effects"

Lack of a formal fire safety plan



Steel oxygen-filled monoplace chamber
 single pt. fatality
 attempted to smoke cigarette



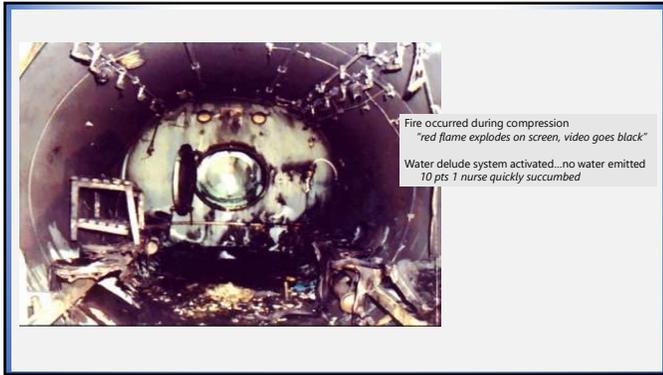
Hospital admitted responsibility...

"We did not warn pt. that smoking or taking a lighter into the chamber could be dangerous"

Inadequate fire safety plan



Multiplace chamber Milan, Italy
 personal clothes; synthetics/pockets
 no pt. or IA checks...pockets
 hood exhaust system disconnected
 "improperly modified hood latex neck seals allowed O₂ to escape into pt. clothes making patients flammable cylinders"
 chamber O₂ concentration commonly exceeded permissible limit
 "O₂ monitor alarm manipulated"



10 patients and nurse die within seconds in hospital fire

Several newspaper accounts/Letter to Lancet

Fire lasted ~ 30 seconds

led some to believe it was extinguished vs burning itself out

Fire dept official, "fire unstoppable in high O₂ content"

inconsistent with previous water deluge experience

Initial official report

"Patients going into the chamber were checked by two doctors for flammable objects, but something must have slipped through"

Court proceedings

"A lady enters the hyperbaric chamber where she is to undergo treatment and brings with her an alcohol-based hand warmer, those with flame. From that hand warmer starts the fire that kills, after a slow agony, all the people who were inside."

Initial official report

"Automatic in-chamber fire-fighting system went into immediate action, and the fire was put out within less than one minute"

Court proceedings

"The fire extinguishing system was not functioning as the tank that was supposed to contain the water was empty, the propellant compressed air cylinder had the tap closed and the water supply hose valve was closed. The hand shower inside the hyperbaric chamber, foreseen in the design phase, had not been installed."

Inadequate fire safety plan

Chamber operator opened 3-way valve to select BIBS O₂ source selected >2,000 psig (non-reduced) option reported hearing 'sizzling bacon' sound

Fire immediately erupted from chamber control panel

flame shot out 3 feet/1 meter, spraying molten stainless steel penetrated steel filing cabinet igniting contents chamber tech burned on face, arms, back, as she moved pt. fire extinguished only when O₂ supply secured

Facility sprinkler system & fire alarm activated

News Briefs

Oxygen Fire at Shands Teaching Hospital in Gainesville, FL

Hyperbaric Medicine Center Dedicated to Dr. Jefferson C. Davis

2nd International Meeting on High Pressure Biology

Chamber Fire Analyzed

Misc. Courses

Desautels DA, et al. PRESSURE Nov/Dec 1990

"Likely cause...high-velocity particle impacts"

ignited valve's Teflon seating & seal material

several fittings significant for "sand blasting" appearance

likely source of particles...HP O₂ cylinder valves & piping

Auto-ignition temperature of valve seating 400-700 F/200-370 C

particle friction heating in HP O₂ exceeds 1,600 F / 870 C

Lessons learned-safety standard failures

- protect disconnected oxygen piping
- oxygen piping "cleaned for oxygen service"
- HP oxygen reduced at source
- quarter turn valves contraindicated > 125 psig
- filtration at source/prior to reducing regulator
- larger diameter piping reduces oxygen velocity/related heating



Apparently adequate fire safety plan not adhered to



Istanbul University Medical Center
 Multiplace chamber fire July 1998
 3 fatalities: 2 divers, 1 physician

Latter stages extended USN TT 6

Chamber O2 atmosphere not monitored nor routinely flushed
one diver/pt. using mask with overboard exhaust, second using hood with inboard exhaust

Two "lightsaber-like" oxygen flames seen emitting (via viewport)
spontaneous ignition within regulators

Chamber operator did not/could not activate water deluge
*Internal fire extinguisher not activated
 Flames only died out when oxygen system completely exhausted*

Relief valves lifted (10 ATA)

Chamber internal temperature estimated to have exceeded 1,000C/1,800F

Inadequate system maintenance; particularly O2 delivery system cleanliness

Operational practices inconsistent with recognized standard of care

Physician entered chamber with cigarette lighter

"In all incidents I have encountered in my 30-year hyperbaric practice, the people who accidentally put a lighter or mobile phone inside are inside attendants and doctors, because patients are checked before each entrance"

Inadequate/non-existent emergency drills

No visible evidence of burns on deceased (hair/eyelashes intact)



Authoritative codes re animal chamber construction
 guided but not certified per human standards?

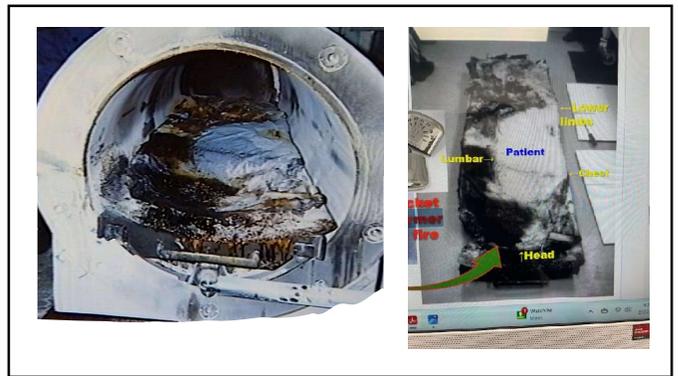
Formal training in hyperbaric technology/safety

Water deluge system?

Methane gas detector-chamber flushing issue?
 becomes explosive 5-17% range in air...? HBO
 loudest explosions >10% in air...? HBO



Year	Type Chamber	Fire/Explosion	Cause	Fire fighting	Severity of the patient (Full body -bed?)
1967	Monoplace (O ₂ compressor)	Fire	Ignition, charcoal pocket treatment	Unknown	1 patient dead
1989	Monoplace	Fire	Ignition, Patient cardiac treatment	Fire extinguisher	1 patient dead
1992	Monoplace (O ₂ compressor)	Fire	Ignition, Patient cardiac treatment	Fire extinguisher	1 patient dead
1996	Monoplace (O ₂ compressor)	Fire and Explosion	Ignition, Oxygen pocket treatment	None	1 dead (1 patient / 2 others)



Apparently adequate fire safety plan not adhered to

Initial statement released by hospital was that all recommended safety procedures were carried out

Oxer H. SPUMS Journal 1996;26(4)



Monthly Safety Notice
 NATIONAL BIOMEDICAL DEVICES, INC.
 JANUARY 2022

Importance of Optimizing Chamber Gas Flow

Background
 The SPECTER 2008 hyperbaric chamber operates under a mode of constant gas (oxygen) flow. Flow can be adjusted via a control valve located within the oxygen source assembly, to the "closed" position the control valve opens approximately 340 lpm of flow. By design, and to avoid a potentially hazardous accumulation of CO₂, flow cannot be completely stopped. In the fully open position, flow peaks at approximately 480 lpm. Adjustment of the control valve between these two extremes provides a corresponding flow volume ranging between 340 and 400 lpm.

The constant flow of gas serves to eliminate metabolic waste gases and provides a cooling mechanism, lower flow rates reduce the cooling effect.

Deluxe
 The principal cause of oxygen or chamber compression and constant flow is the patient's liquid oxygen (LO₂) system. The oxygen is drawn from a liquid oxygen dewar. As the treatment, on demand, to the hyperbaric chamber into a variable gas, via an associated operating system. Replenished of from the dewar, the resulting gas is essentially dry. It contains little to no moisture.

While a dry gas has the benefit of minimizing corrosion damage to system piping and wiring, this beneficial side effect can affect hospital safety. A dry air atmosphere promotes a greater accumulation of static electricity. A resulting static electrical discharge may generate sufficient energy to cause ignition of volatile materials (hydrocarbons) used in the facility, device, or patient materials, hydrocarbon components, etc.

Key Operational Issues

- Under routine operations, as the rate of gas flow through the chamber is decreased the chamber atmosphere's relative humidity increases. This effect is the result of a greater accumulation of the patient's exhaled water molecules within the chamber. This is a good thing.
- If the patient complains of being too warm:
 - Decrease the chamber flow rate of oxygen flow. This is all too frequently the action taken, yet it represents an increasing safety hazard. Should it occur within the chamber, more fuel is available. It could represent the difference between a fire entirely contained within the chamber versus a fire that results in catastrophic failure of the chamber, and potential damage to the entire facility, and its staff.
- If a patient complains of being too cold:
 - Complete the chamber at a low rate of flow rate in order to limit the effect of compression on heat production.
 - Increase chamber flow increase rate for optimal comfort, however, never increase the flow rate until it results in adverse patient health.
 - Monitor the chamber's body temperature with a range of 98-101°F.
- If a patient complains of being too cold:
 - Close the emergency valve.
 - If the staff is unable, switch the sheet out for a blanket.
- Call into the facility regarding the oxygen flow settings and/or the chamber treatment pressure. Don't the patient in position, once a treatment is underway, and you've not been given the flow setting.

Recommendation
 Know the flow rate of all times. Optimize for patient comfort.

Reading Assignment
 Read **IS 1905 Electrically Hazardous Facility Safety A Practical Guide to Prevention**, 2009, 333.

Apparently adequate fire safety plan not adhered to

Follow Instructions for Safe Use of Hyperbaric Oxygen Therapy Devices – Letter to Health Care Providers

August 25, 2020

The U.S. Food and Drug Administration (FDA) is reminding health care providers and facilities about the safe use of hyperbaric oxygen therapy (HBOT) devices and the importance of following the manufacturer's instructions for use. The FDA is aware of reports of serious injuries and deaths with use of HBOT devices and is providing recommendations for health care providers and facilities to help reduce potential risks.

Recommendations for Health Care Providers and Facilities

- Review and follow the manufacturer's instructions for use for each hyperbaric oxygen therapy (HBOT) device being used.
- Ensure the prevention and safety measures are followed for HBOT devices.
 - Be aware that there is a heightened risk of fire with use of oxygen at a high concentration.
 - Ensure proper grounding equipment is used.
 - Ensure proper training is provided and maintained for staff with use of HBOT devices.
 - Ensure the patient is properly monitored and supervised for the duration of the treatment with use of HBOT devices.

Inadequate fire safety plan

One of several chambers Naval Hospital Central Jakarta, Indonesia

Fire & "explosion" > 4 deaths
 3 pts. 1 physician
 room filled with smoke > several occupants hospitalized (2 remained so at 7 days)

Operator...

"tried using water deluge system but too late"
 "failed to activate deluge system"
 "deluge system inoperable"
 "deluge system activated but inadequate to extinguish flames"

Hospital declared...

"It had complied with strict operating procedures"

NEWS NATIONAL
Fire kills 4 inside hyperbaric chamber

Over the wire

AP Wirephoto
 AP Wirephoto
 AP Wirephoto
 AP Wirephoto

Apex from The Japan Post
 January 7, 2019, 12:02 PM

A fire ignited a high-pressure air cylinder at Hiroshima's Navy hospital in December 1988, causing deaths, on Monday, killing four people, including a police officer.

The fire reportedly broke out after an electrical short circuit occurred in the cylinder, which is usually used to treat patients with decompression sickness. At the time, four patients were inside the cylinder... also known as a hyperbaric chamber... intended to be an emergency use treatment room.

It was reported that after the fire breaking out, the doctor and patients started a fire-fighting activity at 11:30 a.m. with the cylinder valves set at a certain pressure. At 1 p.m., the therapy continued as a reduced pressure. The cylinder blew, a fire broke out and the cylinder...

The incident led to a report on the chamber being in the emergency system but was unable to. The fire then caused an explosion which led to the pressure and damaged the room where the cylinder was located.

At 2 p.m., the activities resumed to undergo for the first and removed the cylinder... building, taking them to the hospital... a mortuary.

The fire caused 4 deaths and 4 injuries. The fire occurred in the emergency room for treatment for decompression sickness.

Navy spokesperson Oda, H. Zuhale said the hospital had never before experienced such an accident as the chamber was in good condition.

... but just found the accident by themselves. Therefore, representing the Navy and Hiroshima hospital, we apologize to the citizens. We will not expand this to happen... Zuhale said.

The fire hyperbaric chamber was used to treat decompression sickness. The fire... safety program (General Hospital) workers use the chamber to prevent also done by transferring the oxygen to the tank. Children are also able to use the chamber for...

Police: Negligence may have caused fire at Navy hospital

Over the wire

AP Wirephoto
 AP Wirephoto
 AP Wirephoto
 AP Wirephoto

AP Wirephoto
 January 7, 2019, 12:02 PM

The police Friday said they are investigating the cause of a fire in a hyperbaric oxygen cylinder which caused a fatal fire at a hospital in Hiroshima on Monday, killing four people, including a police officer.

AP Wirephoto
 January 7, 2019, 12:02 PM

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Unanticipated factors

Journal of Hyperbaric Medicine, Vol. 4, No. 2, 1993

Fire in the Multiplace Hyperbaric Chamber

B. A. Youn, D. Gordon, C. Murray, and B. Brown

Department of Hyperbaric Medicine, Denver General Hospital, Denver, Colorado

Multiplace chamber at 2.0 ATA
2 inside attendants
4 patients; 3 adults, 1 4-wk-old

SOP microwave warming of blankets
 some pediatric, all neonates

Youn B, et al. J Hyperbaric Med 1989;4(2)

Cotton blanket warmed for 2.5 mins. high setting

Scorched (ironed shirt) smell upon removal

Examined by unfolding several times
nothing untoward/not unduly hot

Compressed in medical lock

Upon receipt into chamber IA noticed 2 brown spots
blanket immediately developed open flame

IA attempted to reinsert into lock

Chamber deluge activated...twice



Burned 100% cotton blanket



Carbon deposits below medical lock

Pts switched to air breathing

Poor visibility resulted in second deluge

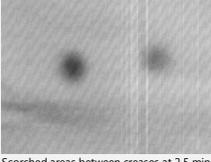
All occupants uneventfully decompressed

Pts counseled & monitored; 3 inpts.

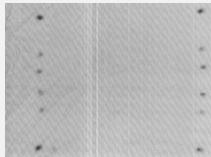
All eventually completed their HBO courses

Tested microwave warming 2.5-4.0 mins.

Scorching not obvious unless blanked fully opened



Scorched areas between creases at 2.5 mins.



Scorched areas between creases at 4.0 mins.

Lack of a formal fire safety plan

The New York Times

Physical Therapist Dies Inside Hyperbaric Chamber After It Catches Fire

Emergency personnel found the 43-year-old physical therapist dead inside the chamber at his Arizona health clinic, which offered oxygen therapy.

