

# Hyperbaric Chamber Fires

## *Lessons Learnt*

Primary Training in Hyperbaric Medicine  
Columbia, South Carolina

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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 O<sub>2</sub>; inboard dump  
no analyzer so unknown O<sub>2</sub> 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

Life Support Technologies group  
 www.lifegas.com

**Absence of design/manufacturing codes: code non-compliance**



**Man died after explosion in a clinic in Bogotá**



**Absence of design/manufacturing codes: code non-compliance**







**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 tx 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

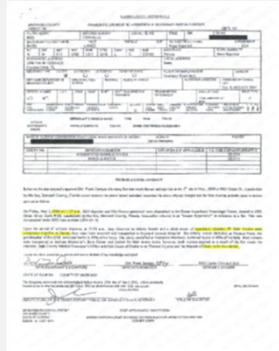
Burn pattern again suggested internal speaker as source

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"



Fire occurred during compression  
"red flame explodes on screen, video goes black"  
Water deluge system activated...no water emitted  
10 pts 1 nurse quickly succumbed

10 patients and nurse die within seconds in hospital fire

Several international newspaper accounts  
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 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 when O2 supply secured

Facility sprinkler system & fire alarm activated

#### News Briefs

##### Oxygen Fire at Shands Teaching Hospital in Gainesville, FL

*By David A. Desautels, MPA, MSJ  
Nursing & Safety, 7/5  
Steve J. Barber*

On Friday, June 4, 2016, a high-pressure, oxygen-enriched fire erupted in the Shands Teaching Hospital, Gainesville, Florida, during a routine procedure. The fire, which was caused by a 3-way valve being opened to select a high-pressure oxygen source, resulted in a fire that burned for approximately 10 minutes, causing significant damage to the facility and the patient.

#### Hyperbaric Medicine Center Dedicated to Dr. Jefferson C. Davis

The Hyperbaric Medicine Center of the University of Mississippi is dedicated to the memory of Dr. Jefferson C. Davis, a pioneer in the field of hyperbaric medicine. The center, which was dedicated on June 15, 2016, is a testament to Dr. Davis's contributions to the field and his dedication to his patients.

#### Chamber Fire Analyzed

A detailed analysis of the chamber fire incident at Shands Teaching Hospital in Gainesville, FL, has been completed. The analysis, which was conducted by a team of experts, identified the cause of the fire as a high-pressure oxygen leak that occurred when a 3-way valve was opened. The analysis also identified several safety failures that contributed to the incident.

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


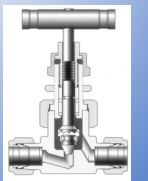
- ignited valve's Teflon seating & seal material
- several fittings significant for "sand blasting" appearance
- likely source of particles...HP O2 cylinder valves & piping

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 otherwise disconnected oxygen piping
- oxygen piping "cleaned for oxygen service"
- HP oxygen reduced at source
- quarter turn valves contraindicated
- 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

- Ongoing contamination O2 piping & valving; inadequate filtration
- 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 exhausted*
- Relief valves lifted (10 ATA)

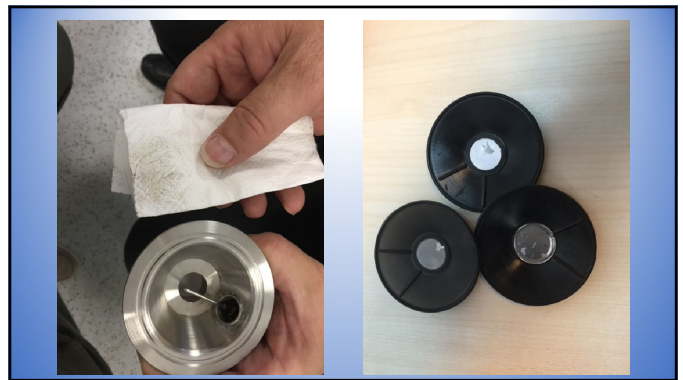
Inadequate system maintenance; particularly O2 delivery system cleanliness

Operational practices inconsistent with recognized standard of care

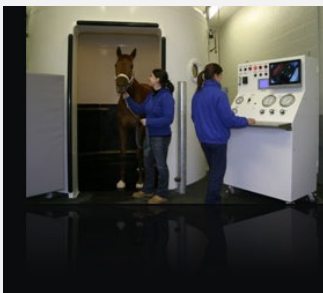
Physician entered chamber with cigarette lighter

*"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

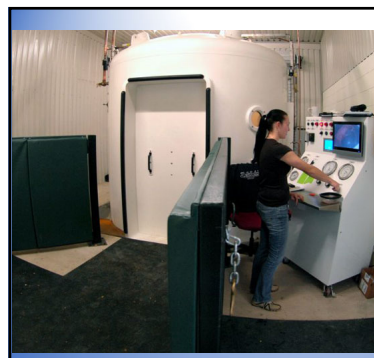


Apparently adequate fire safety plan not adhered to



Steel oxygen-filled multiplace chamber

*animal pt. fatality  
chamber operator fatality*



Patient treatment #5 underway  
*horse unsettled; kicking out  
dislodged protective padding overlying steel hull  
'massive spark' & flames per CCTV  
urgent decompression initiated*

**Marion County Sheriff's Office Incident Report**

**REPORTED BY:** JONATHAN JONES      **REPORTING OFFICER:** JONATHAN JONES

**ON SCENE:** RESPONDED TO THE INCIDENT LOCATION AND ARRIVED AT APPROXIMATELY 10:05 AM. JONATHAN JONES CONTACTED THE INCIDENT AT APPROXIMATELY 10:05 AM. JONATHAN JONES CONTACTED THE INCIDENT AT APPROXIMATELY 10:05 AM. JONATHAN JONES CONTACTED THE INCIDENT AT APPROXIMATELY 10:05 AM.

**1. THEN MADE CONTACT WITH THE MANAGER OF THE FACILITY, REPORTER LEOHORN, WHO STATED THAT THE INCIDENT OCCURRED AT APPROXIMATELY 10:05 AM. JONATHAN JONES CONTACTED THE INCIDENT AT APPROXIMATELY 10:05 AM. JONATHAN JONES CONTACTED THE INCIDENT AT APPROXIMATELY 10:05 AM.**

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Assistant ran to alert fire service; heard two explosions  
*first smaller, followed in ~1 second by massive one, as chamber exploded*  
*sound reported to have been heard several miles away*  
*piece of chamber went through apartment window > 2 miles away*

Operator (29 yo) died immediately; blunt force trauma/thermal injuries  
*remains found buried under chamber debris*

Assistant/trainee suffered multi-trauma, including severe head injuries  
*evacuated to regional trauma center; survived*

Horse remained shod (steel)

Not sedated

His coat contained oil-based lotion  
*not washed with approved soap per FSP*

No formal hyperbaric safety training

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

Formal training in hyperbaric technology/safety

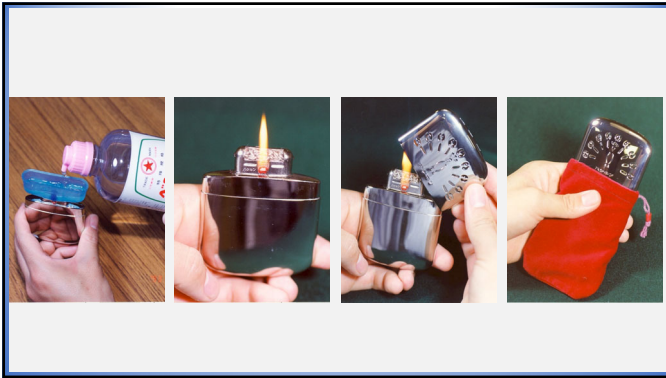
Water deluge system?

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

**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**  
January 2020

**Importance of Optimizing Chamber Gas Flow**

**Background**  
The Sechrist 2000 monophasic hyperbaric chamber operates under a state of constant gas (oxygen) flow. Flow can be adjusted via a control valve located within the oxygen control assembly. In the "closed" position the control valve permits approximately 345 gpm of flow. It is designed to avoid a potentially hazardous accumulation of O<sub>2</sub>. Flow should be completely stopped. In the fully open position, flow peaks at approximately 450 gpm. Adjustment of the control valve between these two extremes provides a corresponding flow volume range between 345 and 450 gpm.

**Risks**  
The constant flow of gas serves to eliminate metabolic waste gases and provides a cooling mechanism to control the patient. Higher flow rates act as a cooling mechanism, lower flow rates reduce the cooling effect.

**However, there are additional aspects to flow control, aspects that have important patient care and safety implications.**

**Risks**  
The principal source of oxygen for chamber compression and constant flow is the hospital's bulk liquid oxygen (LCO) system. The oxygen is stored in a sub-cooled and unheated form. As it is transferred, an increase in the temperature is accompanied with a variable gas, an undesirable vapor (primarily hydrogen) is released off from the LCO. This resulting gas is essentially dry. A container full of no moisture.

**While a dry gas has the benefit of preventing condensation damage to system components, this property also exerts effects on hyperbaric oxygen. As water vapor is introduced, a greater amount of oxygen is required to maintain the same partial oxygen pressure. This property may generate sufficient energy to cause ignition of volatile substances (hydrocarbon based compounds, alcohol, prepreg materials, hydrocarbon containing devices, etc.).**

**Key Operational Issues**

- 1) Chamber routine operations as the rate of gas flow through the chamber is decreased the chamber atmosphere's relative humidity increases. The effect is the result of a greater accumulation of the patient's evaporative moisture loss within the chamber. This is a good thing.
- 2) If the patient complains of being too dry, slow the rate of oxygen flow. Small variable adjustments should be made. It is not frequently the oxygen flow, yet it represents an increasing safety hazard. Should the issue within the chamber move fuel is available. This could represent the difference between a safe entry chamber and a chamber versus a fire that results in catastrophic failure of the chamber, and potential damage to the entire facility, and staff.
- 3) If a patient complains of being too warm:
  - i. Cover them with a blanket, remove a blanket.
  - ii. Compress the chamber or slow rate of descent, in order to null the effect of compression on heat production.
  - iii. Increase chamber flow increases rate for optimal control. Care must be taken to avoid the risk of fire, and oxygen insufficiency.
  - iv. Monitor the periodic facility temperature within a range of 68-72°F.
- 4) If a patient complains of being too cold:
  - i. Close the oxygen supply.
  - ii. If the unit "suffices", switch the sheet out for a blanket.
- 5) Get into the habit of observing the oxygen flow settings upon initial of the compressed treatment pressure. Start that patient in a position where no treatment is underway, and you do not know where the flow setting.

**Additional Notes**  
Know the flow rate of all lines. Optimize for patient comfort.

**Responsible Assignment**  
Source: **David Beckwith**, Hyperbaric Facility Safety, A Practical Issue, an assignment, 1/20/20/20

**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"

**Police: Negligence may have caused fire at Navy hospital**

**Fire kills 4 inside hyperbaric chamber**

The fire reportedly broke out after an electrical short circuit occurred in the chamber, which is usually used to treat patients with decompression sickness. At the time, four patients were inside the chamber, which is located on a hospital's chamber deck used for an operation, who were seriously injured.

The chamber deck is used for the treatment of the hyperbaric oxygen for a therapy session at 11:30 am, with the chamber deck used as a patient pressure. At 1:15 pm, the fire broke out and a red alarm was triggered. The chamber deck is the deck used for the operation.

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### Unanticipated factors

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

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

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 blanket fully opened

Scorched areas between creases at 2.5 mins.

Scorched areas between creases at 4.0 mins.

