

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

© 2006 Safety Research Institute
1. Safety in Hyperbaric Chamber Construction Manual
2. OMSB 2007-10-22 2.2 Chamber Design

Life Support Technologies group
800-762-7626 • 800-762-7626 • 800-762-7626

Absence of design/manufacturing codes: code non-compliance

The image shows a screenshot of a news article from 'wayfar' with the headline 'Man died after explosion in a clinic in Bogotá'. To the right is a photograph of a hyperbaric chamber in a clinical setting, with a person in blue scrubs standing next to it. A red circle highlights a damaged area on the floor in the bottom right corner of the photo.

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 bs 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...

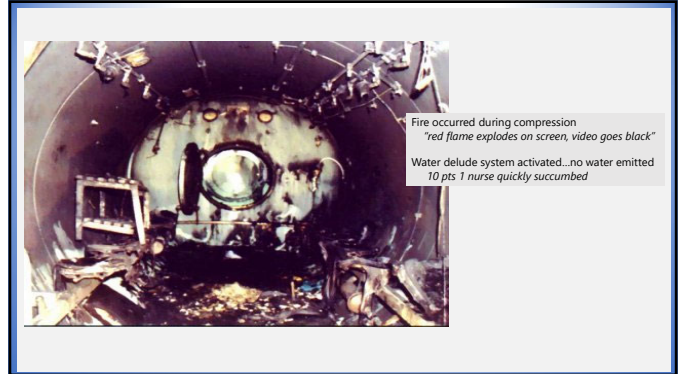
"We did not warn pt. that smoking or taking a lighter into the chamber could be dangerous"

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

Eleven people died within seconds yesterday when fire tore through an eight-high pressure treatment chamber at Illinois' Edward-Elmhurst hospital.

Of those who died, eight were patients. One was a 60-year-old woman who had just checked into the state-subsidized private orthopedic hospital in the Illinois suburb of Elmhurst.

The so-called "hyperbaric" chamber is a room where air pressure can be kept higher than normal so when a mix of oxygen and nitrogen can be administered. Such chambers are used to treat patients with deep-wound infections or divers recovering from the "bends."

"It is like a living tunnel that can hold 10 people," explained a member of the hospital staff.

Mr. Ifford said a technician outside the chamber spotted a spark inside. "It immediately vented on the decompression and control system. The flames were promptly extinguished," he said, but it was too late to save those inside.

The deputy prosecutor in charge of the investigation, Mr. Francisco Peto, said the fire was probably touched off by a metal object taken into the chamber by a patient. The fire also took into the possibility of a oxygen tank from oxygen masks installed in the chamber. An electrical fault was cited as another possible cause.

"The main hypothesis is one involving a hot metal object that was brought into the chamber by a patient. The flames, which only lasted a few seconds, blew back up all the oxygen lines to 200 pounds," he said.

If this hypothesis is correct, the high oxygen content in the chamber would have made the process of combustion unstoppable once the fire broke out.

Ten patients who were being treated in an adjoining room were unharmed.

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. Schwartz, MD, MEd
Andrew B. Sabin, MD
James J. Bland

On Friday, June 8, 2018, a high-pressure oxygen system malfunctioned at the Shands Teaching Hospital in Gainesville, Florida, resulting in a fire that killed 10 patients and a nurse. The fire occurred in a hyperbaric chamber used for treating patients with decompression sickness and carbon monoxide poisoning.

The fire started when a chamber operator opened a 3-way valve to select a high-pressure oxygen source. The valve was set to a pressure of approximately 2,000 psig, which caused a fire to erupt from the control panel. The fire spread rapidly, igniting a filing cabinet and other contents. The chamber technician was burned on her face, arms, and back as she moved a patient.

The fire was extinguished when the oxygen supply was secured. The facility's sprinkler system and fire alarm were activated.

Chamber Fire Analyzed

By David A. Schwartz, MD, MEd
Andrew B. Sabin, MD
James J. Bland

A fire in a hyperbaric chamber at Shands Teaching Hospital in Gainesville, Florida, on June 8, 2018, killed 10 patients and a nurse. The fire started when a chamber operator opened a 3-way valve to select a high-pressure oxygen source. The valve was set to a pressure of approximately 2,000 psig, which caused a fire to erupt from the control panel.

The fire spread rapidly, igniting a filing cabinet and other contents. The chamber technician was burned on her face, arms, and back as she moved a patient. The fire was extinguished when the oxygen supply was secured.

The facility's sprinkler system and fire alarm were activated.

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

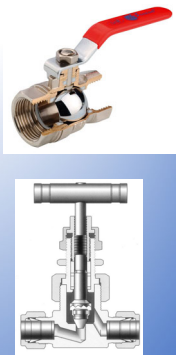
- ignited valve's Teflon seating & seal material*
- several fittings significant for "sand blasting" appearance*
- likely source of particles...HP O₂ cylinder valves & piping*

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

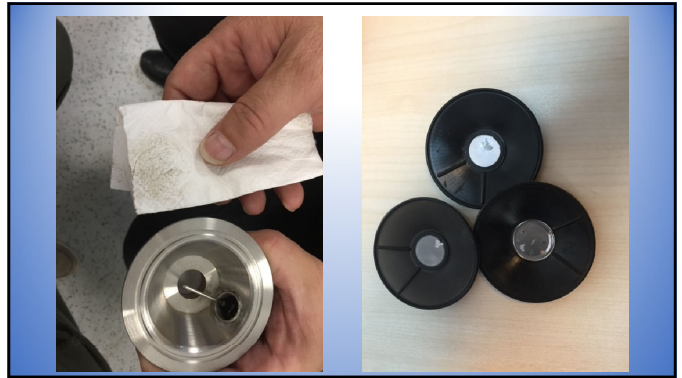
Multiplace chamber fire July 1998

3 fatalities: 2 divers, 1 physician

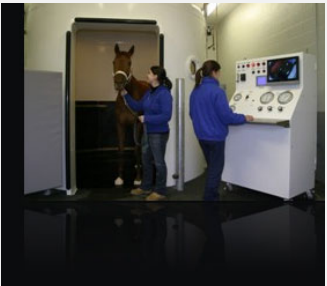
- Ongoing contamination O₂ piping & valving; inadequate filtration
- Latter stages extended USN TT 6
- Chamber O₂ atmosphere not monitored nor routinely flushed
 - one diver/pt. using mask with overboard exhaust, second using hood with inboard exhaust*
- Two "lightsaber-like" oxygen flames seen emitting (via viewport)
 - spontaneous ignition within regulators*
- Chamber operator did not/could not activate water deluge
 - Internal fire extinguisher not activated*
- 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: WES MARSHALL, JAMES
REPORTED DATE: 02/01/2023

ON 02/01/2023, I RESPONDED TO THE INCIDENT LOCATION AND ARRIVED AT APPROXIMATELY 10:27 AM. UPON ARRIVAL, I MADE CONTACT WITH INCIDENT TROOPERS BLAGOJENKA BOKIC AND JEFFREY BOKIC. I MADE CONTACT WITH INCIDENT TROOPERS BLAGOJENKA BOKIC AND JEFFREY BOKIC. I MADE CONTACT WITH INCIDENT TROOPERS BLAGOJENKA BOKIC AND JEFFREY BOKIC.

I THEN MADE CONTACT WITH THE MANAGER OF THE FACILITY, BOKIC, AND ASKED FOR THE CHAMBER OPERATOR. I THEN MADE CONTACT WITH THE CHAMBER OPERATOR, WHO ADVISED ME THAT THE CHAMBER OPERATOR HAD BEEN KILLED BY THE CHAMBER. I THEN MADE CONTACT WITH THE CHAMBER OPERATOR, WHO ADVISED ME THAT THE CHAMBER OPERATOR HAD BEEN KILLED BY THE CHAMBER.

I THEN CONTACTED ALTERNATE CONTACT, WHO WAS ON SCENE. THE DISTRICT COMMANDER, ALONG WITH BOKIC, ADVISED I WAS ADVISED TO START A CHAMBER DECOMPRESSION. I THEN MADE CONTACT WITH THE CHAMBER OPERATOR, WHO ADVISED ME THAT THE CHAMBER OPERATOR HAD BEEN KILLED BY THE CHAMBER.

I INITIATED A CHAMBER LOCK AT 10:58 HOURS. I THEN TOOK ALL PERSONNEL OFF SCENE AND ADVISED THEM TO MOVE AWAY FROM THE CHAMBER. I THEN MADE CONTACT WITH THE CHAMBER OPERATOR, WHO ADVISED ME THAT THE CHAMBER OPERATOR HAD BEEN KILLED BY THE CHAMBER.


DURING THAT TIME, AGENTS FROM THE STATE FIRE MARSHAL'S DEPARTMENT ARRIVED ON SCENE, ALONG WITH THE FIRE DEPARTMENT DIVISION OFFICER. I THEN MADE CONTACT WITH THE CHAMBER OPERATOR, WHO ADVISED ME THAT THE CHAMBER OPERATOR HAD BEEN KILLED BY THE CHAMBER.

CRISIS INTERVENTION SPECIALIST, CINDY CONNOR TURNER, ALSO ARRIVED ON SCENE TO ASSIST. CONTACT WITH THE MEDICAL EXAMINER'S OFFICE ARRIVED ON SCENE TO CONDUCT THE INVESTIGATION.

A REPRESENTATIVE WITH OSHA ARRIVED ON SCENE TO CONDUCT HIS INVESTIGATION. I THEN MADE CONTACT WITH THE CHAMBER OPERATOR, WHO ADVISED ME THAT THE CHAMBER OPERATOR HAD BEEN KILLED BY THE CHAMBER.

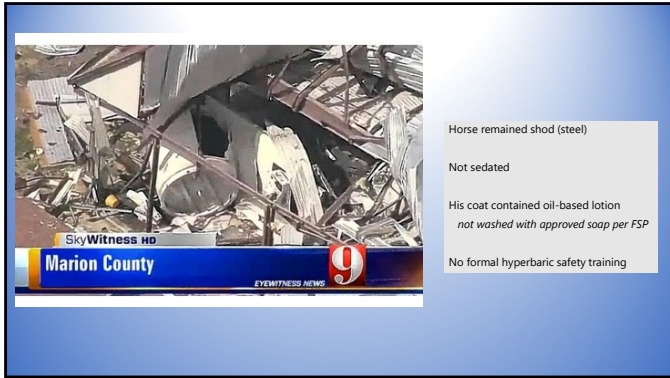
THE INVESTIGATION WAS CONCLUDED THROUGH THE JOINT OPERATION OF ALL AGENCIES. AT THE CONCLUSION OF THE INVESTIGATION, THE BODY OF THE DECEDENT

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

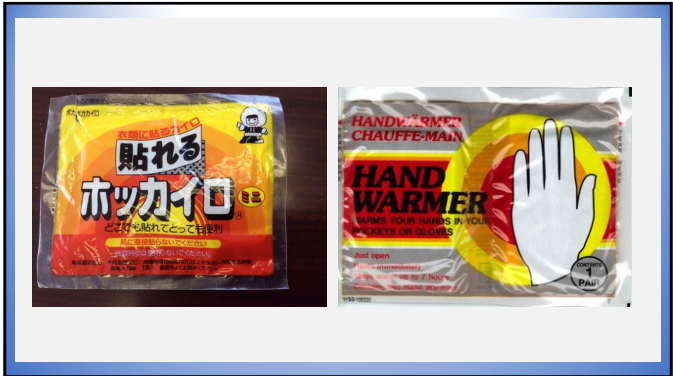
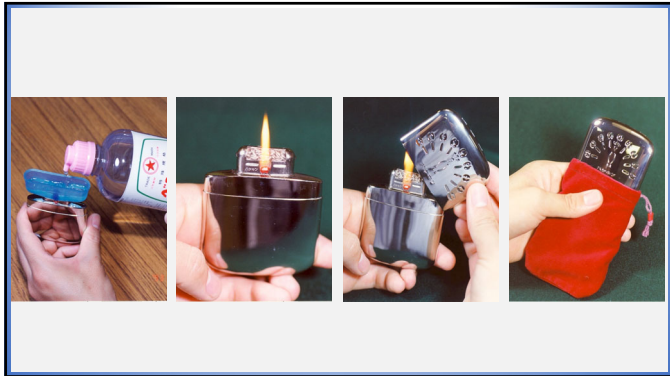
Water deluge system?

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 that all recommended safety procedures were carried out

Oxer H. SPUMS Journal 1996;26(4)



NBS Monthly Safety Notice
January 2022 National Biomedical Services, Inc.

Importance of Optimizing Chamber Gas Flow

Background
The Sechrist 3000B monoplace hyperbaric chamber operates under a state of constant gas flow. Flow can be adjusted via a control valve located within the oxygen exhaust assembly, in the "closed" position the control valve permits approximately 240 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 400 lpm. Adjustment of the control valve between these two settings permits a compensating flow volume ranging between 240 and 400 lpm.

The constant flow of gas serves to eliminate metabolic waste gases and provides a dilution space of atmospheric oxygen to the patient. High flow rates and the cooling mechanism, lower flow rates reduce the cooling effect.

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

The Issue
The principal source of oxygen for chamber compression and constant flow, is the hospital's bulk liquid oxygen (LOX) system. This system is located in the LOX room and is a high-pressure system. It is a treatment in atmosphere, in the machine it is compressed into a usable gas, to an associated piping system. Interconnected with this piping system is a relief valve, a combination of a relief valve and a check valve, a combination of a relief valve and a check valve.

While a dry gas has the benefit of minimizing convective damage to system wiring and piping, this potential adverse effect on hyperbaric safety. A dryer atmosphere promotes a greater accumulation of static electricity. A resulting static electrical discharge may generate sufficient energy to cause ignition of volatile substances. This concern is based on the following, electrical properties of oxygen:

Operating 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 moisture in the chamber. This happens frequently.
- If the patient complains of being too hot, the rate of oxygen flow - don't increase additional oxygen. This is all too frequently the action taken, yet it represents an increasing safety hazard. Should this occur within the chamber, more heat is available. This could represent the difference between an 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 warm:
 - Close the relief valve.
 - Complete the chamber and slow rate of descent in order to limit the effect of compression on head pressure.
 - Threaten chamber flow increases rate for optimal comfort, when the patient is the whole world is in.
 - Adjustment that depends on the temperature within range of 20-22°C.
- If a patient complains of being too cold:
 - Close the exhaust valve.
 - If the left sufficient, switch the sheet out for a blanket.
- Call into the staff about observing the oxygen flow settings, and the rate of the colored treatment pressure. Don't find yourself in a position where treatment is underway, and you do not know your own flow setting.

References
Know the flow rate of all lines, optimize for patient comfort.

Reading Assignment
Wood JZ. **Static Electricity**. Hyperbaric Facility Safety: A Practical Guide. 2018;10:1-10.

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"

Fire kills 4 inside hyperbaric chamber

Police: Negligence may have caused fire at Navy hospital

Background
A fire broke out in a hyperbaric chamber at the Naval Hospital in San Diego, California, on Monday, killing four people, including a police officer.

The incident
The reportedly broke out after an electrical short circuit occurred in the system, which is usually used to treat patients with decompression sickness. At the time, four patients were inside the chamber. The cause of the fire is still under investigation.

The chamber
The chamber is a high-pressure chamber used to treat patients with decompression sickness. It is a cylindrical chamber with a diameter of 1.8 meters and a length of 2.1 meters. The chamber is made of aluminum and is filled with oxygen at a pressure of 2.8 atmospheres. The chamber is used to treat patients with decompression sickness, which is a condition that occurs when a person ascends too quickly from a deep dive.

The fire
The fire started in the chamber at approximately 10:30 a.m. on Monday. The fire spread rapidly and caused significant damage to the chamber and the surrounding area. The fire was extinguished by the fire department, but four people were killed and several others were injured.

The investigation
The fire department is currently investigating the cause of the fire. It is believed that the fire was caused by an electrical short circuit in the chamber's heating system. The fire department is also investigating the possibility of negligence on the part of the hospital staff.

The aftermath
The chamber is currently out of service and is being repaired. The hospital is currently providing medical care to the injured patients. The fire department is currently reviewing the chamber's safety features and is planning to update them to prevent a similar incident from occurring in the future.

Unanticipated factors

Fire in the Multiplace Hyperbaric Chamber

B. A. Vran, D. Gordon, C. Moran, and B. Brown
Department of Hyperbaric Medicine, Harborview Medical Center, Seattle, WA

Background
The incident occurred in a multiplace hyperbaric chamber at Harborview Medical Center in Seattle, WA. The chamber was used to treat four patients, including three adults and one 14-week-old neonate. The chamber was set at 2.0 ATA. The incident occurred during the treatment of the patients.

Unanticipated factors

- Multiplace chamber at 2.0 ATA
- 2 inside attendants
- 4 patients; 3 adults, 1 14-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

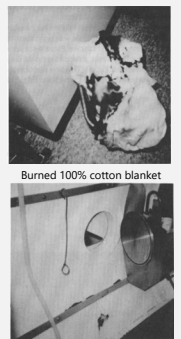
Examined by unfolding several times
nothing upward/not unduly hot

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

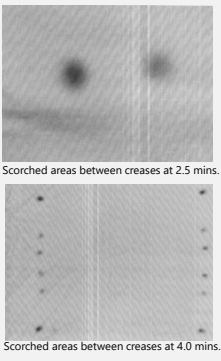
All occupants uneventfully decompressed

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.

