Monoplace Chamber Fire
Lima, Peru, 2006

Incident Report

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Notice to Readers

This document is based on an original PowerPoint presentation developed and presented in Peru by Glenn J. Butler during a visit following the accident in 2006.

It has been updated as appropriate to provide readers with information and guidance that reflects current safe practice guidelines and most recently published editions of relevant codes and standards.
Disclaimer

The contents of this presentation are provided for information only by Life Support Technologies group as a service to our colleagues all over the world involved in the provision of hyperbaric oxygen therapy.

This is not a presentation by the UHMS Safety Committee.
In memory of R.W. “Bill” Hamilton

A dear friend, colleague and mentor

His contribution to the field of deep-diving and hyperbaric medicine will never be surpassed

Donated by Life Support Technologies group, 2013
Explosión de cámara hiperbárica calcinó a paciente y destrozó fachada

La oxigenoterapia hiperbárica

La técnica de oxigenoterapia hiperbárica busca que el paciente reciba el oxígeno necesario para sus órganos y tejidos, con un efecto regenerativo y una mejora general de todos sus sistemas orgánicos.

**¿Qué es?**

Es la técnica de inmersión de un oxígeno a alta presión, (estimulación que se acerca el 100%) por periodos cortos y bajo oxidación de una cámara completamente presurizada.

**El sesenta que responsables completamente está compuesta del 20% de oxígeno y el resto de otros gases.**

**Usos de la cámara**

Se utilizan para tratar de:
- Síntomas de quemaduras y quemaduras aisladas.
- Heridas de alta presión en las piernas.
- Infecciones de heridas de alta presión.
- Complicaciones quirúrgicas.
- Traumatismos craneales.
- Cianotisis (hipoxia).
- Ataque epiléptico.
- Parálisis cerebral.
- Enfermedad inflamatoria.
- Inmunodepresión.
- Lesiones de hígado.

**Normas de seguridad**

- La cámara no debe ser utilizada por pacientes con transición de sangre.
- Se debe tener cuidado de no dejar a nadie dentro de la cámara en una habitación con alta presión.
- Los pacientes deben ser observados por profesionales de la salud.
- No deben haber personas con gases inflamables a la cámara.
- Las cámaras deben ser controladas por personal cualificado.

**Descripción**

La cámara hiperbárica es una cámara de alta presión diseñada para proporcionar un ambiente a presión que excede la presión normal de aire a la superficie de la tierra. Esta presión aumentada permite que el oxígeno se disipe más eficientemente en el cuerpo, lo que puede ayudar a acelerar el proceso de curación de heridas o lesiones. La utilización de la cámara hiperbárica se ha demostrado eficaz en el tratamiento de enfermedades como las quemaduras graves, las úlceras venosas, los abscesos, entre otros.

**Víctima**

Eugenio Quezada, un paciente de Huaycán, había recibido tratamiento gratuito como parte de la mejora social que dicha estación estableció socialmente. En un momento de presión, el paciente tomó aliento profundo de oxígeno para prevenir un colapso muscular y conectó la cámara con el respirador.

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Hyperbaric Chamber Fire in Lima

The Monoplace Hyperbaric Chamber Oxygen Fire in Lima Peru was devastating to all Peruvians and of great concern to the Hyperbaric (HBO) community Worldwide.

While the investigation as to the causes of the Lima Chamber Fire were still underway our immediate concern was that another Fire could occur in Peru and other Countries with similar equipment, operational procedures and levels of training.
Hyperbaric Chamber Fire in Lima

While the final determination of the cause(s) of the fire must be left to the authorities, this is Glenn Butler’s sole opinion of what occurred.
Hyperbaric Chamber Fire in Lima

The chamber was an all steel monoplace with an acrylic window positioned to view the patient’s head and upper torso.

It was pressurized to 2.4 ATA using oil pumped compressed air.

The patient was breathing pure oxygen by demand mask and the oxygen was exhaled into the chamber.

There was normally one attendant outside the chamber and another person in the building.
The chamber was procedurally ventilated with air for approximately one minute out of five. Theoretically, to reduce in-chamber oxygen and carbon dioxide concentrations as well as and cool the patient.

Oxygen was supplied to the patient via demand mask.

There was no oxygen analyzer fitted to the chamber so the actual oxygen concentration at any given time is always an unknown.
Hyperbaric Chamber Fire in Lima

The chamber was fitted with an off-the-shelf home intercom system.

Such systems are NOT designed or approved for use in hyperbaric chamber operations and would be considered dangerous in high Oxygen concentrations above 23.5%.

Based on paint curl, ignition appeared to have occurred at the internal speaker near the patient’s head.
Hyperbaric Chamber Fire in Lima

The fire consumed the entire mattress, bedding and some of the patient. Clearly, internal temperatures during the fire were very high and was supported by approximately 800 Liters of oxygen entering the chamber uncontrolled from the mask supply tanks.

The fire burned for about 25 seconds and reached a pressure of about 300 PSI when the door O-ring gasket failed, hot gases escaped into the room which cut the concrete floor and blew out the building window.

The fire consumed all the available oxygen and the chamber to depressurize back to atmosphere.
2) Patient pushed button on intercom or wire breaks connection causing ignition

1) Oxygen Enriched Air Environment (estimated 90%+ O2)

3) Mask Oxygen Feeds Fire

4) Door seal fails

5) Pressure and flames escape through door seal

It is estimated that chamber fire burns for 25 seconds and reaches a pressure of 300 psig and 1,000°F before door o-ring seal fails and chamber decompresses

Donated by Life Support Technologies group, 2013
Not an Explosion

By NASA standards, this was NOT an explosion because the steel chamber pressure hull did not catastrophically fail.

This incident should be referred to as a contained, high pressure hyperbaric oxygen accelerated fire.

Apollo-One Capsule Fire
Many HBO Facilities at Risk

Based upon government sanctioned inspections of multiple HBO facilities. We were very concerned that there is significant potential for other fires and pressure accidents related to HBO services in Peru and elsewhere in and South America using similar equipment and procedural policies.

Peru HBO services were shutdown and allowed to reopen after a survey of communications system design changes and procedures were reviewed.

Most services simply removed their communications
Many HBO Facilities at Risk

We support the UHMS-Peru and South American membership efforts to adopt proven international standards for chamber construction and hyperbaric operations such as:

NFPA-99, Health Care Facilities, specifically the chapter pertaining to Hyperbaric Facilities which is the basic standard adopted by all Hospital-Based Hyperbaric Medicine Services in the USA and much of the world.

ASME –PVHO 1 Safety Standard for Pressure Vessels for Human Occupancy which provides guidelines for the design and construction of both mono- and multiplace hyperbaric chambers.
Immediate Recommendations

Developed based on inspection of 14 HBO clinics

1 - Patient Clothing Inside Chamber

All patients inside air or oxygen filled chambers must wear 100% cotton clothing, or cotton/polyester blend clothing containing not less than 50% cotton, that is clean and oil free.

These should be hospital scrubs/gowns or similar, and have no pockets. All patients shall have a locked locker for valuables.

All patients are to be questioned and/or examined physically to insure that all contraband such as cigarette lighters, matches, cell phones, beepers, hearing aids, watches, excessive cosmetics, petroleum-based products are removed to minimize acrylic damage and spark risk.
Immediate Recommendations

2 - Patient Clothing Inside Chamber

Jewelry must be removed or taped to minimize acrylic damage and spark risk.

Any rings which cannot be removed should be turned in to the palm of the hand and wrapped with tape.

Eye glasses may be worn inside chamber.

Contact lenses are not recommended.

Provide lockers in order to permit patients to lock up their valuables before entering chamber.
Immediate Recommendations

3 - Patient & Chamber Electrical Grounding

To help eliminate the risk of static spark ignition all patients in chambers capable of exceeding an oxygen concentration greater than 23.5% must be grounded to the chamber by a special strap. The bed frame or chair must be part of this chamber ground. (HBO Ground Strap kits were donated)

The chamber must be grounded to a common building (pipe/steel) or true earth ground.

The resistance between the grounded chamber hull and this electrical ground shall not exceed one (1) OHM.

DO NOT use the building electrical panel or wall outlet ground to ground the Chamber.

Donated by Life Support Technologies group, 2013
Oxygen Chamber

> 23% O2

1 mega ohm resistor strap

1 Meter

Donated by Life Support Technologies group, 2013
Immediate Recommendations

4 - Communication Systems Must Be Oxygen Compatible

The communications system involved in the fire was not designed for oxygen service and may have been the source of ignition that started the fire.

Several other intercom systems were identified during the inspections- including AIPhone and Amron systems. These are NOT oxygen compatible or intrinsically safe in accordance with the requirements of NFPA-99.

Most unapproved systems were removed without replacement.
Hyperbaric Communications System

Isolation Transformer

Intrinsically Safe Barrier

Special Speaker

Oxygen Atmosphere

**ISB Limits Power Into Chamber Speaker To Less Than 0.5 Watts**

**NO SPARK POSSIBLE**
Immediate Recommendations

5 - Remove Patient Activated Push-To-Talk Switches

These switches are typically push-buttons.

They are used in many designs including those produced by AIPhone.

These switches can arc when activated and may serve as a source of ignition in oxygen enriched atmospheres.

They are potentially dangerous and should be disconnected immediately so that no power can be delivered.
Speaker /Microphone Assembly with Push to talk button

Photos courtesy Leader-Life

Donated by Life Support Technologies group, 2013
Immediate Recommendations

6 - Ensure Internal Oxygen Compatible Speakers Are Rigidly Mounted And Wires Protected.

Several internal chamber speaker boxes inspected were loose and able to be torn off the chamber wall, which may cause a short circuit with the potential for a spark.
Immediate Recommendations

7 – Use Oil-Free Air to Compress Chambers

All air used to compress hyperbaric chambers must be free of all liquid oil (mist/vapor) and oil odor.

Oil contamination in hyperbaric air or oxygen enriched atmospheres can cause a fire.

Air filtration systems are available in Peru which will eliminate liquid oil and oil vapor (charcoal) from entering the hyperbaric chamber.
Immediate Recommendations

8 - Periodic Ventilation Of Air Chambers

The arbitrary ventilation of chambers compressed with air for one (1) minute out of five (5) minutes is insufficient to control oxygen levels when the oxygen breathing system is dumping exhaust or leaking into the chamber.

The chamber in which the fire took place was being ventilated every five minutes and is estimated to have had a 90% + oxygen atmosphere when the fire started.

All Chambers designed for Air Service should be equipped with an oxygen analyzer to help the operator maintain oxygen levels below 23.5 % oxygen.
9 - The Patient Ground Strap Connection

The patient must be grounded in a manner that ensures good contact with the skin.

Special wrist bands or “Ground Strap” designed for HBO service are available and include a 1 Mega Ohm electrical resistor that permits electrical differentials to bleed off without producing a spark.

Patient Grounding Assemblies are available FREE as a donation to members of the Peruvian Society of Diving and Hyperbaric Medicine.

**Note:** We are aware that adhesive EKG pads have been used as an alternative to wrist bands but it should be noted these are not approved for this application by either the U.S. Food & Drug Administration (FDA) or the original manufacturer.
Patient’s must ALWAYS be grounded
Immediate Recommendations

10 - Carbon Dioxide Absorbers

The passive Limewater Carbon Dioxide scrubbers placed on the floor of many air and oxygen chambers are given far too much credit for their ability to remove Carbon Dioxide.

They are not an effective substitute for adequate ventilation.
Immediate Recommendations

11 - Technician Supervision of Patient

There is a concern that the technician may not have been immediately available in the chamber room at the time of the fire and that the patient may have been trying to gain attention.

In order to eliminate this risk, there should always be two technicians in the chamber room and at least one dedicated to the chamber operation and within visual and/or audible range of the patient in order to react immediate to outside chamber problems or to respond to patient requests.
Immediate Recommendations

12 – Hyperbaric Safety Director

Each HBO facility is urged to designate their most experienced non-physician as Hyperbaric Safety Director and to organize weekly staff training and chamber maintenance as per NFPA-99 guidelines.
Immediate Recommendations

13 - Confidential Inspections

Mr. Butler has volunteered to visit HBO facilities and to provide a courtesy inspection and to train staff to serve as Hyperbaric Safety Directors.

A series of training programs were organized for technician’s and a team of Peruvian UHMS members now conduct on-going in-service training programs.
SUMMARY

HBO SAFETY GUIDELINES
Should be Based on
U.S. Codes and Standards
as well as
Training and Good Operating Practices
Both are mature standards, internationally recognized and mandated by U.S. Federal Authorities and many states Personnel Certification and Training Standards through UHMS and NBDHMT

Set and Maintain High Standards for Equipment Safety and Personnel Training

In the United States we have these which specifically address hyperbaric equipment and facilities

Donated by Life Support Technologies group, 2013
NFPA 99, Chapter 14, Hyperbaric Facilities

- Scope:
  Establish criteria to minimize the hazards of fire, explosion, and electricity in hyperbaric facilities

- Purpose:
  To provide minimum requirements for the performance, maintenance, testing, and safe practices for facilities, material, equipment, and appliances, including other hazards associated with the primary hazards
NFPA 99, Chapter 14, Hyperbaric Facilities

• Applicability:
  – New facilities
  – Altered, renovated or modernized portion of an existing system or individual component
  – Existing construction or equipment pre-dating the standard may continue to be used when such use does not constitute a distinct hazard to life
  – Applies to both multiplace and monoplace chamber facilities
NFPA 99, Chapter 14, Hyperbaric Facilities

Critical Points:

– Compliance with Chapter 14 is a pre-requisite for Medicare reimbursement in USA

– A Hyperbaric Safety Director must be designated to ensure compliance with this chapter

– Medical Director and Hyperbaric Safety Director cannot be the same person

– Ultimately the governing board is responsible for the care and safety of patients and personnel
The Hyperbaric Safety Director must:

- Participate in development of safety, operational and maintenance policies and procedures
- Have authority to restrict/remove hazardous materials or equipment used in chamber(s)
- Ensure regular inspection, testing and maintenance of equipment is conducted
- **Should:** Serve on the healthcare facility safety committee
NFPA 99, Chapter 14, Hyperbaric Facilities

- **Recommended qualifications for Hyperbaric Safety Director:**
  
  – Demonstrable operational management experience
  
  – Good communication skills
  
  – Sound knowledge of the principles and practice of hyperbaric oxygen therapy
  
  – At least five years experience in clinical hyperbaric operations
NFPA 99, Chapter 14, Hyperbaric Facilities

• **Recommended qualifications for Hyperbaric Safety Director:**
  
  – Most Experienced Person available to service
  
  – Direct experience with the chambers in use
  
  – Knowledge of NFPA 99, ASME-PVHO 1 & 2
  
  – Demonstrate engineering/mechanical aptitude
  
  – Ability to develop policies and procedures
KEEP CONTRABAND OUT!

Contraband: Anything that is imported or exported illegally

For us this means

Anything taken into the chamber that can cause or contribute to the intensity of ignition, damage the chamber or, in any way place the patient at increased risk

Pictures courtesy of International Atmo

Donated by Life Support Technologies group, 2013
KEEP CONTRABAND OUT!

• Do not permit contraband items in your chambers such as:
  – Street/personal clothing - allow only approved facility/hospital supplied clothing in chamber
  – Personal electronics (cell phones, iPods etc)
  – Personal warming devices/heat generating items
  – Anything that could cause ignition or ignite more easily in a high-oxygen environment (make-up etc)

• Display easy to read safety notices around the changing and chamber rooms

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CAUTIONS AND WARNING SIGNS

• Safety/Warning notices should be displayed in the following locations:
  – Gas storage area(s)
  – Exhaust outlet point(s)
  – Access doors into the hyperbaric room
CAUTIONS AND WARNING SIGNS

• Patient Safety Notices should be displayed in the following locations:
  – Chamber room (s)
  – Patient preparation and changing rooms
ELIMINATING CHAMBER IGNITION SOURCES IN CLINICAL HBO$_2$

• Keep chambers and chamber rooms clean and free of:
  – Hydrocarbon-based grease
  – Hydrocarbon-based oils
  – Dirt
  – Dust and lint
ELIMINATING CHAMBER IGNITION SOURCES IN CLINICAL HBO$_2$

Circuits such as Chamber Speakers, Headsets, Sensors, etc must be intrinsically safe, designed for less than 23.5% or for PURE Oxygen Service and limited to no more than

- 28V and 4.0W under normal and circuit fault conditions

- All non-essential electrical systems outside chamber

- Ensure chambers are properly grounded

Donated by Life Support Technologies group, 2013
PATIENT CHAMBER CLOTHING

- Patients must **NOT** be permitted to wear street clothes in the chamber

- Hyperbaric Facilities **MUST** provide gowns or other garments for patients to wear

- **ONLY** 100% cotton or cotton/polyester blend with a minimum 50% cotton is allowed

- Hyperbaric facilities must provide secure lockers for clothes and valuables
PATIENT CHAMBER CLOTHING

- Clothing and other articles made of silk, wool or unblended man-made materials **MUST NOT** be allowed in the chamber because of their tendency to cause electrostatic discharge (static sparking)
INTRINSICALLY SAFE?

• All hyperbaric chambers have the potential for elevated oxygen atmospheres greater than 23.5%

• All electrical systems used in a hyperbaric chamber must be intrinsically safe:
  - An intrinsically safe device comprises electrical circuits in which any spark or thermal affect is incapable of causing the ignition of a flammable mixture or combustible material in air
• Grounded means: Connected to earth, in order to provide a low-impedance return path for leakage and fault currents
  – All patients must be grounded to the chamber using a dedicated ground
  – Each chamber must be permanently grounded to its own ground or the building

• Grounding systems can degrade, they should be checked regularly using an ohmmeter
APPROVED?

• Only equipment approved for use in oxygen enriched atmospheres should be used inside a hyperbaric chamber

• Of greatest concern are communication systems supplied by original chamber manufacturers or fitted as replacement units that are specifically **NOT** approved for use in hyperbaric and oxygen enriched atmospheres as shown in the following examples
Standard AIPhone installed on unit

Photo courtesy Leader-Life

Donated by Life Support Technologies group, 2013
Standard AIPhone installed on unit

Photo courtesy Leader-Life

Donated by Life Support Technologies group, 2013
Standard AIPhone installed on unit

Photo courtesy Leader-Life

Donated by Life Support Technologies group, 2013
Holster for standard AIPhone fitted to a hyperbaric chamber

Photo courtesy Leader-Life

Donated by Life Support Technologies group, 2013
Standard AIPhone installed on unit

Donated by Life Support Technologies group, 2013
Speaker /Microphone Assembly with Push to talk button

Donated by Life Support Technologies group, 2013
February 27, 2006

To whom it may concern,

Subject: Use of APhone intercom systems in Oxygen Enriched Environment

Please be advised that NONE of APhone products, being exported and sold outside Japan, are designed nor recommended to use in Oxygen Enriched Environment, Hyperbaric Oxygen Environment and Explosive Atmosphere, i.e. coal mines, petrochemical complexes, etc. Most of the APhone products are designed and produced for use in general environments such as residences and businesses.

In the event, when APhone products are used in such environment and caused any accident, i.e. fire and/or explosion, we will not be able to take responsibility for any loss, damage, injury etc.

If there is anyone, who is not certain that the environment is not in either one of environment described above, please contact to the local APhone agent or to APhone Co., Ltd.

We thank you for your understanding and cooperation to this matter.

Best regards,

Ryuichi Asano
Director and General Manager
/Quality Assurance Department
APhone Co., Ltd.
Marzo 16, 2006
Estimados clientes,
Asunto: Uso de sistemas de comunicación manufacturados por Amron International en ambiente de alto concentrado de oxígeno.
El equipo de comunicación diseñado y manufacturado por Amron es para uso exclusivo en cámaras hiperbáricas que utilizan aire comprimido y no excedan concentración de oxígeno del 23.5%. Nuestros productos de comunicación (incluyendo comunicadores, bocinas, sistemas de entretenimiento y otros accesorios de comunicación) NO son diseñados para servicio de oxígeno, y no siendo intrínsecamente seguros. Estos productos no cumplen con el criterio de NFPA-99, capítulo 20 y otras definiciones aplicables a esta norma. Uso de nuestros productos en alta concentración de oxígeno, puede resultar en un accidente serio y/o muerte.
Amron International no se responsabiliza por daños y/o perjuicios causadores por uso inadecuado de sus productos.
Para mayor información favor contactar a su representante de Amron.
Agradecemos su atención y cooperación referente a esta materia.

Best Regards,
Scott C. Ritchie
Vice President of Manufacturing
Amron International, Inc.
Communications systems must be suitable and rated for intended service

Photo courtesy of Amron International

Donated by Life Support Technologies group, 2013
Finally a safety sign on the door serves as a double check before the patient enters the chamber.
NFPA 99, Chapter 14, Hyperbaric Facilities

• **Conclusions:**
  
  – Placing humans in hyperbaric chambers involves a degree of risk. **It is imperative, therefore, that safety is the key driver**
  
  – Any incident could quickly develop and have catastrophic consequences for chamber occupants and operating personnel
  
  – All accidents on record have been a result of human error
  
  – **It is not perfect but the U.S. safety record is a testament to the value of NFPA-99 and ASME PVHO 1 & 2**
Acknowledgments

There are so many very special people that made this effort possible that it is impossible to acknowledge them all individually – the groups that helped made our efforts on the ground possible are as follows:

• Peruvian Society of Diving and Hyperbaric Medicine
• Peruvian Ministry of Health
• Peruvian National University
• Amron International
• Atmo International
• AiPhone Co. LTD
• Environmental Tectonics Corporation

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