FirePASS®

A REVOLUTION IN FIRE SAFETY

FirePASS®
Fire Prevention and Suppression Systems

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CONTENTS

01

02

03

04

BACKGROUND ON INDEPENDENT MEDICAL REVIEW

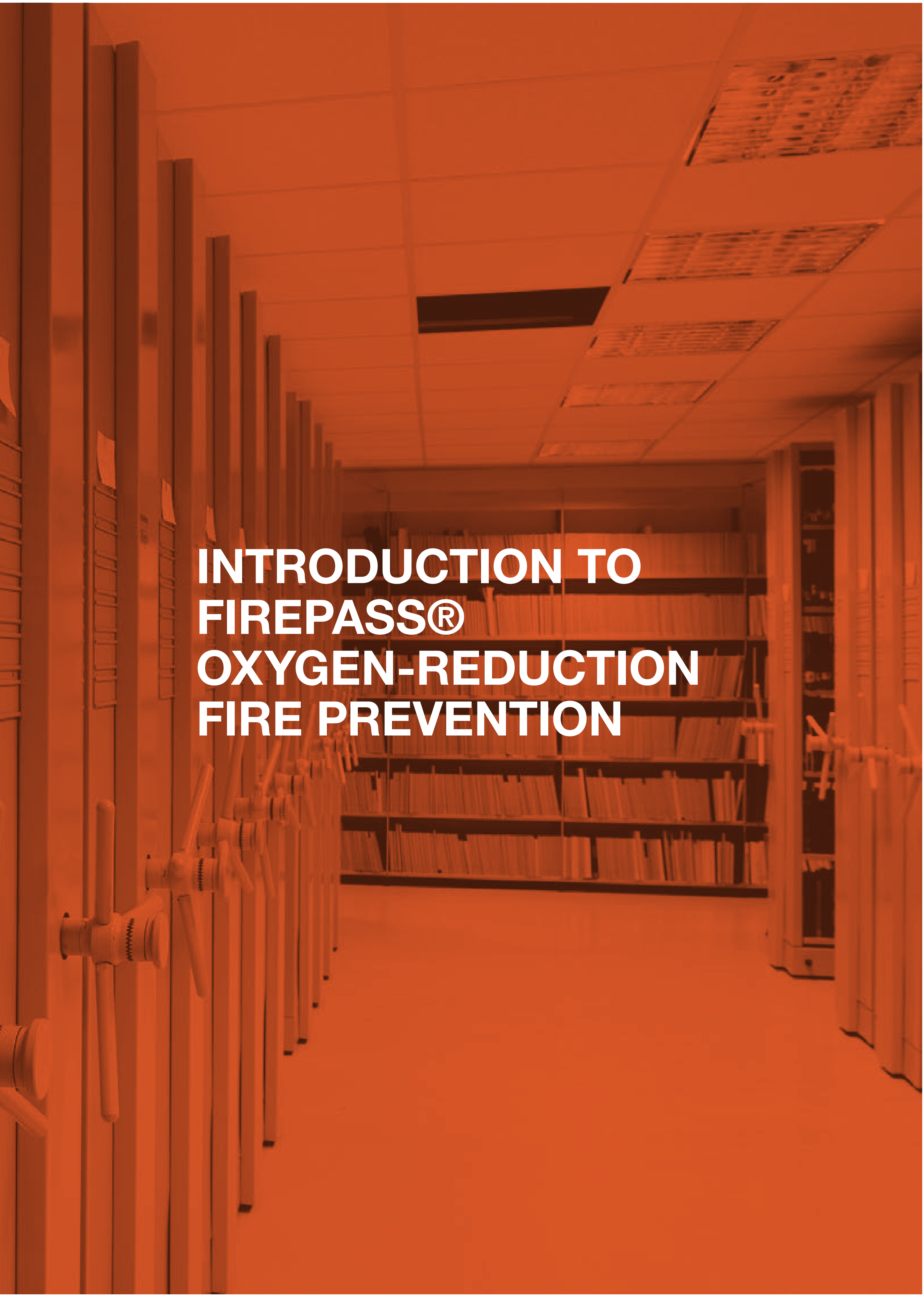
05

MEDICAL REPORT BY PROFESSOR MATTHEW PETERS

06

HYPOXIC ENVIRONMENT CHECKLIST BY PROFESSOR MATTHEW PETERS

01



INTRODUCTION TO FIREPASS® OXYGEN-REDUCTION FIRE PREVENTION

INTRODUCTION TO FIREPASS® OXYGEN REDUCTION FIRE PREVENTION

FIREPASS® Oxygen Reduction Fire Prevention, is a revolutionary fire prevention technology that is designed to prevent fire from occurring by reducing and maintaining oxygen at non-combustible levels.

SUDDEN DISCOVERY

Many hundreds of years scientists and engineers around the world tried to find a way to make us safe from fire. Different technologies were introduced to fight fire with water, sand, foams, water mist, inert gases, etc. The problem is that they are all reactive and deployed after a fire actually starts providing at least some damaging results.

The amazing property of breathable hypoxic (oxygen-reduced) air to suppress ignition and fire was discovered in 1998 in the U.S.A. by Russian scientist and engineer Igor (Gary) Kotliar. He made this breakthrough during his experiments with the Hypoxic Room System, which he invented in 1993 for simulating altitude in athletic training.

In 1995 Igor Kotliar formed Hypoxico Inc. in New York and started marketing the Hypoxic (Altitude) Room and Hypoxic Tents to cyclists, runners and fitness clubs around the world. This revolutionary concept allowed many famous athletes (see www.hypoxico.com) to achieve incredible results.

LEADS TO REVOLUTIONARY CONCEPT

Since then simulated “altitude training” became a standard in training of top level athletes and is used in wellness and medical field as well as for acclimatization at home.

A hypoxic environment for both, athletic training or fire prevention is established by ventilating a room with hypoxic air. Hypoxic air can be produced by filtering out a part of oxygen from ambient atmospheric air that contains 20.9% of oxygen.

For instance, 15% oxygen content corresponds in partial pressure of oxygen to an altitude of 2700 m. By experimenting in this environment, Igor Kotliar discovered a Phenomenon of Ignition Suppression in Breathable Hypoxic Atmosphere and introduced a new scientific term Ignition Threshold. It was discovered that most common materials can not be ignited at 15% of oxygen. However, in order to extinguish a fire the oxygen % must be reduced to at least below 12% but some materials may require the oxygen % to be reduced to 8%. Even though the scientific community did not initially accept this, this discovery allowed a birth of a totally new industry in the fire protection field.

FIREPASS® has the unique ability to create an environment of breathable, controlled oxygen-reduced air that prevents fire ignition.

FIREPASS® prevents fire pro-actively, eliminating damage and business interruption that occurs when suppressing a fire after it has already started.

There has been extensive medical research in the UK, Europe and Australia to support the safety of working in a hypoxic environment of oxygen at 15%.

At sea level, 15% oxygen content is equivalent, in terms of human physiology, to normal atmospheric air at an elevation of around 2,700 metres (9,000 feet) above sea level or being on a commercial flight. Millions of people around the world live at altitudes equivalent to exposure at or below 15% oxygen concentration at sea level.

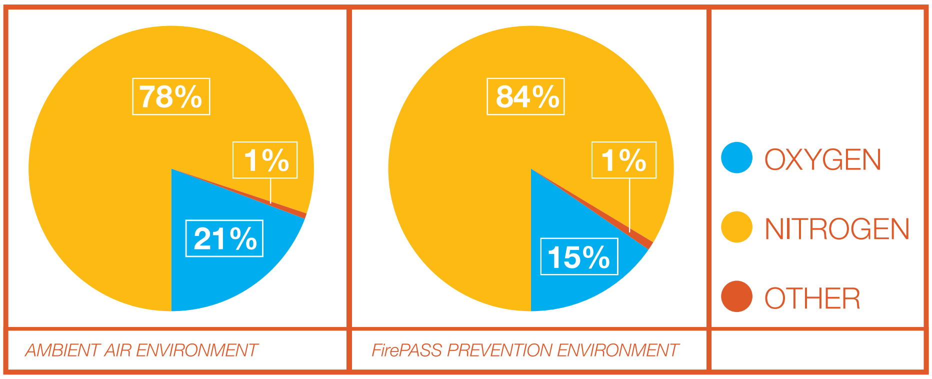
Hypoxic air environments are currently used for physical training and rehabilitation of athletes, as well as in medical research.

AN INDEPENDENT REVIEW

FirePASS® engaged a thoracic specialist, Professor Matthew Peters, President of the Thoracic Society of Australia and New Zealand, to conduct an independent review on working in hypoxic conditions, with a goal to develop a protocol for workplace safety.

A copy of Professor Peters' report including a Hypoxic Environment Checklist is set out in Sections 5 and 6 of this document.

ENVIRONMENT



HIGHEST PROTECTION FOR VALUABLE ASSETS

The oxygen-reduced environment slows oxidation and is perfect for preservation of irreplaceable items such as archived documents, artworks, museum exhibits and rare artifacts. The deterioration of materials and stored goods is strongly diminished due to the reduced-oxygen content of the hypoxic air produced.

APPLICATIONS:

- Data Centres
- Server Rooms
- Electrical Switch Rooms
- Warehouses
- Museums
- Archives
- Libraries
- Art Galleries
- Control Rooms in power plants
- Hazardous materials storage
- Food storage areas/deep freeze/cold storage rooms

FirePASS® takes great pride in introducing the world's latest innovations and technologies to the Australian market.

02

FEATURES AND SPECIFICATIONS

FEATURES AND SPECIFICATIONS

- Provide a safe and breathable oxygen environment
- Patented and proven technology
- Very small footprint
- Plug and use
- Multiple hazards can be protected with just one system
- Generators require very little maintenance – a cycle of 6 months is typical
- No nitrogen injection, so safer than other systems
- No extensive piping
- No expensive refilling
- No pressurized cylinders, no leaking
- No false discharge and no discharge failures
- Designed, engineered and manufactured to customer requirements and specifications
- Easily installed into existing premises as well as in newly built spaces
- Can fit any application ranging from self-contained units for smaller volumes, to vast systems for large buildings, protecting single or multiple rooms and compartments
- Can be used as an alternative, but also as a complementary or supplementary option that enhances conventional fire-safety without interfering with performance

FirePASS is the inventor and patent holder of this technology, which is protected by the United States Patents No.:

Patents: 6,314,754; 6,334,315; 6, 401,487; 6,418,752; 6,502,421; 6,557,374; 6,560,991; 7,207,392; 7,900,709; 7,931,733; US; RE 40,065; European Patent No. 1274490 and other patents worldwide.

BASIC DESIGN

Two standing cabinets for generator and distribution system with inbuilt control unit and separate hypoxic air buffer vessel

Two compressors on buffer vessels

The system consists of a hypoxic air membrane generator system and a distribution system which is built into standing metal cabinets; one separate hypoxic air buffer vessel, separate compressors mounted on compressed air buffer vessels plus a separate refrigerant air dryer and one separate condensate cleaner. The system produces hypoxic air with never less than 10% O_2.

The included control unit monitors the effective O_2-level in the protected areas with the help of the respective oxygen monitoring units. The O_2-level is regulated by opening the valves for the associated rooms as well as switching the compressor on and off depending on the pre-set O_2-levels and on the actual need for hypoxic air of the total system. As a need for additional hypoxic air increases (due to inherent leakage within the room), hypoxic air is delivered via the buffer vessel into the room.

HYPOXIC VENTILATION SYSTEM

The key factor that determines the running costs of any hypoxic air venting system is the leakage rate of the protected volume. We therefore recommend improvements to sealing in order to reduce running costs. An investment in improving the sealing typically has short payback times as there is immediate pay-off through reduced energy consumption and reduced maintenance costs

We are happy to provide recommendations on sealing improvements and to discuss any additional requirements.

In order to control and maintain the environment to the desired oxygen level, the system will include an advanced oxygen monitoring system with ultra-stable, long-life zirconium oxide oxygen sensors.

PRINCIPLE OF OPERATION

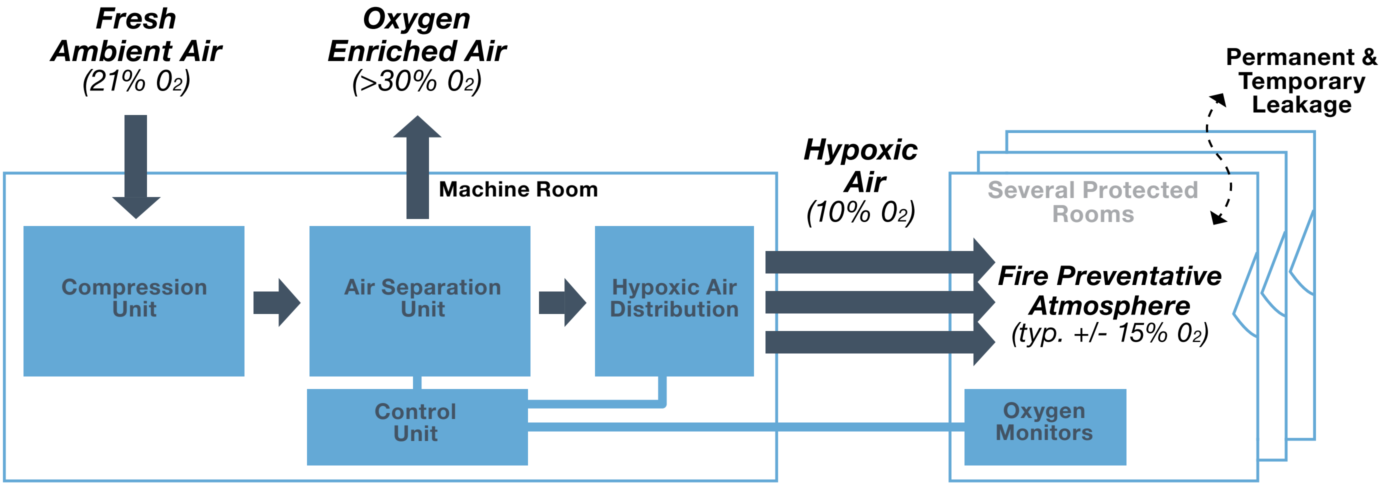
Hypoxic air generators operate by filtering a part of the oxygen from ambient air and providing fresh hypoxic air for the ventilation of the protected areas. As a result, a slight positive pressure will be established inside the protected room. The positive pressure will keep out dust and other impurities, while constant hypoxic ventilation will aid in the removal of gaseous products that may be generated inside the room.

The flow of the hypoxic air will be adjusted to maintain a level of oxygen in the internal atmosphere between 14.5% and 15.7% typically (these levels may change depending on the room and contents to be protected). Hypoxic flow will shut down at 14.5% O_2 and automatically resume when a level of 15.7% is detected. This provides a good margin for safety in the event that excessive access creates leakage. At the same time, this provides a level of oxygen that is perfectly safe for long-term exposure (full working day) of personnel.

COMMON CHARACTERISTICS OF THE SYSTEM

- Generator system and distribution system with control unit mounted in standing metal cabinet
- Multistage filtration consisting of a fine coalescing filter (1mu), a coarse coalescing filter (0,01mu), an activated carbon absorber and a dust carry-over filter (1mu)
- In-built moisture control and automatic draining for each section
- Standing hypoxic air buffer vessel
- Condensate cleaner
- Oxygen monitoring units and control panel to monitor protected areas
- UPS (with 24 hour battery back-up) for the control unit and oxygen monitoring units
- Three phase alternating current 400V/50Hz power supply for the compressors and 220V/50 Hz for the generator

SYSTEM CONFIGURATION



Additional Benefits

The hypoxic air venting system offers additional value when used to protect historical materials and valuable goods. The deterioration of the materials and stored goods is strongly reduced due to the air's reduced oxygen content. This will slow down or even stop the process of oxidation. The oxygen reduced air provided by the system is completely clean and particle free air (< 1mu).

OPTIONAL FUNCTIONALITIES FOR THE SYSTEM MAY BE ADDED UPON REQUEST

- Additional dry contacts in the control unit to connect separate visable/audible alarms
- Signal inputs for a door switch that enables the hypoxic air supply to be turned on or off
- Separate, additional display located outside the protected area, showing the oxygen concentration level
- Remote location of the control unit, built into a separate metal cabinet
- The system can be connected to a building management system or other central monitoring unit with ModBus TCPIP

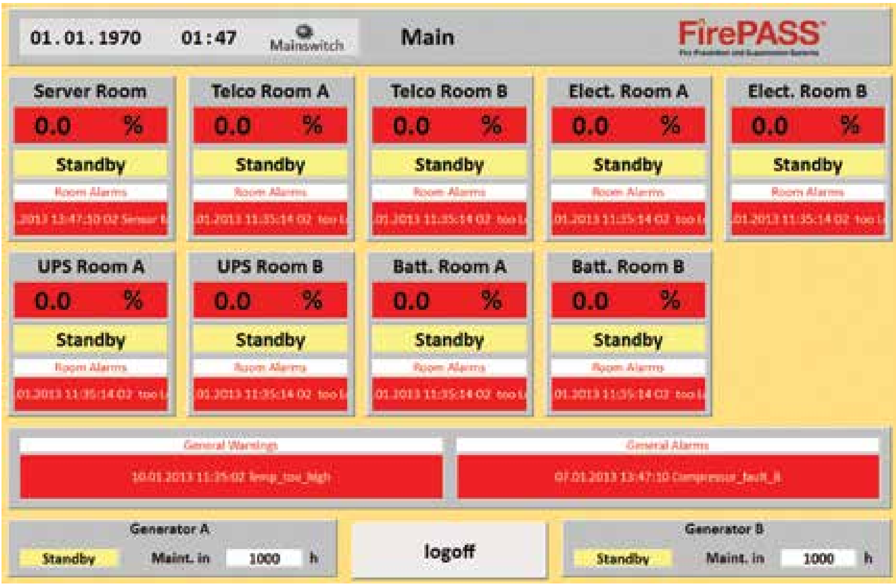
IMPORTANT NOTES

1. All FirePASS systems perform with nominal data at 20 degrees Celsius ambient conditions. They are normally designed to operate at temperatures between 5 and 30 degrees Celsius. In order to sustain higher ambient temperatures in the machine room of up to 45 degrees Celsius for some hours, the overall design of the system will be amended. This means that the supplied compressors will be equipped with special lubricant and that the refrigerant air dryers used in the system design have been chosen with a capacity reserve. Nevertheless, this does not allow a permanent operation above 45 degrees Celsius
2. Operating the system at room temperatures above 45 degree Celsius or below 5 degree Celsius will result in reduced performance and may cause damage
3. The units shall be protected from excessive moisture and dust
4. The provided air shall comply with the ISO standard ISO8573-1:2010 class 3.4.4. The air temperature has to stay within the range of 10 to 30 degree Celsius

CONTROL UNIT

The control unit has a user-friendly touch screen for easy programming and settings, protected by passwords to provide various levels of security. The touch screen will be installed in the generator metal cabinet jointly with the control unit. It may be optionally installed in a separate small metal cabinet and located remotely. The control unit shows and tracks all alarms and warnings and stores the system performance data over a period of time of more than one year, including the regularly tracked O2-levels measured by the oxygen monitoring units. The data can be written to a USB drive and transmitted to a computer for analysis.

See below example of the main screen of the control unit touch panel interface. Additional functionalities can be supplied upon request.



The control unit may be enabled to communicate with a building management system installed on site by Modbus TCPIP protocol via standard Ethernet cable. Alternatively, the system can be upgraded to be monitored and controlled from any PC via a web-browser based interface.

The control unit will be equipped with a UPS (hold-time 24 hours) that supplies the control unit and the touch panel as well as the oxygen monitors and the BMS interface. This will keep all monitoring and alarming functionalities working even in the event of mains power failure.

Example: The “room info screen” shows all relevant system parameters including actual and past oxygen values.

OXYGEN MONITOR

FirePASS provides a high quality, dedicated and certified stand-alone continuous oxygen monitoring unit for the detection of oxygen content specifically in hypoxic environments. The system consists of a digital touch panel display and a sensor head with a zirconium oxide sensor cell for the detection of O2 with a range of 0-25%. It has an inbuilt relay for local alarms for a pre-set oxygen concentration and is equipped with a buzzer. The oxygen monitoring unit stores the measured oxygen values and allows for displaying them on the local touch panel.

The monitor is 24VDC powered and continuously transmits O2 concentration data via a 4-20mA signal. The sensor head, the electronics and the display are built into a wall-mounted aluminum housing that is installed in the protected room. The O2 sensor cell has a minimum life of 5 years.

INSTALLATION

FirePASS® systems have a smaller footprint compared to conventional gaseous suppression systems and do not require rigid piping within the protected spaces. The only requirement is simple, minimal pressure piping to each protected area and to the ambient air, along with wiring of the oxygen monitoring units in the protected areas.

It is recommended that protected areas be equipped with highly sensitive smoke detectors such as VESDA or equivalent. This is to ensure that any smouldering combustion from cable faults, for example, is reported in its incipient stages.

A comfortable, breathable atmosphere is created inside the protected space by the ongoing ventilation with fresh hypoxic air.

The highly reliable hypoxic air generators require very little maintenance – a maintenance cycle of 6 months is typical. Regular monthly inspections are recommended to ensure a fire preventative atmosphere is maintained.

FirePASS® systems can be implemented as an alternative, but also as a complementary or supplementary option which enhances the conventional fire-safety means without interfering with their performance.

Note: The protected areas have to be well sealed in order to minimize the permanent leakage of air in and out of the room. All spaces in the protected area must have split-type air cooling or closed, dedicated air recirculation systems.

PREPARATORY WORK

Sealing the rooms

The key factor relating to running costs (energy consumption and maintenance) of an installation of FirePASS® fire prevention systems, is the leakage. This is the sum of permanent leakage of the protected area and the temporary leakage created by door openings. Investing in improving the sealing of the protected areas will have a direct impact on running costs as they are directly proportional to the leakage rate achieved. The payback for such improvements typically, is less than one year.

To evaluate the current leakage of the area to be protected, we recommend performing an integrity fan test prior to any works being commenced.

VENTING / COOLING

The area where the compressors and filtration units are housed is required to be well-vented in order to allow a permanent supply of fresh, ambient air to the compressors. Alternatively, the room can be cooled with chillers but this will also require a supply of fresh air.

There is a requirement for a small drain in the machine room for the wastewater of the condensate cleaner.

Note: The final design of the machine room (the manner in which it is being cooled/vented) has to be agreed jointly. Separate recommendations will be given regarding all preparatory work. Material and diameters of tubing/piping mentioned in the following sections are to be verified, based on the final design.

INSTALLING THE SYSTEM

FirePASS® systems come readily mounted and tested. Once on site, the system is connected to the room sensors and to the power supply. The system is then connected to the rooms via the installed tubing. The by product oxygen-enriched air is vented outside.

The power supply for the compressors is 400 Volts/50 Hz/3-phase with slow fuses to serve the compressors. The generator units need 220Volts/50 Hz and shall be buffered via the central UPS.

Tubing to the protected area
Supply of the protected area with hypoxic air can be achieved either with metallic, PVC, PA, ABS or similar material tubes or pipes. If the piping for the provision of hypoxic air to the protected area crosses other fire sections, it shall be acheived with steel piping.

The tubes or pipes shall be installed in a way that they build the shortest possible connection to the room and have as few bends as possible. For the piping to the protected area, the sufficient inner diameter will depend on the length and number of bends (generally, 11 mm for all areas, with two tubes or pipes in parallel for the supply of the bigger area). The installation of tubing or piping is to be planned, prepared and carried out by certified installers.

Noise generated at the air outlets is reduced by installing sound mufflers.

PIPING

Piping for the oxygen enriched air outlet may be done with a PVC, PPS, ABS or similar pipe, or with a metal duct. It is to lead directly outside the building, ideally up to the roof level, to avoid any increase of the danger of fire.

A sufficient inner diameter will be approximately 10-12mm, depending on the location of the protected area and the respective distance and number of bends required.

The installation of the piping is to be planned, prepared and carried out by certified installers.

Note: The oxygen enriched airflow has to be vented outside the protected area whilst the system is operating, as this waste flow will carry up to 35% oxygen content.

WIRING THE ROOM’S OXYGEN SENSORS

Each room is to be equipped with two Oxygen Monitoring Units as a minimum. The monitoring units are typically placed at eye level, at an appropriate distance from the door of the room. This is to provide for monitoring of oxygen conditions and alert if doors are wedged open or not closed properly, whilst minimising the amount of false high oxygen alarms.

Each sensor is to be wired directly to the FirePASS® control panel with its own 7-wire, fire rated shielded cable.

MAINTENANCE

The FirePASS® hypoxic air generators are highly reliable passive units that can operate for decades with proper maintenance. This normally includes, as a minimum, changing the filters after every 3,000 operating hours or at latest after 12 months. This cycle applies if the supplied fresh air is compliant with the required quality. If the air quality is lower (in the event of dust, humidity, temperature etc.) the cycle of filter changes needs to be reduced.

The compressors require regular maintenance with a cycle of 2,000 running hours. We recommend a maintenance cycle of 2,000 hours for the whole system (both for compressors and generators).

INSPECTIONS

Acceptance test
The operator/operating company must subject the FirePASS® oxygen-reduction system to an acceptance test by a qualified person after installation or after any significant modification to the system. This test must take place prior to commissioning.

Regular Inspections
The operators/operating company must have the proper function of the FirePASS® oxygen-reduction systems tested by a qualified person at least once per year. Special operational circumstances may make it necessary to carry out more frequent inspections.

Record of Inspections
The results of the inspections must be recorded in an inspection report. The records of the acceptance tests must be kept throughout the operating time of the FirePASS® oxygen reduction system. The records of the regular inspections must be kept for at least 4 years. These may be stored on computer data carriers. These documents must be presented to the competent supervisory authorities upon request.

WARRANTY

The FirePASS® hypoxic air generator systems come with a regular warranty of two years. The warranty commences on the date of delivery.

Note:

- **Damage caused by using compressed air, not following the specifications, is not covered. This includes too high or too low pressure, wet air and air with high oil content etc.**
- **Maintenance is to be carried out per the times outlined in the manual**
- **Warranty does not cover consumables (filter elements and activated carbon refill)**
- **Warranty applies to parts only**
- **Damage caused due to excessive leakage resulting in high duty cycles is not covered**

FirePASS®
Fire Prevention and Suppression Systems

Declaration of Conformity

ALL COMPONENTS USED ARE CE-MARKED.

THE PRODUCTION OF FIREPASS® FIRE PREVENTION
SYSTEMSIS ISO 9001 CERTIFIED.
THE SAME APPLIES FOR ALL SUPPLIERS.

THE FIREPASS® SOLELY USES UL-LISTED COMPONENTS WITH DNV AND
LLOYD'S REGISTER TYPE APPROVALS FOR ITS ELECTRONIC CONTROL UNITS.

THE OXYGEN MONITORING UNITS USED FOR
FIREPASS® FIRE PREVENTION SYSTEMS
HAVE DNV, BUREAU VERITAS AND LLOYD'S REGISTER TYPE APPROVALS.

BICKENBACH, GERMANY, JANUARY, 2012

FIREPASS EUROPE GMBH

GARY (IGOR) KOTLYAR - DIRECTOR
APPOINTED BY FIREPASS GROUP AS THE RESPONSIBLE PERSON FOR CE MARKING
AND CONFORMITY WITH RELEVANT DIRECTIVES AND STANDARDS

PAS 95:2011

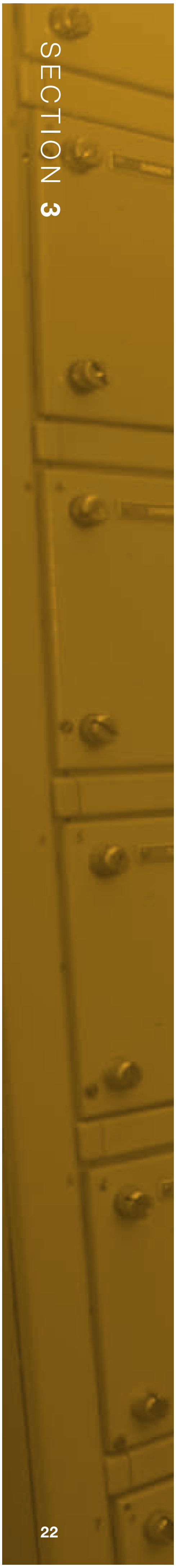
ISO 9001:2008

SN 123456:2009

03


SURGE DIVERTER
DO NOT TURN OFF
LIFT No3
MAIN
SWITCH
EXCEPT FOR EMERGENCIES OR SERVICING DO NOT OPEN THIS SWITCH UNLESS HYDRAULIC LIFT IS AT BOTTOM LANDING
MAIN SWITCH
DISTRIBUTION BOARD FS
FIRE SERVICES
BUSBAR ZONE
BUSBAR ZONE

CASE STUDIES



SYDNEY ADVENTIST HOSPITAL, SYDNEY, AUSTRALIA

In June 2013, FirePASS installed Australia's first oxygen-reduction fire prevention system at the Sydney Adventist Hospital (SAH), located in Wahroonga on Sydney's North Shore.

SAH started in 1903 as a 'Sanitarium' to provide a place of healing where people learned to stay well, and since then has been affectionately known as 'the San'. SAH is NSW's largest single campus private hospital, a multi-award winning facility offering access to world-class doctors, nurses and other health professionals. With approximately 2,300 staff, 500 volunteers and 750 accredited medical practitioners, SAH offers comprehensive surgical, medical, and emergency services to more than 53,000 inpatients and 180,000 outpatients each year.

Darren Walsh from FirePASS' fire protection company, Automatic Fire Protection, presented the FirePASS® fire prevention solution to Bernard Jakovac, Director of Engineering Services at SAH. Bernard could immediately see the benefits of a fire prevention system that would never let a fire start, compared to a traditional fire detection and suppression system.

FirePASS installed a FirePASS® FP-500 System into several rooms at the SAH including the power factor correction room and the hospital's main switch room that feeds the operating theatres. FirePASS® FP-500 System typically protects a volume of 500m3.

A few months after the installation of FirePASS' FirePASS system, there was a fault in the power factor correction room. The VESDA system detected the fault and the FirePASS system prevented a fire starting.

Bernard and the SAH offer interested parties the opportunity to view the FirePASS® FP-500 System in operation. Several consultants and insurance providers have visited SAH to see the new technology and have reported very favourably on this innovation in fire safety.

Images: 1. FirePASS FP-500 Twin System **2.** Bernard Jakovac, Director of Engineering Services in front of Sydney Adventist Hospital **3.** Switch Room

FIREPASS CORPORATE OFFICE, SYDNEY, AUSTRALIA

FirePASS installed a FirePASS® FP-145 System at their corporate office located at Stanmore in Sydney.

The FirePASS® system is set up in FirePASS' boardroom and is used for demonstration purposes.

FirePASS® FP-145 is a self-contained unit protecting one room of up to 200 m3.

This system has a simple installation - plug and play.

Images: 4. FirePASS FP-145 **5.** FirePASS Touch Screen Control Unit **6.** FirePASS FP-145 outside FirePASS Boardroom **7.** FirePASS Boardroom, Sydney

1.

2.

3.

OSLO MUSEUM OF CULTURAL HISTORY, UNIVERSITY OF OSLO, NORWAY

The Museum of Cultural History is one of Norway's largest cultural history museums. It holds the country's largest prehistoric and medieval archaeological collections, including the Viking ships at Bygdøy, a substantial collection of medieval church objects, and a rune archive. The museum also has a comprehensive ethnographic (study of people and their cultures) collection that includes objects from every continent, as well as Norway's largest collection of historical coins.

FirePASS® is protecting 6 areas of around 14'000 m3.

Images: 1. The Oseberg Viking Ship. Copyright: Museum of Cultural History, University of Oslo, Norway / Photographer Unknown **2 & 3.** Archive Rooms at the Museum of Cultural History, University of Oslo, Norway

OSLO CITY ARCHIVES, NORWAY

The Oslo City Archives is the city's executive authority within the archival domain.
The City Archives has a supervising and advisory responsibility for the city's records management, both electronic and paper. The Oslo City Archives holds and preserves historically and judicially important archives for the City of Oslo, and is responsible for making them available for future generations.

FirePASS® FP-8000 Twin System is protecting 2 large archive rooms with a volume of 8,000 m3. Offering full redundancy of air compression and air separation units.

Images: 4. Archives

MINISTRY OF DEFENCE PENSION FUND, MUSCAT, OMAN - TIER 4 DATA CENTRE

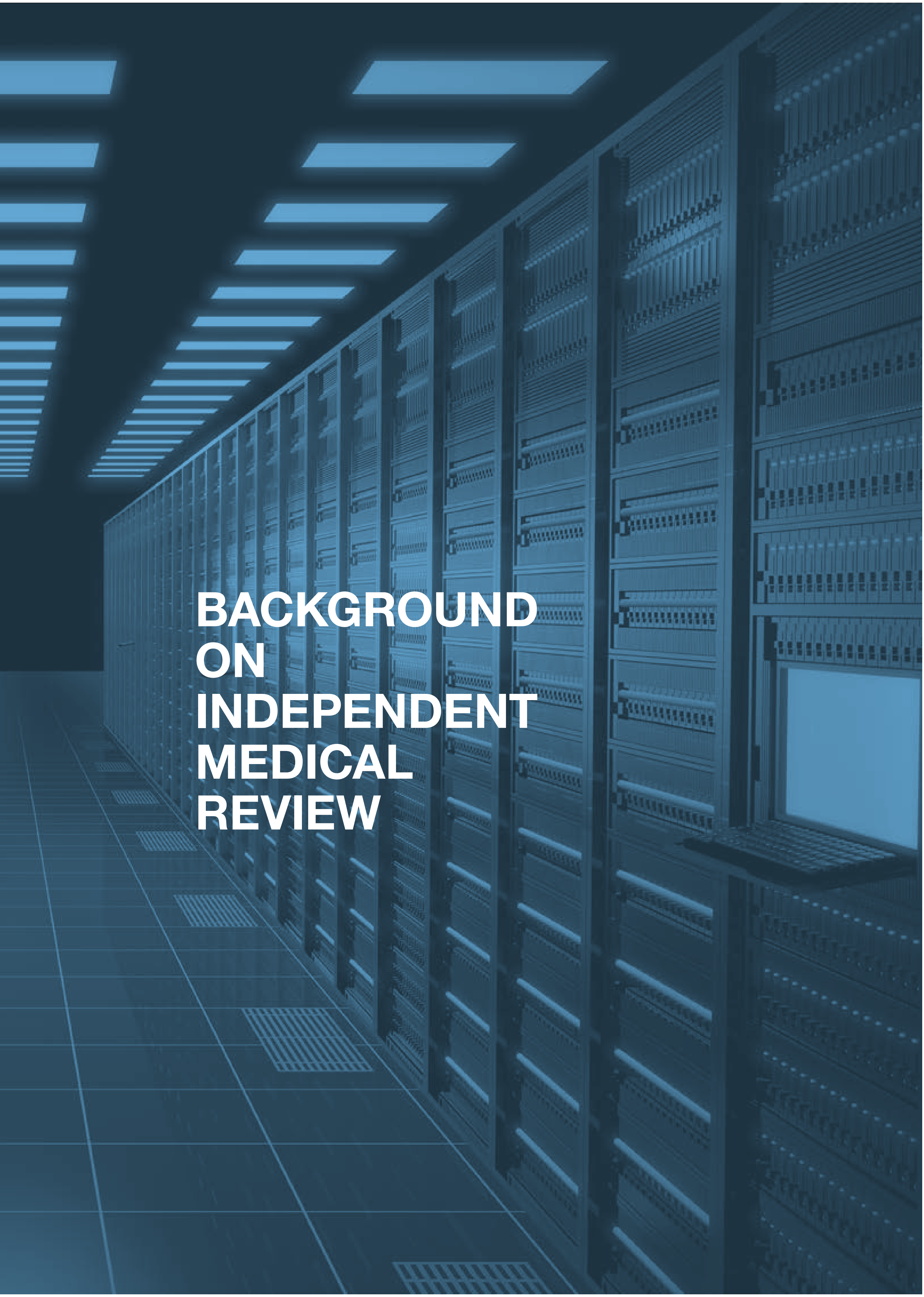
Ministry of Defence Pension Fund, Muscat, Oman - Tier 4 Data Centre

Muscat is the capital of Oman. The city lies on the Arabian Sea along the Gulf of Oman and is one of the Middle East's oldest cities.

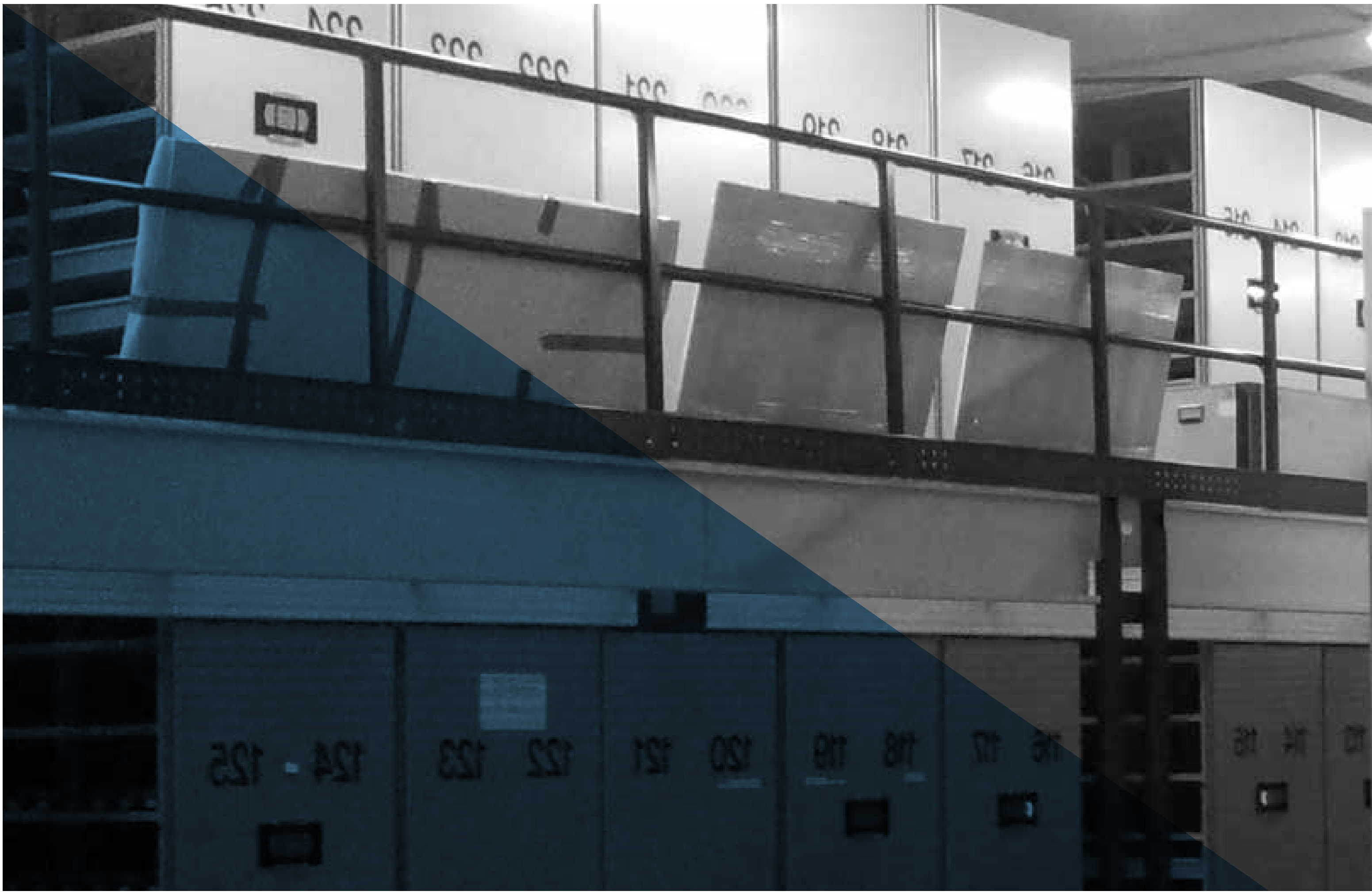
FirePASS ® FP-1000 Twin System is protecting 9 areas in the Data Centre.

Images: 5 & 6. FirePASS ® FP-1000 Twin System


04



BACKGROUND ON INDEPENDENT MEDICAL REVIEW



BACKGROUND ON INDEPENDENT MEDICAL REVIEW

When FirePASS® first became involved with oxygen reduction fire prevention technology, medical reviews of the safety of the system had been conducted in the UK and Europe. The British Standards Institute issued a publicly available specification, PAS 95:2011.

To address any concerns about the health and safety impact of hypoxic environments, FirePASS® engaged a thoracic specialist, Professor Matthew Peters, President of the Thoracic Society of Australia and New Zealand, to conduct an independent review on working in hypoxic conditions, with a goal to develop a protocol for workplace safety. A copy of Professor Peters' report is in Section 5 of this document.

In addition to the report, Professor Peters produced a simple checklist of considerations for anyone working in or visiting a hypoxic environment, see Section 6.

The report and checklist clearly outline measures required when working with hypoxic systems.

FirePASS engaged Professor Matthew Peters, President of the Thoracic Society of Australia and New Zealand, to conduct an independent review on working in hypoxic conditions.

05

MEDICAL REPORT BY PROFESSOR MATTHEW PETERS


FirePASS®
ygen reduction fire prev

The effects and potential hazards of exposure to hypoxia in specialised hypoxic rooms or facilities.

Matthew J Peters MD FRACP
Leigh M Seccombe M Sc

For

Thoracic Society of Australia and New Zealand

President
24 Jan 2014.

Executive Summary

A hypoxic environment is an environment with a reduced level of oxygen available to breathe whilst maintained at a safe level for human occupation. This report considers the impact of hypoxic environments on persons with specific medical conditions, including heart and lung conditions, asthma, diabetes and pregnancy.

Normal air contains 21% oxygen. This report considers the health effects of entering and working in a hypoxic environment with 15% oxygen. Environments with lower oxygen levels, down to 13% oxygen, have been created for specific purposes. The risk analyses for these are different and are not considered here. Because of normal atmospheric physics, at altitude, air pressure is lower and the partial pressure or availability of oxygen to breathe is lower. At sea level, an environment with 15% oxygen has similar oxygen availability as that at 2400m altitude.

Similar conditions are commonly experienced during commercial aircraft flight. A short-haul flight from Sydney to Melbourne reaches a cabin pressure altitude of 2000 – 2400m but for only a short time during the flight. Longer flights will stay at this cabin altitude for a longer duration. It is highly likely that a hypoxic environment at sea level will be well tolerated by any person who has recently flown without an adverse experience and is not working heavily in the low oxygen environment.

All persons who enter a reduced oxygen environment will have a reduced maximum exercise capacity. Whether this is at all noticeable depends on the background level of fitness and the intensity of work required. Only those patients with severe lung or heart disease are likely to experience undue symptoms in a 15% oxygen room, although all workers should be aware of the risks. A hypoxic room clearly differs from a commercial aircraft, or other high altitude environments, in that a person is able to immediately access normal air by exiting the hypoxic room. This ability to exit the hypoxic environment will resolve the symptoms caused by the environment – thus addressing the rare safety issues that may arise.

In conjunction with policies that control persons being or working alone in a low-oxygen environment, the risks are extremely small.

•

Structure of this report

It is intuitive that the low-oxygen room must be dangerous and that there is an inherent hazard in any situation where the level of arterial oxygen is reduced. However, this is untrue for the great majority of those workers and other visitors who may enter or work in the rooms. As this relative safety is somewhat counter-intuitive, much of this review focuses on the physiology that allows humans to accommodate well to this environment and this provides the background to our recommendations.

The Hypoxic Room Environment

A room with 15% oxygen is moderately deficient in oxygen. Air contains 21% oxygen so that at sea level, fully saturated air, has an oxygen partial pressure of 149mmHg. Hypoxic rooms at 15% oxygen have a partial pressure of approximately 110mmHg. During ascent to altitude, barometric pressure declines and by Dalton's law the partial pressure of oxygen must fall. Rooms with 15% oxygen are similar in their oxygen availability to air at an altitude of 2400m[1].

By way of comparison, a range of altitudes and an estimation of how low the inspired oxygen in a room would have to be at sea level to replicate oxygen availability at that altitude are shown in the following table.

Table 1: Examples of high altitude destinations with equivalent pressure of inspired oxygen (P_IO_2) experienced at the barometric pressure.

Location	*Elevation*	*P_B*	*PIO_2*	*Equivalent FIO_2 at sea level*
Sea Level	*0*	*760*	*149*	*21%*
Mt Hutt Ski field, NZ	*2086m*	*598*	*115*	*16%*
Aircraft cabin(min)	*2438m*	*574*	*110*	*15%*
Telluride, Colorado	*2600m*	*563*	*108*	*15%*
Cusco, Peru	*3300m*	*518*	*99*	*14%*
Lhasa, Tibet	*3600m*	*499*	*95*	*13%*
Pike's Peak Colorado	*4300m*	*458*	*86*	*12%*
"Lhasa train" peak	*5074m*	*416*	*79*	*11%*
Mt Everest summit	*8848m*	*253*	*43*	*6%*

37°C body temperature, P_B; barometric pressure, PIO_2; partial pressure of inspired oxygen, FIO_2; fraction of inspired oxygen.

In considering the risks of low oxygen rooms, we are therefore fortunate in having considerable experience of these conditions in persons travelling to such altitudes (or higher) and travelling or working in commercial aircraft. It can be seen that a room with 15% oxygen is similar in terms of oxygen availability to many mountain destinations including ski fields where there is a high level of physical activity undertaken by skiers or walkers with a range of physical fitness standards. It is estimated that there are 30 million visitors annually to the American Rocky Mountains alone.

The major way that the hypoxic room differs from either a commercial aircraft or terrestrial moderate altitude is that immediate access is available to 21% oxygen by exiting the room. This will, in a rare circumstance, address a safety issue but it also allows for periods in normal room air to be interspersed with periods of hypoxia in the room or facility.

<u>A summary of the normal physiology of oxygen and energy utilisation</u>

Oxygen is essential for life as it is required to generate energy for all physiological function. Core elements include brain functions, heart(myocardium) activity required to achieve circulation of blood, respiratory muscle work for breathing, and the energy required to keep other tissues including gut, liver and skin alive and functioning. Oxygen demand rises further during any physical activity or locomotor work and also must increase whenever there is a greater demand for ventilation or cardiac output.

In the mammalian circulation, blood enters the lung from the systemic circulation (brain, heart, gut, liver, muscles). This blood is low in oxygen and high in carbon dioxide. The gas within the lung has a higher level of oxygen and oxygen will flow into the blood from the lung if the alveolar oxygen level is higher than that in the pulmonary capillaries (and carbon dioxide will flow in the other direction). Except when there is severe lung disease, oxygen transfer to blood is complete well before the blood leaves the capillary circulation of the lung.

The normal circulation then carries newly oxygenated blood into the systemic circulation. There a gradient exists between blood and the energy dependent tissues and oxygen diffuses down this gradient to be used for metabolism. Oxygen in arteries and capillaries is never fully absorbed by tissues leaving an amount of oxygen left over in the mixed venous circulation.

In health and under resting conditions, there is considerable excess capacity in this system. This is true for ventilation, gas transfer, cardiac output and the extent of peripheral extraction of oxygen[2]. Even in the presence of disease, where the maximum potential for one of these core functions may be reduced compared to normal, the demand on that system at rest will be lower than that maximum sustainable output so that life goes on. What varies most in patients with cardiac and respiratory disease is the extent of reserve capacity.

The core oxygen requirements at sea level breathing normal air can thus be considered as those needed for:

1. Basal work at rest equivalent to that of a normal person
2. Increases in work of breathing or myocardial work related to disease such as
    a. Severe COPD
    b. Valvular heart disease
3. Muscle work associated with locomotor activity
4. The increased work of myocardium and respiratory muscles during incremental exercise required to boost circulation and oxygen delivery

In any person, this leaves many ways that this system can fail or otherwise be unable to further increase its function in the face of demand.

With reduced oxygen availability or inadequate ventilation, alveolar oxygen level falls so that there is a reduced gradient for oxygen to flow into the circulation	COPD Uncontrolled asthma Hypoxic environment
Transfer of oxygen from alveolar gas to the circulation is ineffective or inefficient	Emphysema Pulmonary embolism Severe interstitial lung disease Pulmonary hypertension
The cardiac output required to match the workload cannot be achieved	Systolic or diastolic heart failure Valvular heart disease Ischemic heart disease Angina Uncontrolled hypertension
Oxygen carriage is impaired	Anemia Heavy smoking
Circulation to exercising muscles is impaired	Peripheral vascular disease

Regardless of which of these problems exist the same outcome is seen. Total work capacity is reduced compared to that which would be produced by an optimal system. If oxygen delivery is low, muscles can switch partially to anaerobic metabolism but this is only sustainable to a limited extent.

<u>The Concept Of Symptom-Limited Exercise</u>

This is an important concept of relevance to the hypoxic room environment. Any person who pushes themselves will eventually come to the point that they cannot increase or sustain their workload. Even elite athletes are breathless after a race as we commonly see live or on TV broadcasts.

The symptoms commonly present are breathlessness, fatigue and discomfort in the exercising muscles. These can be present in varying proportions. Thus two patients, one with heart and one with lung disease, may have identical symptoms of breathlessness on exercise. A severely anemic patient would also be breathless on exercise.

These symptoms are important and protective as they prevent us from harming ourselves particularly exercising muscles. They present us with the option of continuing at a slower pace (lower workload) or to stop, rest and then continue.

Normal Physiology At Moderate Altitude

We know for certain that this is a very safe environment from the low rate of adverse events during commercial aircraft flight for travellers, who are mainly at rest, and for cabin attendants who exercise to a moderate degree. The rate of all medical emergencies is 16 per million flights[3]. This is the case even though it is likely that many patients with heart and lung disease do travel with no oxygen and there is not intense cardiopulmonary health screening for cabin attendants who obviously fly frequently and some for long periods. The fundamental protection here for passengers is the low workload.

In a 15% oxygen environment, alveolar and arterial oxygen do fall in healthy people but this is well tolerated[4]. There is a very small increase in ventilation. Normal physiology always defends key functions and operating conditions so that by implication hypoxemia by itself must be well accommodated. Cardiovascular changes are minor. Heart rate at rest increases only by 3bpm at 2400m[5,6]. What this tells us is that maintaining an unchanged oxygen saturation is not critical if there is preservation of an adequate circulation and sufficient oxygen extraction from systemic capillaries.

At higher altitudes or when an exercise task is added, there is a need to increase both ventilation and cardiac output. Hyperventilation becomes essential, for basal and usual exercise tasks, above 3000m at which elevation P_IO_2 is 100mmHg and PaO_2 typically ≈50mmHg[1].

There is a linear decline in maximum work capacity with increasing altitude. At 2400m altitude, or in 15% oxygen, this amounts to 10% in sedentary normal subjects[7]. This applies to everybody. The higher the maximum work capacity at sea level, the higher the workload achievable at higher altitude[8]. The corollary of this is that patients with impaired physiology at sea level, may tolerate altitude or 15% oxygen rooms at rest (such as in an aircraft) but become more symptomatic than a healthy person in performance of a similar work task that both would tolerate well at sea level. In a study of obese patients undergoing moderate-intensity exercise training in 90 minute sessions in a 15% oxygen room, there were no adverse events but the intensity of the work achieved at 60% of their maximum heart rate was lower in hypoxia than that in a comparison group exercising in normal air[9].

It follows also from this that an impaired worker will not be able to complete a heavy workload task in a hypoxic room as easily as under normal conditions. Symptoms will limit this but this is very unlikely to become a safety issue unless the partial completion of the task creates a work safety risk. The more impaired at sea level the lower the workload that will produce symptoms at altitude.

The effect of lung disease in low-oxygen environment

Under hypoxic conditions, a greater degree of arterial hypoxemia is consistently seen in those with pulmonary disease than healthy subjects. During commercial aircraft flight, subjects with pulmonary disease including chronic obstructive pulmonary disease (COPD), interstitial lung disease (ILD), cystic fibrosis and restrictive disorders experience significant arterial desaturation while seated at rest. With only mildly reduced PaO_2 at sea level ≈78 mmHg, subjects with COPD and ILD experience a PaO_2 ≈48 and 51mmHg mmHg respectively during an AST[10]. In-flight measurements at cabin pressure altitudes near 2400m are similar, with a mean SpO_2 85-86% in subjects with COPD and restrictive lung disease. On Mt Hutt, terrestrial altitude of 2086m, patients with moderate COPD (sea level PaO_2 75mmHg) experienced a resting PaO_2 ≈ 51mmHg[11].

Importantly, altitude and altitude simulation are well tolerated at levels of oxygenation that would and should cause concern in the context of acute medical illness. It is likely that these patients have some reserve in peripheral oxygen extraction so that the actual delivery of oxygen to tissues remains normal or near-normal.

Exercise at altitude leads to further arterial desaturation. PaO_2 with exercise, walking slowly, when breathing 15% oxygen, fell to ≈40mmHg in COPD and to ≈38-40mmHg in patients with restrictive disease. No serious adverse events however were reported. Younger subjects with cystic fibrosis, at a terrestrial altitude of 2650m, desaturate significantly following exercise (PaO_2 <50mmHg) however with no or only minor symptomatology.

While the level of hypoxemia at rest at moderate altitude generally elicits minimal symptoms in subjects with pulmonary disease, physiological impairment becomes evident once a mild exercise task is attempted. During an AST, 70% of subjects with severe COPD and 67% with ILD were unable to complete a 50m walk task. Similarly on Mt Hutt (2086m), some subjects with COPD were unable to complete a 6-min walking task due to dyspnoea, with a mean PaO_2 of 41mmHg, tachycardia to 130bpm and an elevated $PaCO_2$ suggesting true ventilatory limitation. It can therefore be reasonable concluded that patients with severe lung disease will generally tolerate being in a hypoxic room and low activity in that room but will be symptom limited at lower workloads relative to their usual.

Barotrauma

Barotrauma or pressure damage to the lung is a risk during rapid ascent to altitude but is not a risk in hypoxic rooms.

Cardiac disease in a low-oxygen environment

As with pulmonary disease, travel to altitude is generally well tolerated in subjects with cardiac disease. Patients with stable coronary artery disease tolerated travel and exercise atop the Jungfraujoch at 3454m[12]. Similarly at altitudes of up to simulated 3000m, maximal symptom-limited exercise in those with Grade III-IV heart failure did not elicit angina, arrhythmia or ischemia[13]. In the same study, the intensity of exercise was reduced and those with greatest impairment at sea level had the greatest impairment at altitude.

Patients with ischemic left ventricular dysfunction displayed reduced walk distance at 2970m but not at 2000m but without serious adverse events[14]. Repeated exposure for periods of 3-4 hours at altitudes up to 2700m with a training program in patients with moderately severe heart failure was safe and there was a modest improvement in exercise capacity over 10 weeks[15].

There is a lack of evidence in relation to valvular heart disease. The physiology at altitude needs to be considered from basic understanding.

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A person with both heart and lung disease and/or other additional co-morbidity

There are a number of potential interactions between heart and lung disease. Similarly to those with pulmonary disease, ineffective ventilation with exercise stress is a feature of chronic cardiac disease. The higher metabolic demand of work of breathing and reduced oxygen transport could cause diaphragm fatigue and compromise limb blood flow, limiting exercise tolerance[16].

What is the effect of a room that is very hot – such as one housing computer servers?

In a hot environment, the amount of total circulation that goes to the skin is increased. Therefore in a hot rather than a cool room, this additional skin flow will deprive exercising muscles of circulation or otherwise require additional myocardial work and work of breathing for a given exercise task. Symptoms would not necessarily be any different but it is that discomfort will be experienced at a lower workload in a hot room. This should be managed with simple fluid replacement and rest breaks from the room. The frequency of these will depend on how hot the room is and the workload required.

What is the effect of a room that is very dry – such as archival storage?

An additional effect is unlikely. In a cold dry environment, there is greater risk for exercise induced asthma in those with poor asthma control and only then at higher workload. This would be addressed rapidly by treatments such as Ventolin or similar.

Specific conditions worthy of further comment

Asthma

Clinically stable asthma is not a contra-indication to travel into or work within a hypoxic environment. Standard asthma guidelines can be used to assess current asthma control. Reliever inhalers such as salbutamol (Ventolin) or terbutaline (Bricanyl) will function normally.

If asthma is poorly controlled, additional breathlessness is likely to be experienced under moderate exercise conditions. Wheeze or breathlessness is possible with higher intensity exercise and would be accentuated if the air is cold and dry[17]. This should be relieved by standard bronchodilator inhalers and exiting the room.

Asthma symptoms in the room would require exclusion and a Specialist report confirming that asthma had been stabilised and that no alternate condition might have contributed to the symptoms experienced(rather than asthma).

Pregnancy

There is very limited evidence in relation to the effect of brief hypoxia. Most of the data is derived from commercial aircraft flight in passengers and cabin attendants. These data are further complicated by some different outcomes known in working vs non-working women. Cabin attendants experience a modest increase in cosmic radiation that is not relevant to this discussion. Aspects of the following guidance are thus poorly evidence based.

After 33 weeks there is reduced fetal growth in babies of mothers resident at altitude. Babies are however born healthy as distinct from other causes of intra-uterine growth retardation. Without evidence to support the argument, a full working week with 40/168 hours in 15% oxygen is unlikely, based on first principles, to cause fetal or maternal harm. In the light of the evidence available we suggest:-

First trimester/uncomplicated pregnancy - no restrictions additional to any imposed by intercurrent disease

Second/third trimester to 34 weeks – visit and light workload as specified elsewhere are reasonable. High intensity workload should be avoided. This may not necessarily be dangerous to mother or baby but there is likely to be more breathlessness given that pregnancy is already a high cardiac output situation.

After 34 weeks

Brief visit/inspection without workload as specified is acceptable. Leave room if respiratory distress develops.

Complicated or high-risk pregnancy

This includes but may not be limited to

- pre-ecclampsia or at increased risk
- pregnancy hypertension
- diabetes
- renal impairment
- severe anemia
- multiple pregnancy
- significant cardiac disease

No outcome data exist. A brief visit to a hypoxic room is very likely safe but should be considered in the category of needless risk. We therefore advise exclusion.

Type 1 Diabetes

Mountaineering to much higher equivalent altitudes has been achieved by people living with well-controlled type 1 diabetes – there being many more practical challenges during trekking[18]. The major concern in the hypoxic room would be unattended hypoglycaemia with the possibility that the experience of hypoglycaemia might be altered or the course more rapid. The principle of not working alone should apply here.

For extended stays (>2 hours), BSL should be checked before entering the environment in low workload conditions and again at 4 hours if work of high intensity is required. There should be the access to a source of sugar should hypoglycaemia symptoms be experienced.

Type 2 Diabetes

The risk of hypoglycaemia is low and the major issue is the need to address relevant cardiovascular risks. There is considerable evidence that exercise in hypoxic environments, in Switzerland and in Austria, for patients at risk of Type 2 diabetes is safe. The altitudes were slightly lower, around 1700m, but the programs included a moderate amount of physical exercise[19]. Exercise in hypoxic conditions actually increases insulin sensitivity and this is a good thing. [20]

Acute Mountain Sickness (High Altitude Illness) In The Context Of Hypoxic Room

A proportion of people will experience acute mountain sickness at 2400m. It may be 10-20% depending on the classification used. AMS will be characterised by headache and one other feature – such as nausea or fatigue as featured in the Lake Louise acute mountain sickness questionnaire. The true altitude effect may be less than this as there is a background frequency of these symptoms at lower altitudes[21]. High altitude illness will only be seen in those who remain in a 15% oxygen room environment for a period of hours at least (but can occur sooner with rapid ascent to higher altitude). In a hypoxic room as described, symptoms may be unpleasant but not life-threatening. We take it that no-one will need to sleep in these rooms. If this were necessary, the effect of altitude on sleep would require consideration.

More concerning in a technical environment would be the potential for subtle high-altitude cerebral symptoms. It is generally agreed that ataxia or subtle cognitive changes are manifestations but usually at altitudes well over 3,000m and no changes in measurable psycholopgical parameters were seen during exposure to 2400m altitudes [22]. This may relevant to workers at risk of greater hypoxemia, such as from pre-existing lung disease, completing complex technical tasks or tasks requiring both a moderate physical workload and high dexterity. Visual deficits can be detected from 1500m and impaired colour perception from 3000m. Thus the 15% oxygen room may produce impairment in low-light vision but it would require the development of a 13% oxygen room for colour vision to be compromised.

There is inter-individual variability in the susceptibility to AMS but a moderately high reproducibility in individuals. Obesity is a risk factor based on studies of workers at altitudes >4000m[23]. Experience of high altitude illness at altitudes much greater than 2400m should not be a disqualifying feature for work in a hypoxic room as the illness is altitude dependent. In the same way, tolerance of a 15% oxygen room may not predict tolerance of 13% oxygen if those rooms are created.

Where a highly technical task is required and the requisite technical skills are limited to an individual who has previously suffered AMS symptoms at 2400m, fragmentation of periods in and out of the hypoxic room should mitigate the risk or discomfort. Where this is impossible, use of a battery powered portable oxygen concentrator would address the individual's symptoms. At a flow rate of 2l/minute given that some of this oxygen will be taken up by the worker, the effect on room oxygen will be trivial. The technical and fire implications would have to be separately considered. We believe this circumstance to be rare indeed.

Relevance of recent travel on commercial aircraft in assessment of risk

In some circumstances, a person being considered for access or work in a 15% oxygen room will have undertaken recent commercial air travel.

Prop-jet aircraft are pressurised but have a cabin pressure higher than that equivalent to a 15 oxygen room. Tolerance of these is not relevant to risk assessment.

Short-haul flights in narrow body aircraft (e.g. Boeing 737 and Airbus 320 series) most commonly have cabin pressure altitudes of 2000-2400m. However on a flight from Sydney to Melbourne that pressure might only be experienced for 10-15 minutes. Pressure is higher during ascent and descent. Considering this, it is highly likely that a brief visit to a 15% oxygen room will be well tolerated by any person who has recently flown without an adverse experience.

Wide body aircraft on long-haul flights will have variable pressure altitudes in the range from 1500-2100m[24]. This is obviously sustained for longer. Most passengers need to walk around the cabin to go the bathroom at least. Considering this, it is highly likely that a visit to a 15% oxygen room and a low level of physical activity will be well tolerated by a person who has recently flown long-haul without an adverse experience and has not experienced a deterioration in cardiac or pulmonary function in flight.

The reverse is also true - that a person who has become distressed in flight should be evaluated by a knowledgeable medical practitioner. Early in the development of long distant plane travel, 8/11 patients admitted to a medical facility near Heathrow airport with heart failure after plane flight had experienced a previous similar event[25].

Management and planning for incidental medical events

This does not feature prominently in other hypoxic room guidance but is relevant.

No matter how careful the screening is, there will be incidental or unpredictable medical events that might occur at any time in life. A severe cardiac or neurological event occurring in a hypoxic environment is likely to be further complicated by hypoxia. A conscious mobile patient would be able to return rapidly to normal conditions by exiting the room but not a person who has collapsed.

This risk can and should be mitigated by "not-working alone" practices. A warning buzzer may not be adequate in all circumstances. This is a Workplace, Health and Safety issue that will have to be managed consistent with the relevant legislation.

Comments on systems and engineering

The hypoxic rooms will be expected to have some degree of inherent leak. In an unoccupied room, as long as oxygen levels are monitored all is well.

In the following combination of circumstances it is possible that oxygen levels will fall and carbon dioxide levels increase over time

- a relatively small hypoxic room
- multiple occupants in the room for some time
- a very good room seal with no or negligible leak

If an occupied room goes below target oxygen concentrations, airflow into the room should be increased not decreased.

Summary of recommendations

A table setting out possible guidance for the key areas of heart and lung disease is attached in Appendix 1.

Summary

Travel to low oxygen environments is generally well tolerated. All workers will have reduced exercise capacity in a 15% oxygen room. In those who have more functional impairment, symptoms will limit exercise capacity at lower workload. If the exercise is terminated, symptoms will resolve as they would after any symptom limited exercise task. Only those patients with severe lung or heart disease are likely to experience undue symptoms in a 15% oxygen room but all workers should be warned.

Therefore, risk assessment and planning must take into account

1. The degree of baseline functional impairment
2. The required intensity of workload

For some people, previous travel to altitude or aircraft flight may provide useful information. However, there is some specialist knowledge required to interpret the latter.

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APPENDIX 1

Suggested recommendation

	Brief visit	Low workload	Sustained higher workload
Description	Entering room Being seated Slow inspection walk	Entering room Curator work – sorting, carrying light loads Light manual operating work not normally associated with breathlessness at sea level	Work of moderate intensity that would invoke some breathlessness even if performed at sea level. Examples would include moving furniture, physical installation work, carrying heavy loads
Healthy - no known heart or lung disease	No testing needed	No testing required	No testing required. Fragment work as needed or include periods out of the hypoxic environment titrated to symptoms. If respiratory distress develops a medical review is required before re-entering room to perform similar work.
Mild-moderate chronic lung disease. Estimated VO2max >15ml/min/kg 6MWD >400m	No testing needed if able to walk into room and exit is available. Leave if symptomatic. If clinically unstable visit should be deferred.	Clinical evaluation Lung function tests and resting SaO2 to confirm that severe lung disease is not present because symptoms may not be a reliable guide	Similar evaluation. Must be well at time of work. Task fragmentation if breathless. If respiratory distress develops a medical review is required before re-entering room to perform similar work.

Appendix 1 - The effects and potential hazards of exposure to hypoxia in specialised hypoxic rooms or facilities
Page 1

Known severe lung disease. Estimated VO2max <15ml/min/kg 6MWD <50% predicted	No additional testing needed if able to walk into room and exit is available. Leave promptly if symptomatic. If clinically unstable visit must be deferred until medical review confirms return to optimal state.	Not excluded on safety grounds. Medical evaluation required to confirm that the worker is stable at time of first visit. Leave promptly if symptomatic. It is then the worker's responsibility to report any symptom deterioration and seek a medical review before further visits. Previous breathlessness at rest or slow walking preclude further work in the environment. These patients will be more hypoxemic and there is uncertainty about cognitive performance. Highly technical tasks may be compromised.	Excluded in favour of another worker at low risk. In rare event of highly specialised skills being required consider a portable concentrator
Type 1 Diabetes	No testing needed if able to walk into room and exit is available. Should have glucose source – jelly beans or similar. Leave if symptomatic. If clinically stable visit should be deferred.	No testing needed if able to walk into room and exit is available. Should have glucose source – jelly beans or similar. Leave if symptomatic. If clinically stable visit should be deferred.	If an adult should be cleared by Specialist as not having significant heart disease complicating the diabetes If respiratory distress develops a medical review is required before re-entering room to perform similar work.

Appendix 1 - The effects and potential hazards of exposure to hypoxia in specialised hypoxic rooms or facilities
Page 2

Asthma	No testing needed if able to walk into room and exit is available. Asthma inhaler should be available. Leave if symptomatic. If clinically unstable visit should be deferred.	Clinical evaluation. Lung function tests and resting SaO2 to confirm that asthma is well controlled. Asthma inhaler should be available	Similar evaluation. Must be well at time of work. Task fragmentation if breathless. Asthma inhaler should be available If respiratory distress develops a medical review is required before re-entering room to perform similar work.
Early Pregnancy	No additional restriction	No additional restriction	No restriction additional to any other disease present. Leave room if distressed and in that situation formal medical review is required before further work in the hypoxic room
Pregnancy - Second/third trimester to 34 weeks	No additional restriction	No additional restriction	High intensity workload should be avoided.
Late pregnancy *(After 34 weeks)*	No additional restriction	No restriction additional to any other disease present. Leave room if distressed and do not work in room again	Exclude
Complicated or high-risk pregnancy	No restriction required but it is a needless small risk. Leave room if distressed and do not re-enter	Exclude	Exclude

Appendix 1 - The effects and potential hazards of exposure to hypoxia in specialised hypoxic rooms or facilities
Page 3


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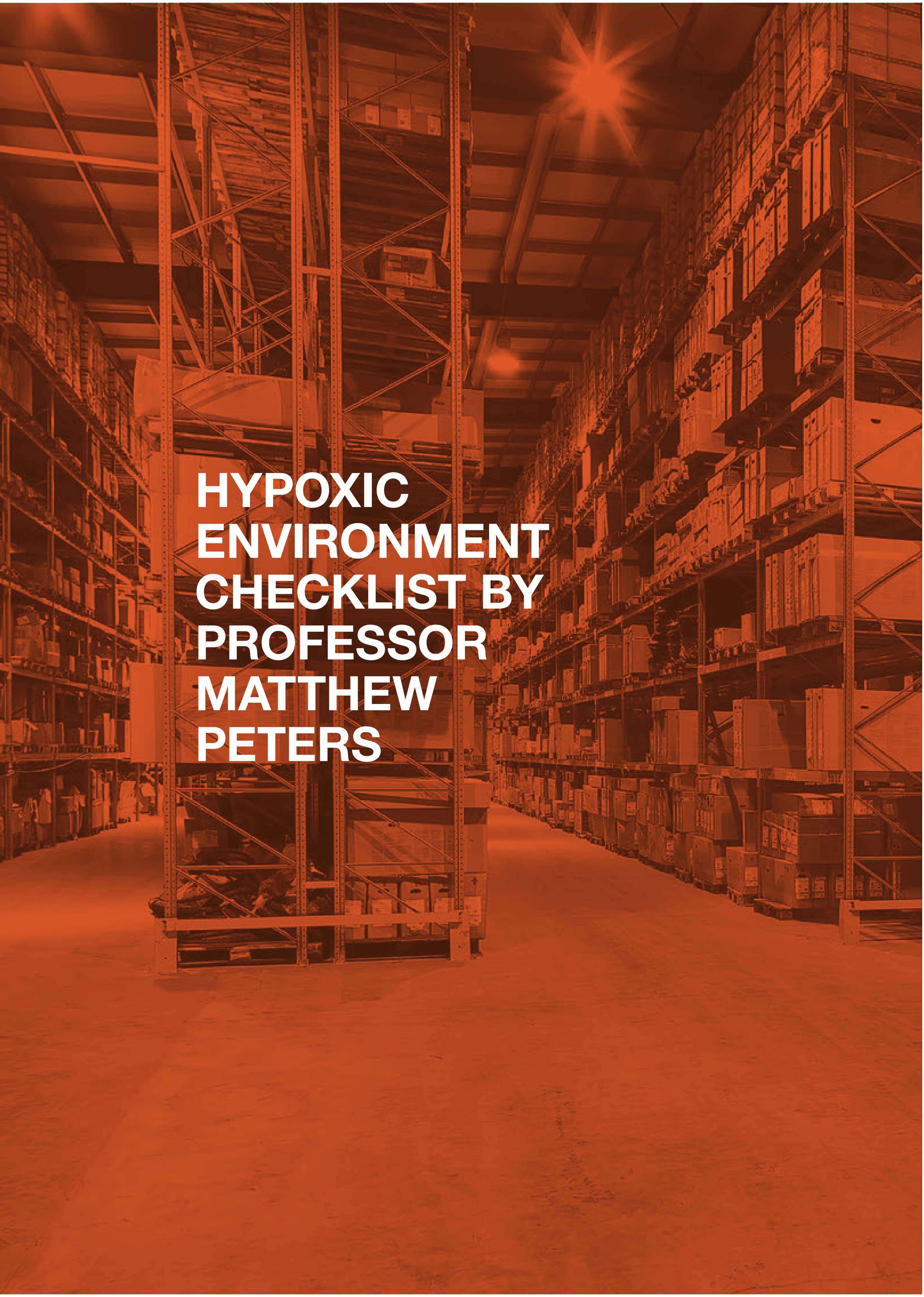
HYPOXIC ENVIRONMENT CHECKLIST BY PROFESSOR MATTHEW PETERS



HYPOXIC ENVIRONMENTS *SIMPLE CHECKLIST*

Normal air contains approximately *21% oxygen.* This hypoxic environment contains approximately *15% oxygen*. In terms of available oxygen, being in a *15% oxygen* environment is similar to being on a commercial airplane, or at a high-altitude location of around 2,400m
(eg Mt Kosciuszko, Aspen Colorado).

The great majority of people will not experience any adverse reaction or discomfort in a hypoxic environment. If you consider that it would be safe for you to travel on a commercial aircraft flight, it is likely that the hypoxic environment will not pose a risk to you.

However, in the event that you experience discomfort or shortness of breath, you should leave the hypoxic environment. If the hypoxic environment is the reason for this discomfort or shortness of breath, it will resolve rapidly following exposure to normal air.

You should not enter the hypoxic environment if you have any of the following medical conditions:

- Severe or unstable heart or lung disease. Stable angina and well-controlled asthma are not contra-indications.
- Severe anemia.
- If you have had a stroke of any sort in the past 12 months.
- Pregnancy (third trimester).
- If you have experienced any of the following adverse effects during previous stays at altitudes of 2000-3000m (6,500-10,000ft) or during airplane flights:
    - Troublesome, persistent headache
    - Nausea or vomiting.
    - Abdominal, chest or joint pains.
    - Shortness of breath at walking pace or severe fatigue.
- Any other medical issues that you are concerned may affect you working in a reduced oxygen environment.

If one of the above applies to you, you will need an expert evaluation should you need or want to work or visit a hypoxic environment.

HYPOXIC ENVIRONMENTS *IN-DEPTH CHECKLIST*

STAGE 1: *Questionnaire for persons likely to enter a hypoxic environment*

	Yes/No
1. Do you have any known heart disease?	
2. Do you have any known lung or airway disease?	
3. Do you have anemia?	
4. Do you have, or have a family history of, inherited blood disease, low blood count, anemia or sickle-cell anemia?	
5. Did you experience any pains (with the exception of headaches), such as abdominal, chest or joint pains, nausea, vomiting, shortness of breath or fatigue during previous stays at high altitude (mountains) or during airplane flights?	
6. Have you ever had a stroke or a “mini” stroke (transient ischemic attack)?	
7. Have you ever been treated for rhythm problems of the heart?	
8. Have you had any episodes of dizziness within the last 3 months that have prevented you from pursuing your normal daily activities?	
9. Do you have to pause during your daily activities at work or at home because of shortness of breath?	
10. Have you experienced any chest pain within the past 3 months while at rest, or while under physical or mental stress?	
11. Have you woken up in the past 3 months because of shortness of breath?	
12. If female, are you currently pregnant?	
13. Are there any known medical issues that you think might affect you working in a low-oxygen environment? If so, please specify.	
14. Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?	

If the person responds with “YES“ to any of the above statements, they should be referred to a qualified physician to determine whether they should be allowed to enter the hypoxic environment and, if so, under what limitations (if any).

STAGE 2: *Further examination by a qualified physician*

It is important that this clinical evaluation is performed by a Physician who has relevant environmental physiology knowledge experience and the technical equipment necessary to simulate a low-oxygen environment if needed. The Physician should provide a report to the organization and advise on any controls or limitations required to ensure that safe practices are maintained.

HYPOXIC ENVIRONMENTS
FREQUENTLY ASKED QUESTIONS

TOPIC	COMMENT
PREGNANCY: WHAT IF I AM PREGNANT?	PREGNANT WOMEN SHOULD NOT BE EXPOSED TO RISK CLASS 3 OR 4 HYPOXIA. THEY CAN BE EXPOSED TO RISK CLASS 2 HYPOXIA, BUT FOR MINIMAL WORKLOAD ONLY (E.G. INSPECTION, SUPERVISION).
COMPARISON WITH AIR TRAVEL: HOW DOES THE HYPOXIC ENVIRONMENT COMPARE WITH AN AIRCRAFT CABIN?	FOR RISK CLASSES 1 AND 2 THE HYPOXIA DOES NOT EXCEED THE PERMITTED DEGREE OF HYPOXIA OF AN AIRCRAFT CABIN. THIS GIVES THE PERSON AN IDEA HOW HE/SHE WILL EXPERIENCE THE ENVIRONMENT.
INFLOW EXPOSURE RISK:	DELIBERATE AND DIRECT INHALATION OF GAS FROM THE DEVICES CAN BE EXTREMELY HAZARDOUS. STAY AT LEAST 1.0 M FROM THE INJECTOR ORIFICES. THIS PROVIDES FURTHER SAFETY, PARTICULARLY IN RELATION TO NITROGEN INJECTION SYSTEMS.
ACUTE MOUNTAIN SICKNESS (AMS) SYMPTOMS:	HEADACHE DIZZINESS, OR NAUSEA MAY OCCUR IN SOME PEOPLE WHO ARE SUBJECT TO CLASS 2 HYPOXIA FOR A PERIOD OF HOURS. THESE SYMPTOMS SHOULD RESOLVE WITHIN 30 MINUTES OF LEAVING THE HYPOXIC ENVIRONMENT. IF SYMPTOMS ARE SIGNIFICANT AND NON-RESOLVING, MEDICAL ADVICE SHOULD BE SOUGHT. IF SYMPTOMS REAPPEAR AFTER RETURN TO HYPOXIA, SPECIFIC ADVICE BY A PHYSICIAN TRAINED IN ALTITUDE MEDICINE/HYPOXIC ENVIRONMENTS IS NECESSARY BEFORE ENTERING THE HYPOXIC ROOM AGAIN. AMS SYMPTOMS ARE MORE FREQUENT AND CAN BE MORE SEVERE IN CLASS 3 AND CLASS 4 HYPOXIC ENVIRONMENTS BUT THESE ARE NOT PRESENTLY BEING USED IN AUSTRALIA.
ALARM SYSTEM/EMERGENCY EXIT:	IF THERE SHOULD BE ANY ALARM SIGNAL GENERATED BY THE HYPOXIA SYSTEM, LEAVE THE HYPOXIC AREA IMMEDIATELY (BUT DO NOT RUN IN AN UNCONTROLLED MANNER, TO AVOID ADDITIONAL DANGER OR ACCIDENTS). ANY FURTHER INVESTIGATION, PROCEDURE OR ACTION SHOULD BE DISCUSSED OUTSIDE THE ROOM (IN NORMOXIA).

CLASS OF HYPOXIA EXPOSURE

1	>17% OXYGEN
2	16.9% - 14.8%
3	14.7% - 13%
4	12.9% - 11.1%

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