Skill Development Course

Gas Blender

Nitrox Blender
Mixed Gas Blender

Instructor Manual

BSAC
Dive with us

Issue 2, April 2012

Published in the United Kingdom

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Contents

DOCUMENT CHANGE AND VA EFFECTIVITY

This document has been raised to Issue 2 for consistency with the Issue version of the Gas Mixing Planner, which has been updated. Opportunity has also been taken to correct some minor typographical errors in the Tables in Appendix E of this document.

Also for consistency of issue date across all materials, all support documents have been similarly increased in issue and all Visual Aids have been re-issued dated 05/12.

BSAC are grateful to the members of the BSAC Technical Group and others for their contributions to the development of this course and its supporting materials. In particular:

Trevor Davies

Nick Jewson

Gareth Leyshon

Jeff Reed

Mike Rowley

Richard Scarsbrook

Janos Suto

Jim Watson

GAS BLENDER COURSE

Aim of Course

To safely train divers and others involved in BSAC diving activities with little or no knowledge and experience of nitrox blending and or mixed gas blending, paying particular attention to precautions required to safely manage and handle blending equipment.

The course assumes the most rudimentary blending system to enable high pressure filling by the most commonly found method called partial pressure filling. The course identifies the issues and processes to fill SCUBA cylinders up to 300 bar.

Entry Level

The course is open to any diver who is qualified as an Ocean Diver.

Minimum age of students, 18 years old.

Before proceeding onto the BSAC Mixed Gas Blender Course, the student must have successfully passed the BSAC Nitrox Gas Blender practical assessment or alternatively hold an nitrox blending qualification issued by a training agency which is recognised by the BSAC. Refer to the BSAC website (www.bsac.org) Technical Section to review recognised gas blending courses.

Duration

Nitrox blender 4½ hours.

Mixed gas blender 3 hours

Instructor Qualifications

The lead instructor must be an Approved Nitrox Blending Instructor (NBI) or a Mixed Gas Blending Instructor (MBI).

Advanced Instructors (or above) who hold a relevant Gas blending qualification are automatically credited as Gas Blending Instructors on obtaining the Instructor resources. Advanced Instructors who are also active ITS Instructor Trainers will also be accredited as Gas Blending Instructor Trainers (IT).

Open Water Instructors need to obtain the Instructor resources and teach competently on a course under the supervision of a Gas Blender Instructor Trainer (IT).

Registration Form included in Resources Pack

All Instructors and Assistant Instructors must have practiced and updated their skills in gas blending within 12 months prior to the course. Where this period is exceeded the lead instructor should arrange for instructors to receive adequate practice before they instruct students.

Instructors

Approved gas blending instructors may be assisted by QIs as Assistant gas blending instructors who may only give instruction under the direct supervision of the approved gas blending instructor. No more than one Assistant gas blending instructor per approved gas blending instructor and no more than two Assistant gas blending instructors per course.

Student - Instructor Ratio

Six students to one instructor for the practical sessions. The maximum number of students who can be accommodated on any course will be determined by the venue, equipment available and logistics for the practical session. It is unlikely that most venues would be suitable for more than 6 students, but there is no absolute maximum.

Venue Facilities and Equipment

A suitable classroom with teaching aids for the presentation of theory lessons and the running of the blending application workshop.

The practical lessons should be located in a separate safe and appropriately clean room or safe working area, if outdoors. The student is required to:

- Fill an empty cylinder
- Remix a partially used cylinder

The following equipment and accessories are required for the nitrox blender module:

- Compressor or air bank supplying 'clean air'

If a compressor is to be used, a competent and confident compressor operator must be present, i.e., a person who is totally familiar with the safe operational practices and use of the compressor.

- Blending whip

- Diving cylinder in oxygen service
- Cylinder of diving grade oxygen - of adequate capacity and pressure. For a course of six students a full 'J' size cylinder is recommended.
- Oxygen analyser

The following additional equipment and accessories are required for the mixed gas blender module:

- Cylinder of diving grade helium - of adequate capacity and pressure.

Recommended optional equipment:

- Helium analyser

Student Materials and Course Documentation

Approved Instructors should order the appropriate student materials and course documentation from the BSAC Shop sufficiently in advance of the course to enable them to be delivered before the course commences.

Following completion of the course, the course and student reports should be returned promptly to HQ.

Examination/Assessment

There is no written assessment for this course. Performance standards for practical skills are defined in the practical lesson notes.

Qualification

Course certification will be issued to students who achieve a satisfactory standard in practical nitrox gas blending and/or practical mixed gas blending.

Student Feedback

A student feedback report form is issued with the student course packs . The student is requested to complete this report in confidence at the end of the course and submit it directly to HQ. The form and its contents are treated with absolute confidentiality.

Student Evaluation

Each student will be issued with a Student Evaluation Form. This document forms part of the recording system for the course and becomes a record of the training given, the standards of performance achieved and details any remedial training necessary for each individual student. The instructor should fill in each section of the form as he /she completes each section of the course or at the completion of each day. The instructor should discuss the contents with the trainee in order to agree current achievement and future progress. At the end of the course the instructor should have completed one of these forms for each student. The contents of the document should be agreed with each student and any future actions noted and explained to that student. A copy of this report should be given to the student. An additional copy should be sent to HQ. It is recommended that the instructor / centre retain a copy for his / her own records as proof of training given.

Course Content

Nitrox Module:

- Introduction to nitrox blending
- Equipment for blending
- Getting the desired mix
- Safety precautions
- Practical blending workshop:
  - Component parts of a blending system
  - Blending nitrox

Mixed Gas Module:

- Mixed gas blending
- Practical blending workshop:
  - Component parts of a mixed gas blending system
  - Blending mixed gas

Course Arrangements

The course may run using one of the following arrangements:

- Nitrox Gas Blender Course
- A combined Nitrox and Mixed Gas Blender Course

Or, for those students already qualified to blend nitrox:

- Mixed Gas Blender Course

For students holding an alternative agency qualification, prior to commencing the mixed gas blender course, the student should be requested to familiarise themselves with the content of the BSAC Nitrox Gas Blender course materials. The Mixed Gas Blender Instructor should review the materials and review the theory lesson on 'Safety Precautions' prior to commencing on the theory lesson 'Mixed Gas Blending'.

COURSE OVERVIEW

Lesson Objectives

Guide duration: 15 minutes.

This lesson sets the scene for the course overall. It briefly outlines the course content, domestics and timetable.

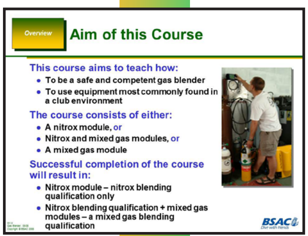
Achievement Targets

At the end of this lesson students should:

- **Understand the overall structure of the course**
- **Understand what is required of them to make the course run smoothly**
- **Understand that they are required to achieve certain standards and how this will be assessed**
- **Understand the domestic and logistical arrangements for the course**
- **Understand the course timetable.**

Lead Instructor should welcome students and introduce other instructors on the course and an instructor familiar with the venue should explain locations of toilets, fire exits and other house keeping.

Aim of this Course



The overall objective of the course is to teach a diver how to safely blend nitrox or, if the appropriate module is included, mixed gas for diving in the branch using the method of partial pressure filling.

This course aims to teach how:

- **To be a safe and competent gas blender**
- **To use equipment most commonly found in a club environment**

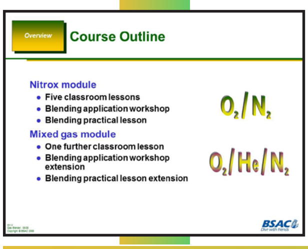
The course consists of either:

- **A nitrox module or**
- **Nitrox and mixed gas modules or**
- **A mixed gas module**

Successful completion of the course will result in:

- **Nitrox module = nitrox blending qualification only**
- **Nitrox blending qualification + mixed gas module = a mixed gas blending qualification**

Course Outline



The course consists of two blending modules.

Nitrox module:

The blender must successfully complete the nitrox blending module before proceeding to the mixed gas blender module.

The course focusses on the technique most likely to be encountered in branch - i.e. blending by partial pressures. Other techniques for producing nitrox exist but are much less likely to be encountered in the branch environment and hence are beyond the scope of this course.

- **Five classroom lessons**

  Essential theory to blend nitrox safely and accurately.

- **Blending application workshop**

  This workshop allows the students to familiarise themselves with blending software/tables and prepare for the practical.

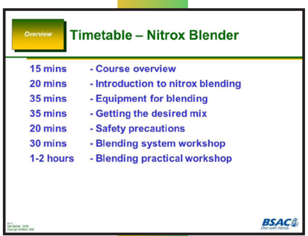
- **Blending practical lesson**

  This element consists of blending nitrox mixes. This element assesses the students ability to mix nitrox gas blends safely and accurately.

Mixed gas module

This Is an optional blending module. Requires the availability of helium and ideally a helium analyser for the practical exercises.

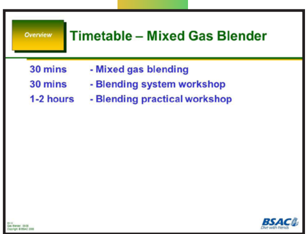
- **One further classroom lesson**
- **Blending application workshop extension**
- **Blending practical lesson extension**



Timetable – Nitrox Blender

This VA provides a sample 'ideal' programme that may need to be adapted to the specific programme for the course. Some of these lessons clearly rely on other lessons preceding them and these requirements are defined in the course outline section of this manual. It is important that this interdependence is maintained in any adaptation of the programme.

15 mins	**- Course overview**
25 mins	**- Introduction to nitrox blending**
35 mins	**- Equipment for blending**
35 mins	**- Getting the desired mix**
20 mins	**- Safety precautions**
30 mins	**- Blending system workshop**
1-2 hours	**- Blending practical workshop**



Timetable – Mixed Gas Blender

The VA specifies the additional theory and practical to become a qualify as a mixed gas blender. The module follows the same format as for the nitrox blender module and builds on the theory and practical by adding in the additional complication of blending with helium.

30 mins	**- Mixed gas blending**
30 mins	**- Blending system workshop**
1-2 hours	**- Blending practical workshop**

INTRODUCTION

Lesson Objectives

Guide Duration 25 minutes.

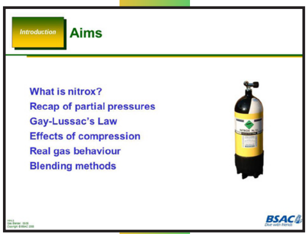
To introduce the background for gas blending and improve the students overall understanding of the implications of compressing gases.

Achievement Targets

At the end of this lesson students should:

- **Have a clear understanding of nitrox and partial pressures**
- **Understand compression of gases**
- **Understand the difference between ideal gas laws and real gas models**
- **Provide a background for alternative Gas Blending and delivery methods**

Explain that this is a general introduction to mixed gas blending and sets the scene for the more detailed lessons that will follow.



Aims

What is nitrox?

A quick review of nitrox and its basic definition.

Recap of partial pressures

A review of partial pressure theory and Dalton's Law as this concept is rudimentary when performing calculations to achieve the desired blend.

Gay-Lussac's Law

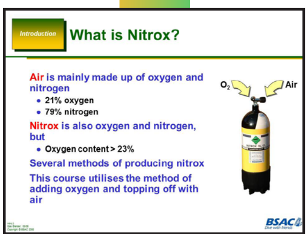
Understand that for a fixed vessel, temperature increases with increased pressure, for example, filling a cylinder.

Effects of compression

Emphasise that the side effect of compression is heat and its implications on accurate gas blending.

Real gas behaviour

Understand that high pressure effects the accuracy of gas blending.



What is nitrox?

Air is mainly made up of oxygen and nitrogen

- **21% oxygen**
- **79% nitrogen**

This Is a realistic approximation. Air also contains trace gases, that are inconsequential to the diver. Oxygen and nitrogen can both have adverse effects on the diver.

Nitrox is also oxygen and nitrogen, but

Is generally applied to mixtures containing a higher oxygen percentage than that found in air.

- **Oxygen content > 23%**

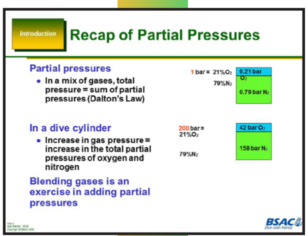
This higher percentage of oxygen in the mix is also referred to as a hyperoxic mix or Enriched Air Nitrox (EAN). Consequently, these are often referred to as shallow dive mixes.

Technically, the term nitrox describes any mixture of nitrogen and oxygen.

Several methods of producing nitrox

There are several methods to accurately produce nitrox blends. The majority of methods are extremely expensive requiring high capital investment in specialised equipment. This course focuses on the least expensive and most frequently used solution to achieve gas blends, i.e., partial pressure blending.

This course utilises the method of adding oxygen and topping off with air



Recap of Partial Pressures

This section reviews the fundamental concepts of partial pressures.

Partial pressures

In simple terms, partial pressures are derived from Dalton's Law, which can be simple stated as;

- **In a mix of gases, total pressure = sum of partial pressures (Dalton's Law)**

In the following example, 1 bar (atmospheric pressure), i.e., what our bodies experience at the earths surface, by simple definition consists of

1 bar = 21% O_2 + 79% N_2

In a dive cylinder

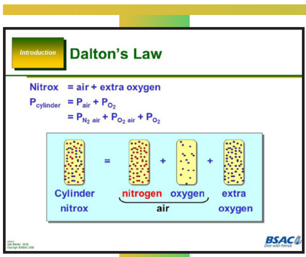
- **Increase in gas pressure = increase in the total partial pressures of oxygen and nitrogen**

In this example, increasing the total pressure to 200 bar in the dive cylinder by adding air, increases the number of molecules of each gas component, i.e., increase in partial pressure of the gas constituents, but preserves the percentage ratio of the gas components provided that the delivered gas composition remains constant.

200 bar = 21% O2 + 79% N2

Blending gases is an exercise in adding partial pressures

This concept is fundamental to managing gas mix composition and is the technique applied throughout the whole course.



Dalton's Law

A nitrox mix consists of blending air with oxygen.

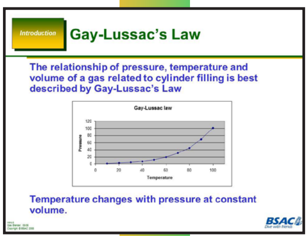
Nitrox = air + extra oxygen

When filling a cylinder the blender can simply measure the pressure within the cylinder to obtain the desired blend.

PCylinder = Pair + PO2

What is often overlooked when blending is that you have to account for the composition of air that contains both oxygen and nitrogen when trying to achieve a predefined mix.

Cylinder nitrox = Air (nitrogen + oxygen) + extra oxygen



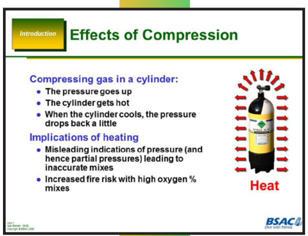
Gay-Lussac's Law

The relationship of pressure, temperature and volume of a gas related to cylinder filling is best described by Gay-Lussac's Law

This law best describes what is happening when a cylinder is being filled.

Temperature changes with pressure at constant volume.

The graph illustrates that for a fixed vessel, for example a cylinder, as the pressure increases the temperature increases during filling due to compression.



Effects of Compression

When speaking about compression, in practical terms the gas pressure is increasing inside the cylinder. As more gas is added, gas molecules become more tightly packed, that is the molecular density is increasing due to the fixed capacity of the vessel.

Compressing gas in a cylinder:

- **The pressure goes up**

  This is the expected effect.

- **The cylinder gets hot**

  An undesired, but consequential effect of adding gas to the cylinder. The cylinder temperature will typical reach temperatures in excess of 38 degrees Celsius. The rate of fill has a significant affect on the amount of heat generated, the faster the fill, the higher the temperature of the cylinder (kinetic energy).

- **When the cylinder cools, the pressure drops back a little**

  The cooling of the cylinder takes time. The analysed blend is dependent on the temperature of the gas. The nearer the cylinder is to ambient conditions the more reliable the analysis.

Implications of heating

- **Misleading indications of pressure (and hence partial pressures) leading to inaccurate mixes**

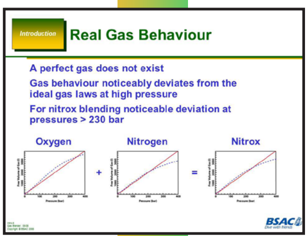
  Between dives there maybe insufficient time to allow a cylinder to cool adequately to take make an accurate analysis of the gas composition. On arrival at site the mix may vary significantly from the requested blend. One practical solution is to create a cooling bath ideally with free flowing water, combined with a reduced rate of filling.

- **Increased fire risk with high oxygen % mixes**

  At high concentrations of oxygen, oxygen becomes its own ignition energy due to the compression. In the presence of a fuel, for example an unclean cylinder, the fire triangle is closed and a fire may result. Oxygen is an oxidiser and lowers auto ignition temperatures.

  The compression effect is more correctly referred to as adiabatic compression.

  This refers to the property of a gas to create heat when exposed to a sudden increase in pressure. For example, opening the valve suddenly on a cylinder connected to a filling whip with a closed check valve. The high velocity gas leaving the cylinder flows though the high pressure hosing until it hits the closed check valve, heat will then be rapidly generated. The amount of heat generated can be significant, for example, if the pressure the gas in the cylinder was only 7 bar, the adiabatic compression temperature would reach 234 °C. While a cylinder containing 70 bar could theoretically reach a compression temperature of 706 °C.



Real Gas Behaviour

A perfect gas does not exist

The ideal gas law if researched is not a true representation of gas behaviour, but is a good approximation within proscribed operational constraints.

Gas behaviour noticeably deviates from the ideal gas laws at high pressure

A number of the postulates that define the ideal gas law are far from true particularly at higher pressures or at lower temperatures.

Examining the graphs, the real oxygen behaviour curve is overlaid on the ideal gas law. The ideal gas law is a good approximation for the blending of oxygen within the operational envelope of working pressures for dive cylinders. Nitrogen is observed to deviate significantly from the ideal above 200 bar. Overall, combining oxygen and nitrogen to create nitrox, oxygen compensates for some of the behaviour of nitrogen, blenders can sensibly rely on using the ideal gas law for mixing nitrox up to 230 bar.

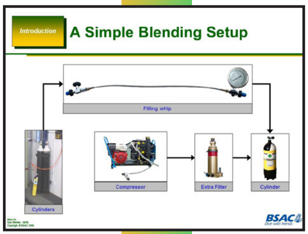
For nitrox blending noticeable deviation at pressures > 230 bar

Above 230 bar, blenders should use tools that account for real gas behaviour. This course provides an example of a tool for high pressure nitrox blending.

Blending methods

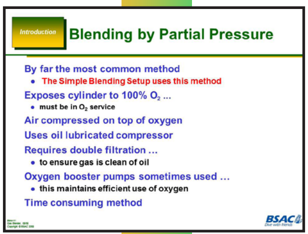
Explain List covers types of Blending methods to be covered.

Do not read out each one.



A Simple Blending Setup

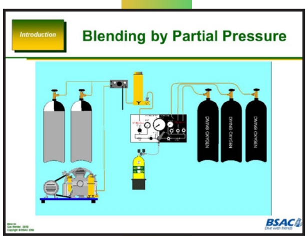
This is the focus of the course and will be covered in more detail.



Blending by Partial Pressure

Briefly detail

- **most common method.**
- **expose the cylinder to 100 % oxygen and so must be in oxygen service**
- **air is compressed on top of this.**
- **Traditionally uses an oil lubricated**
- **Requires double filtration system to ensure gas clean of oil**
- **Oxygen booster pumps are sometimes used, which will maintain an efficient extraction of the oxygen which comes in storage cylinders.**
- **Time consuming**

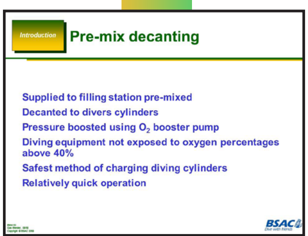


Blending by Partial Pressure

Point out on diagram the key features of

- **Oxygen source**
- **Air source (compressor and/or air bank)**
- **Additional filter**

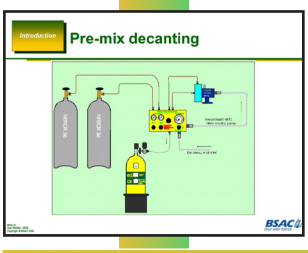
Do not explain in detail how to operate the process!



Pre-Mix decanting

Briefly detail

- **Supplied pre-mixed**
- **Decanted into cylinders**
- **Pressure needs to be boosted by booster pump**
- **Equipment not subject to oxygen > 40 %**
- **Relatively quick**

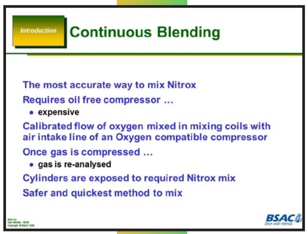


Pre-Mix decanting

Point out on diagram the key features of

- **Pre-mix cylinders**
- **Booster pump**

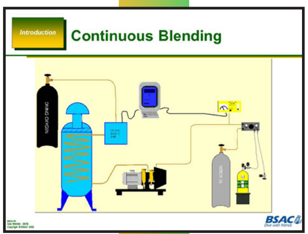
Do not explain in detail how to operate the process!



Continuous Blending

Briefly detail

- **Accurate method**
- **Requires oil free compressor**
    - expensive
- **Calibrated flow of oxygen mixed with air in mixing coils before compression**
- **Cylinders only exposed to required mix**
- **Safer and quicker method to mix**

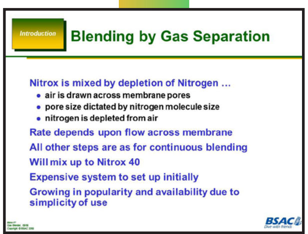


Continuous Blending

Point out on diagram the key features of

- **Mixing coils**
- **Calibration unit**
- **Oil free compressor**

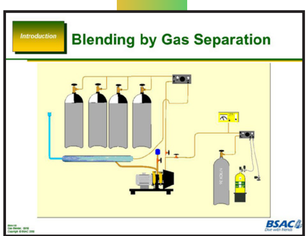
Do not explain in detail how to operate the process!



Blending by Gas Separation

Briefly detail

- **Nitrox mixed by depletion of Nitrogen**
- **Rate depends on flow rate across membrane**
- **Subsequently similar to continuous blending**
- **Will mix up to Nitrox 40**
- **Cylinders only exposed to required mix**
- **Expensive system to set up initially**
- **Growing in popularity due to simplicity of use**

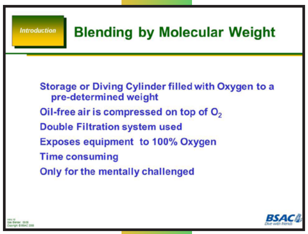


Blending by Gas Separation

Point out on diagram the key feature of

- **Gas Separation unit**
- **In line analyser**

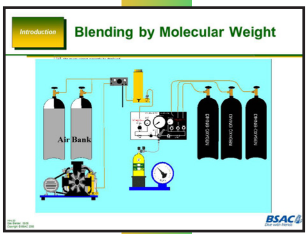
Do not explain in detail how to operate the process!



Blending by Molecular Weight

Briefly detail

- **Very Accurate method**
- **Cylinder filled with oxygen and/or helium to pre-determined weight(s)**
- **Oil free air compressed on top**
- **Exposes equipment to 100 % oxygen**
- **Time consuming**

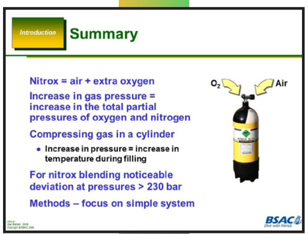


Blending by Molecular Weight

Point out on diagram the key feature of

- **Very accurate scales**

Do not explain in detail how to operate the process!



Summary

Reiterate the key points of the lesson using the summary interactively as a means to check that the students have understood them.

Nitrox = air + extra oxygen

Essential to recognise that blending nitrox consists of mixing air that contains nitrogen plus oxygen with pure oxygen.

Increase in gas pressure = increase in the total partial pressures of oxygen and nitrogen

The primary method for blending is by partial pressure filling. Increasing the fill pressure increases the partial pressure of it constituents.

Compressing gas in a cylinder

- **Increase in pressure = increase in temperature during filling**

Managing the temperature of a fill is vital to ensuring the final accuracy and safety of the blender. Compressing gas into a cylinder will naturally increase its temperature. Managing the rate of filling or providing a cooling mechanism is essential to accurate filling.

For nitrox blending noticeable deviation at pressures > 230 bar

The ideal gas law is inappropriate for high pressure filling. Gases are defined by empirical real gas equations.

Allow time for the students to ask questions.

EQUIPMENT FOR BLENDING

Lesson Objectives

Guide duration: 35 mins

To introduce the equipment essential to safely blend nitrox, look at equipment which will improve the effectiveness of a basic blending system and to enhance the students overall understanding of the implications of compressing and blending gases.

Achievement Targets

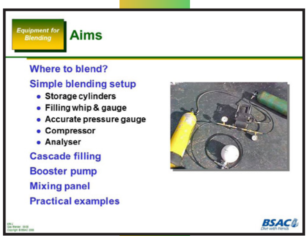
At the end of this lesson students should:

- **Understand the minimum equipment and its function to blend nitrox**
- **Understand the safe setup of the equipment and procedure to enable accurate partial pressure blending**
- **Understand the benefits of some of the specialised equipment to simplify blending**

Additional visual aids

- **Examples of blending whips, pressure gauges and analyser**

This lesson reviews the requirements of blending equipment for use with pure oxygen and air. Guidelines are provided for the selection and combination of equipment required for nitrox blending. The section discusses current trends, apportioning value and reason to available equipment including methods and techniques used to safely manage gas blending.



Aims

By its very nature, blending requires the user to manage a complex array of equipment. This ranges from an air bank , oxygen cylinder and decanting whip, to specialised equipment such as a compressor, booster pump and blending panels. The blender therefore needs to consider and be totally familiar with the equipment, ensuring that it is appropriate, simple as possible, supported by operational procedures and is properly serviced and maintained.

Where to blend?

Personal safety and local regulations must be accounted for when considering where to blend. Basic requirements and potential risks are highlighted.

Simple blending setup

The minimum key components to enable safe and successful blending of nitrox are identified including:

- **Storage cylinders**
- **Filling whip & gauge**
- **Accurate pressure gauge**
- **Compressor**
- **Analyser**

Cascade filling

A simple and effective method to efficiently fill cylinders.

Booster pump

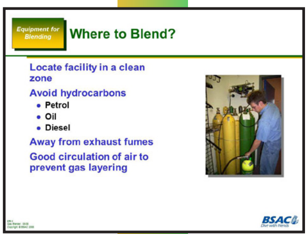
Booster pumps provide a means to scavenge gas cylinders and boost cylinder pressures. The pros and cons are considered. There are a number of suitable portable units in the market and new units are being added every day, lowering the price and making the purchase of a booster pump cost effective.

Mixing panel

Mixing panels simplify blending and range from simple to complex installations. Some branches already benefit from an installed mixing panel. The principal of the mixing panel is reviewed.

Practical examples

Two practical blending systems typically used by branches are reviewed.



Where to Blend?

Safety is paramount and local regulations should always be adhered to when designing and operating a high pressure system. The blending system environment needs to be taken into consideration for delivery of clean air and management of noise pollution.

Locate facility in a clean zone

Oxygen supports combustion and the presence of a high percentage of oxygen makes almost any material burn faster and easier. All common metals will burn in oxygen. It is essential to blend in a clean area.

Avoid hydrocarbons

Great care must be taken not to let compressed oxygen come into direct contact with hydrocarbons. In a pure oxygen atmosphere, the flash point of gases, or the ignition point of solids is greatly reduced. Examples of hydrocarbons to avoid are:

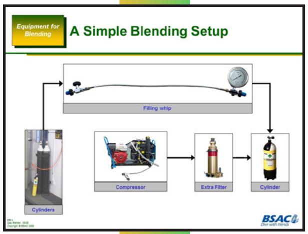
- **Petrol**
- **Oil**
- **Diesel**

Away from exhaust fumes

Exhaust fumes contain many hydrocarbons, some extremely poisonous to humans, especially when breathed off a contaminated dive cylinder. Exhaust fumes contaminate blending systems, leaving residual hydrocarbons which act as the fuel for fire, especially in the presence of high pressure pure oxygen. Compressor intakes must be kept well clear of potential exhaust fumes from cars and industrial processes to avoid contamination of the dive cylinder.

Good circulation of air to prevent gas layering

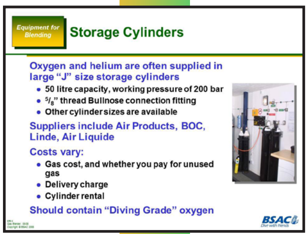
In a confined room, free gas from oxygen cylinders will initially layer at the bottom of a the room. This oxygen layer supports combustion. If the oxygen comes into contact with a heat source, for example, a hot component of a poorly maintained compressor, a fire may be ignited which will spread fan very quickly in the dense oxygen layer. Blending with oxygen (or helium to avoid hypoxia) should always take place in a well ventilated room or zone.



A Simple Blending Setup

The simplest blending systems consists of a compressor with a special filter or combination of filters to provide clean air to a dive cylinder in oxygen service. Pure oxygen is supplied from a dedicated oxygen cylinder via a decanting whip to the diver's cylinder.

Each of these components will be addressed individually over the course of the next few slides.



Storage Cylinders

Oxygen (and helium) will need to be obtained from a dedicated gas supplier. The gas is normally supplied in a predetermined size of cylinder requiring a special adapter.

In the UK, gas is normally supplied in what is referred to as 'J' cylinders. Overseas, the size of storage cylinders and fill pressure may differ and a different adapter may also be required.

Oxygen and helium are often supplied in large "J" size storage cylinders

- **50 litre capacity, working pressure of 200 bar**

  The water capacity of a 'J' cylinder is standard but the overall fill pressure varies from supplier to supplier. It is possible to obtain up to 250 bar supply pressure.

- **5/8" thread Bullnose connection fitting**

  This is a standard U.K. high pressure fitting for delivery cylinders. Europe have a similar fitting, but uses a slightly different gauge size and is referred to as the European bullnose adapter.

- **Other cylinder sizes are available**

  Alternative size of cylinders of gas may be purchased. Ranging from 'D' size (oxygen administration cylinder) through to 'G'. Greater than G is too cumbersome and heavy to manage.

U.K. suppliers include:

Suppliers include Air Products, BOC, Linde, Air Liquide

Costs vary:

- **Gas cost, and whether you pay for unused gas**

  It is down to the purchaser to negotiate a reasonable price for delivered gas.

- **Delivery charge**

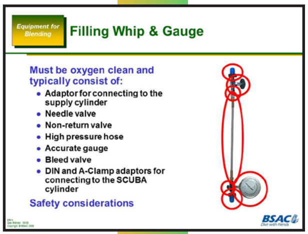
  The overall cost needs to take into account delivery charge.

- **Cylinder rental**

  The overall cost needs to take into account the cylinder rental charge.

Should contain "Diving Grade" oxygen

In 2006, a new British Standard (BS 8478) was introduced which defines in detail the recommended quality standards for the delivery of oxygen, nitrox, helium and helium based gases for the diving industry. The UK suppliers all conform with this new standard. The new standard has tightened the overall quality of delivered gas for diving applications (see appendix E for details).



Filling Whip & Gauge

Must be oxygen clean and typically consist of:

- **Adaptor for connecting to the supply cylinder**

  This is most frequently for a 'bullnose' fitting, but others may be required depending upon the supply cylinders used.

- **Needle valve**

  Needle valves are designed to enable fine control over the rate of flow of oxygen into the SCUBA cylinder. They should only be opened slowly.

- **Non-return valve**

  This is fitted to prevent contamination of the gas in the supply cylinder should the whip be inadvertently connected a SCUBA cylinder containing a gas mix at a higher pressure. In order for it not to interfere with their correct functioning, it should be located upstream of (i.e. on the supply cylinder side of) the gauge and bleed valve.

- **High pressure hose**

  The hose material must be oxygen compatible and fit for purpose.

- **Accurate gauge**

  Either a large diameter analogue gauge or a digital gauge. Any gauge needs to be in calibration and easy to read to 1 bar accuracy. If located upstream of the non-return valve, the non-return valve will prevent the gauge reflecting the SCUBA cylinder pressure if the SCUBA cylinder pressure is higher than that in the supply cylinder.

- **Bleed valve**

  Necessary to enable the high pressure gas to be bled from the whip to allow it to be disconnected from the cylinders. In order to be able to bleed the gas from the whole of the whip it is essential that this component is on the downstream side of the non-return valve.

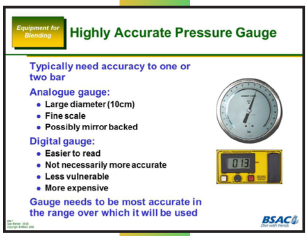
- **DIN and A-Clamp adaptors for connecting to SCUBA cylinders**

  A range of standard adapters are required for connecting SCUBA cylinders such as DIN 25 mm, DIN 26 mm and A-clamp. 250 bar and 300 bar DIN fittings may also need to be considered.

The whole of the decanting whip must be maintained in oxygen service.

Safety considerations

It is not unknown for flexible high pressure hoses to fail, the remaining length of hose flailing about with the resultant potential for risk of injury to people. Depending upon the equipment configuration and location, it may be practical to fit flexible high pressure hoses with restraining cables that will restrict such motion to enable operators to safely turn off the gas supply. Where this is not practical, blenders should be conscious of this risk, keep all other personnel well clear of the equipment at all times (at a distance of at least twice the length of any flexible hoses) and should have a preconceived plan of how to deal with such an occurrence that will not put themselves at risk.



Highly Accurate Pressure Gauge

Typically need accuracy to one or two bar

Analogue gauge:

These gauges are not usually as accurate as digital gauge because of the lack of resolution for reading small variations in pressure.

- **Large diameter (10 cm)**

  The larger the better. A 10 cm face is a minimum size. A larger face sized between 15 - 25 cm is ideal.

- **Fine scale**

  A fine scale makes it easier to read with a higher degree of accuracy. The scale graduations should be marked off at 0.5 bar or better.

- **Possibly mirror backed**

  Removes parallax error.

Digital gauge:

- **Easier to read**

  Simple clear digital display. The readings are presented in measurements of 1% increments or better, typically 0.1%.

- **Not necessarily more accurate**

  The reading can jump around and may take some time to settle. This occurs due to variances in temperature. The overall unit can be smaller than its equivalent analogue gauge.

- **Less vulnerable**

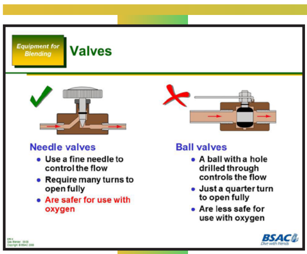
  It is easier to protect the unit and, being small, they are less prone to being damaged.

- **More expensive**

  Generally 2 to 3 times more expensive than an equivalent analogue gauge.

Gauge needs to be most accurate in the range it will be used

Whatever type of gauge is used its actual accuracy needs to be known. This can only be achieved by ensuring that gauges are properly calibrated on a regular basis - e.g. annually.



Valves

Needle valves

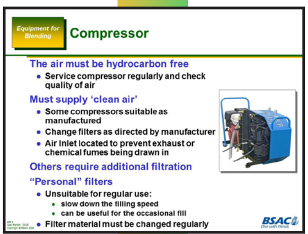
Needle valves are designed to be opened slowly, with fine pitch threads, regulating stems for gradual opening, and soft seats for gas tight shut-off. The soft seat allows for a non frictional gas tight shut off.

- **Use a fine needle to control the flow**
- **Require many turns to open fully**
- **Are safer for use with oxygen**

Ball valves

Ball valves are quick opening, requiring only a quarter turn to go from closed to fully open.

- **A ball with a hole drilled through controls the flow**
- **Just a quarter turn to open fully**
- **Are less safe for use with oxygen**



Compressor

There are three classical varieties of compressors used for pumping air into dive cylinders. Oil lubricated, oil-less and oil free. All three systems if maintained and the air properly filtered are viable for partial pressure filling.

The air must be hydrocarbon free

Compressed air for breathing apparatus is specified in BS EN 12021. This is a European standard. Air supplied for nitrox is recommended to conform with the new 'breathing gases for diving and hyperbaric applications' standard BS 8478 which reduces the amount of impurities acceptable in the breathing gases at elevated oxygen percentages.

- **Service compressor regularly and check quality of air**

  This is a fundamental requirement that should be in line with the manufacturers recommendations. The servicing of the compressor should be carried out by a qualified technician.

Must supply 'clean air'

It is general practice to add air on top of pure oxygen in the dive cylinder. Moisture or hydrocarbons can be transferred into the cylinder by over-looking the need to supply clean air. The problem is that a contaminated cylinder may be unknowingly considered to be in oxygen service reading its expiry certificate. There is a duty of care to uphold by the diver to inform the blender if the cylinder has been contaminated. The cylinder needs to be oxygen cleaned to bring it back into oxygen service.

- **Some compressors suitable as manufactured**
- **Change filters as directed by the manufacturer**
- **Air Inlet located to prevent exhaust or chemical fumes being drawn in**

Others require additional filtration

"Personal" filters

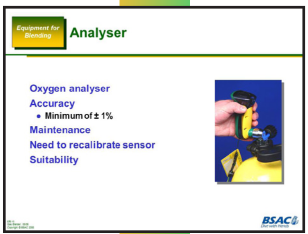
Personal filters are used to protect against contamination of the dive cylinders when travelling.

- **Unsuitable for regular use:**
    - **slow down the filling speed**

      The filters act as a flow restrictor.
    - **can be useful for the occasional fill**

      Not designed for long term use.
- **Filter material must be changed regularly**

  The filters generally contain a throw away cartridge. Being small in volume the cartridges have a restricted working life before they must be changed. For some this may be a little as 5 hours. It is essential that the manufacturer's recommendations on filter cartridge life are conscientiously observed.



Analyser

An essential component of the blending system is to be able to verify the mix. There are number of models on the market today. Essentially, they are simple and very straightforward to use and allow for accurate gas analysis.

Oxygen analyser

The analyser is made up of two parts:

A sensor designed to measure the partial pressure of oxygen present in the gas. The sensor consists of chemical materials that produce a voltage proportional to the partial pressure of oxygen to which it is exposed. The sensor actually measures PO_2 but this is equal to FO_2 at 1 bar.

The second part contains the display and analysis circuitry which measures the voltage. The voltage measurement is then displayed as a corresponding oxygen percentage on the display.

Accuracy

Many of the more recent analysers have an accuracy of ±0.5% or better.

- **Minimum of ± 1%**

Maintenance

The analyser should be protected when not in use. To increase sensor life, the analyser or sensor may be placed in a small bag to prevent continuous oxygen reaction. The sensor and batteries should be changed as recommended by the manufacturer.

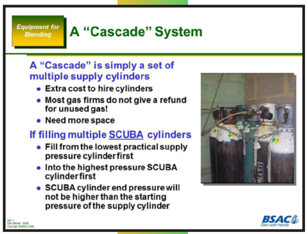
Need to recalibrate sensor

The analysis circuitry contains adjustments to allow for calibration due to variations in sensor characteristics and age. The sensor should be calibrated before each use. The more recent units auto calibrate when they are switched on.

In addition it is necessary to periodically perform a two point linearity check to monitor the decay in the health of the sensor with age. This requires the sensor to be calibrated in air and then again in pure oxygen. Again the manufacturer's recommendations should be followed.

Suitability

Analysers can either be purchased as portable or fixed in location units. Some units are more robust than others. Unless you intend to fill many cylinders per day then there is no need to look at alternative technology for gas analysis, for example, parametric diffraction.



A "Cascade" System

A cascade system of cylinders allows the blender to use the supply gas more efficiently without a requirement to have a booster pump. The system primarily allows the blender to maintain a higher pressure in a cylinder for longer by first draining down the lower pressure cylinder and then using the higher pressure cylinder for topping off.

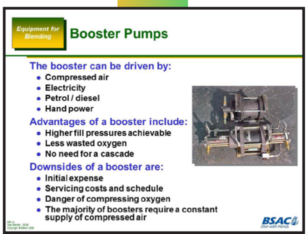
A "Cascade" is simply a set of multiple supply cylinders

The cascade can be as few as two cylinders, typically three or more.

- **Extra cost to hire cylinders**
- **Most gas firms do not give a refund for unused gas!**
- **Need more space**

If filling multiple SCUBA cylinders

- **Fill from the lowest practical supply pressure cylinder first**
- **Into the highest pressure SCUBA cylinder first**
- **SCUBA cylinder end pressure will not be higher than the starting pressure of the supply cylinder**



Booster Pumps

Booster pumps are in effect a mini compressor. They can be purchased as portable or fixed units. The units have become more affordable.

The booster can be driven by:

The booster power source can be, by order of popularity:

- **Compressed air**

  Air is generally readily available from a cylinder, air bank or compressor. Typical gas feed rate for small units is around 10 litres per minute to drive the booster pump. Feed gas can be tapped directly off the compressor through a restriction valve, or from an air bank or a dive cylinder.

- **Electricity**

  An arrangement for a permanently mounted booster pumps. One key benefit is that it is a quieter operational arrangement.

- **Petrol / diesel**

  An option rarely taken up.

- **Hand power**

  Not a practical solution although available on many of the portable units.

Advantages of a booster include:

- **Higher fill pressures achievable**

  Enables cylinders to be fully charged to their working pressure.

- **Less wasted oxygen**

  The booster acts as a scavenger allowing all supply cylinders to be emptied.

- **No need for a cascade**

  Generally, the blender cascades the filling and then tops off using the booster for high pressure fills.

Downsides of a booster are:

- **Initial expense**

  Typical outlay including fittings of around £1000 for a small portable unit.

- **Servicing costs and schedule**

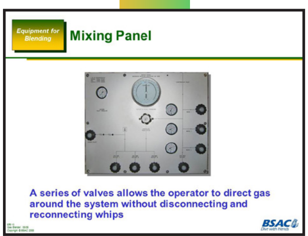
  Boosters are a very simple device, easy to service and maintain. The servicing schedule is set down by the manufacturer and should be adhered to. Small portable boosters can however require significant maintenance.

- **Danger of compressing oxygen**

  The dive gas boosters are generally designed with appropriate seals for compressing oxygen and helium.

- **The majority of boosters require a constant supply of compressed air**

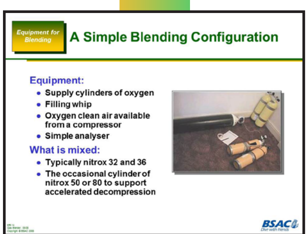
  The majority of booster pumps in use are driven by an air supply. This running cost needs to be considered when purchasing a booster pump. For small booster pumps this can be a significant limitation on the size of cylinder which they can practically supply.



Mixing Panel

Mixing panels should be purchased from a reputable manufacturer and installed by a registered engineer. The panel design is down to the user requirements, for example, how many cylinders can be filled simultaneously. The design should mitigate against cross contamination of fills, minimise the potential for adiabatic compression, i.e., avoid 90 degree bends, correct valve types chosen, minimise changes in pipe diameter, etc.

A series of valves allows the operator to direct gas around the system without disconnecting and reconnecting whips



A Simple Blending Configuration

This is the absolute minimum setup to blend nitrox.

Equipment:

- **Supply cylinders of oxygen**
- **Filling whip**
- **Oxygen clean air available from a compressor**

- **Simple analyser**

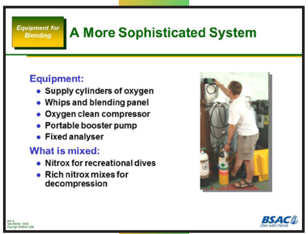
What is mixed:

- **Typically nitrox 32 and 36**

  Nitrox 32 and nitrox 36 are the most frequently used gas mixes.

- **The occasional cylinder of nitrox 50 or 80 to support accelerated decompression**

  For rich oxygen mixtures the final gas pressure is dependent on the oxygen supply pressure.



A More Sophisticated System

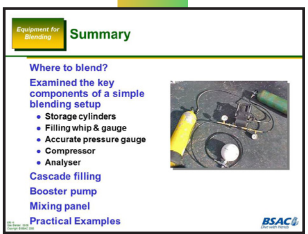
This is an example of a branch that has invested in a quality blending for the benefit of all of its members.

Equipment:

- **Supply cylinders of oxygen**
- **Whips and blending panel**
- **Oxygen clean compressor**
- **Portable booster pump**
- **Fixed analyser**

What is mixed:

- **Nitrox for recreational dives**
- **Enriched nitrox mixes for decompression**



Summary

Reiterate the key points of the lesson using the summary interactively as a means to check that the students have understood them.

Where to blend?

Reiterate the key safety issues, for example, locate in clean area, in a well ventilated room away from contaminates and exhaust fumes.

Examined the key components of a simple blending setup

Review the key components of a basic blending system.

- **Storage cylinders**
- **Filling whip & gauge**
- **Accurate pressure gauge**
- **Compressor**
- **Analyser**

Cascade filling

A simple solution consisting of two or more to more supply gas cylinders to use the gas more effectively.

Booster pump

Useful tool to enable high pressure filling and prevent waste of supply gas. Main disadvantage is initial cost.

Mixing panel

Effectively a means to manage gas without constantly changing connections.

Practical Examples

Two typical blending systems were examined:

1) **A simple blending system**
2) **A sophisticated blending system**

Allow time for the students to ask questions.

GETTING THE DESIRED MIX

Lesson Objectives

Guide duration: 35 mins.

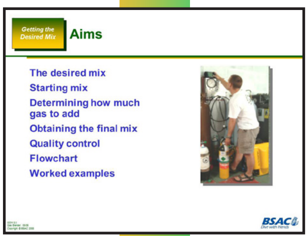
To provide an understanding and a systematic approach to calculate the desired gas mix based on predetermined nitrox user requirements.

Achievement targets

At the end of this lesson students should know

- Understand how to calculate how much gas to add to a cylinder to achieve the desired mix
- Understand best practice for gas blending
- Understand quality control for gas blending

This lesson will address how to calculate the desired gas mix depending on the initial start mix. As the lesson develops it will explain gas filling procedures and the checks and balances required of the gas blender.



Aims

The lesson illustrates how to logically approach the problem of how to calculate how much gas is required to blend a target nitrox mix and provide procedures to manage filling.

The desired mix

A definition of how to achieve the desired mix.

Starting mix

The start point is to accurately determine what is in the cylinder at the beginning of the exercise.

Determining how much gas to add

This introduces the blender to how they should approach the problem of calculating how much gas should be added to the cylinder to reach the final mix composition and pressure.

Obtaining the final mix

Practical principals of how to approach blending a mix in a cylinder.

Quality control

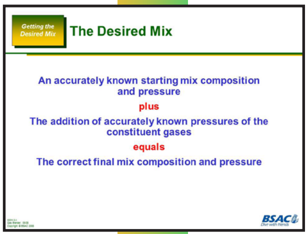
Maintaining accurate logs and records of gas fills.

Flowchart

A simple flowchart steps the blender through the required stages to prepare, fill and finish a desired mix.

Worked examples

Four example illustrates the different methods of approach to calculate how much gas is required to obtain the desired mix.



The Desired Mix

This is a fundamental definition of what is required of a gas blender to successful achieve the desired result.

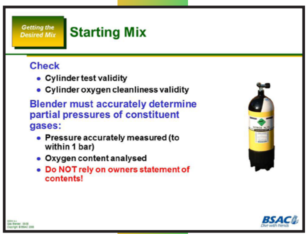
An accurately known starting mix composition and pressure

plus

The addition of accurately known pressures of the constituent gases

equals

The correct final mix composition and pressure



Starting Mix

Check

Prior to commencing to fill a cylinder the gas blender has a duty of care to confirm that the equipment is safe to use. This includes verifying the:

- **Cylinder test validity**

  The cylinder is in operational service with a valid stamp.

- **Cylinder oxygen cleanliness validity**

  The cylinder is in oxygen service.

Blender must accurately determine partial pressures of constituent gases:

In order to accurately determine how much gas is required to be added to a cylinder, the gas blender must know the pressure and current gas composition.

- **Pressure accurately measured (to within 1 bar)**

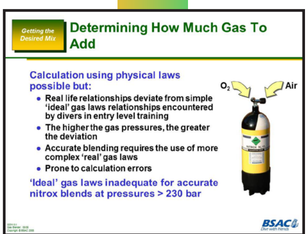
  Use an accurate pressure gauge to determine current cylinder pressure.

- **Oxygen content analysed**

  Verify the oxygen fraction of the gas.

- **Do NOT rely on owners statement of contents!**

  Owners tend to rely on what is written on the cylinder or memory and frequently overlook updating their cylinder labels.



Determining How Much Gas To Add

Calculation using physical laws possible but:

- **Real life relationships deviate from simple 'ideal' gas laws relationships encountered by divers in entry level training**

  Certain theories about how the molecules of 'ideal' gases behave are far from true in real gases, particularly at higher pressures and at lower temperatures.

- **The higher the gas pressures, the greater the deviation**

  It can be observed that the greatest deviation from ideal behaviour always tend to occur at higher pressures and often at lower temperatures and both positive and negative deviation occur.

- **Accurate blending requires the use of more complex 'real' gas laws**

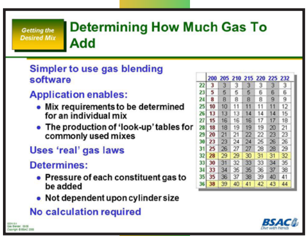
  The measurement and predictions of gas behaviour is very important in industrial processes and so many mathematical models have been devised to accurately describe the real behaviour of gases. Van der Waals equation is one of the earliest and simplest equations to model real gas behaviour.

- **Prone to calculation errors**

  Determining how much gas to add is a lengthy mathematical process. Solving real gas behaviour equations involves iterative solutions which are best left to computer programs. A simple example of determining how much gas to add using partial pressures is illustrate later.

'Ideal' gas laws inadequate for accurate nitrox blends at pressures > 230 bar

Generally speaking for any gas the lower its pressure and the higher its temperature, the more closely it will be 'ideal', i.e., closely obey the ideal gas laws. Also, the smaller the molecular mass or the weaker the intermolecular forces, the nearer the gas behaviour will be to 'ideal'. For gas blending below 230 bar, a simple ideal gas analysis may be applied.



Determining How Much Gas To Add

Simpler to use gas blending software

There are many commercial and freeware applications available to facilitate the calculations for gas blending. The BSAC has created a simple real gas behaviour spread sheet calculator and a separate ideal gas blender program.

Application enables:

- **Mix requirements to be determined for an individual mix**
- **The production of 'look-up' tables for commonly used mixes**

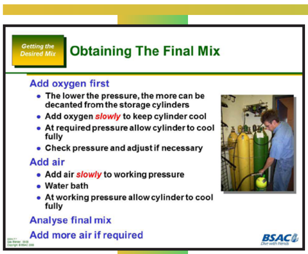
Uses 'real' gas laws

The real gas behaviour spread sheet enables the user to compare real and ideal gas behaviour. There are many other applications that provide real gas determination. Each will produce slightly different answers as the real gas behaviour equations are a model of the gas behaviour and each model has subtle differences.

Determines:

- **Pressure of each constituent gas to be added**
- **Not dependent upon cylinder size**

No calculation required



Obtaining The Final Mix

A simple procedure for filling the cylinder. Start by:

Add oxygen first

- **The lower the pressure, the more can be decanted from the storage cylinders**

  Always start by adding oxygen from the lowest pressure cylinder provided it is greater than the cylinder contents. Once the pressure has equalised, then use the next lowest pressure cylinder until the desired pressure is obtained in the target cylinder.

- **Add oxygen slowly to keep cylinder cool**

  This operational process reduces the probability of an incident and controls the rate of change of temperature by minimising the overall rise in temperature of the target cylinder.

- **At required pressure allow cylinder to cool fully**

  Ideally, allow the target cylinder to cool to ambient conditions.

- **Check pressure and adjust if necessary**

  Verify the pressure and add/subtract gas as required.

Then:

Add air

- **Add air slowly to working pressure**

  Again, this minimises the overall rise in temperature of the target cylinder.

- **Water bath**

  A free flowing water bath is the ideal. A static water bath needs to be regularly emptied and refilled to keep the water cool enough to be effective.

- **At working pressure allow cylinder to cool fully**

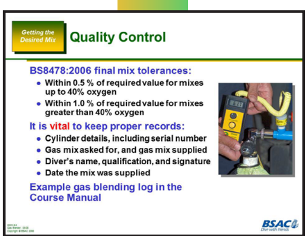
  Allow the target cylinder to cool to ambient conditions.

Analyse final mix

Note the fraction of oxygen in the mix.

Add more air if required

Generally, on cooling, depending on the initial fill rate, a top off of air is required to achieve the final mix.



Quality Control

In September 2006, The UK introduced a new British Standard for the quality of diving gases. The document defines the expected final mix tolerance, the values are currently a recommendation only and not law.

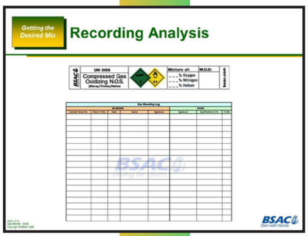
BS 8478:2006 final mix tolerances:

- **Within 0.5 % of required value for mixes up to 40% oxygen**

  This is a tighter standard requiring a special analyser.

- **Within 1.0 % of required value for mixes greater than 40% oxygen**

  This can be accurately measured with a fuel cell oxygen analyser.



It is vital to keep proper records:

This point cannot be over emphasised. It is essential that the following details are verified, logged and documented:

- **Cylinder details, including serial number**
- **Gas mix asked for, and gas mix supplied**

  It is the user's responsibility to plan their dive and define what mix they require. It is the blender's responsibility to gas blended accurately to that requirement.

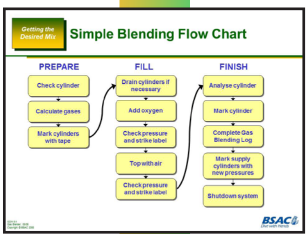
- **Diver's name, qualification, and signature**

  Gas should only be provided to divers with the appropriate qualification. It is the diver's responsibility to furnish proof of that qualification and, if necessary, what gas mixes that qualifies them to use. Advice regarding qualifications from other training agencies can be found on the BSAC website.

- **Date the mix was supplied**

Example gas blending log in the Course Manual

A sample gas blending log sheet is located in appendix C.



Simple Blending Flow Chart

The flowchart is split into three groups. Each group contains the key activities defined in operational order. In essence, the flowchart is the operational procedure for filling a cylinder.

The first phase:

Prepare

Check cylinder

Calculate gases

Mark cylinders with tape

Second phase:

Fill

Drain cylinders if necessary

Add oxygen

Top with air

Check pressure and strike label

Third and final phase:

Finish

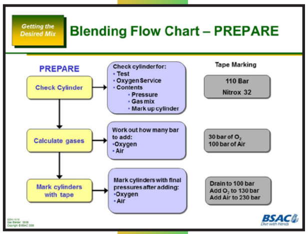
Analyse cylinder

Mark cylinder

Complete gas blending log

Mark supply cylinders with new pressures

Shutdown system



Blending Flow Chart – PREPARE

Phase 1 - operational procedure:

Check cylinder

Check cylinder for:

- **Test**
- **Oxygen Service**
- **Contents**
  - **Pressure**
  - **Gas mix**
  - **Mark up cylinder**

Calculate gases

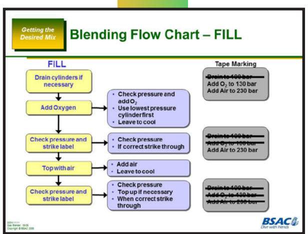
Work out how many bar to add:

- **Oxygen**
- **Air**

Mark cylinders with tape

Mark cylinders with final pressures after adding:

- **Oxygen**
- **Air**



Blending Flow Chart – FILL

Phase 2 - operational procedure:

Drain cylinders if necessary

Add oxygen

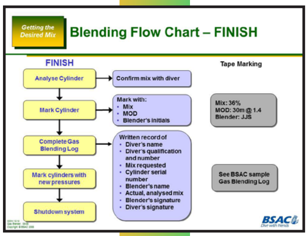
- **Check pressure and add O2**
- **Use lowest pressure cylinder first**
- **Strike through mark**
- **Leave to cool**

Top with air

- **Add air**
- **Leave to cool**

Check pressure and strike label

- **Check pressure**
- **Top up if necessary**
- **When correct strike through**



Blending Flow Chart – FINISH

Phase 3 - operational procedure:

Analyse cylinder

Confirm mix with diver

Mark cylinder

Mark with:

Mix

MOD

Blender's initials

Complete Gas Blending Log

Written record of:

Diver's name

Diver's qualification and number

Mix requested

Cylinder serial number

Blender's name

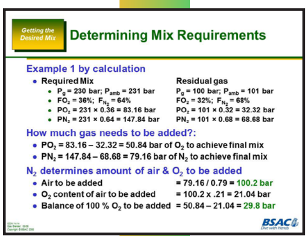
Actual, analysed mix

Blender's signature

Diver's signature

Mark cylinders with new pressures

Shutdown system



Determining Mix Requirements

Example 1 by calculation

This is a calculated example of partial pressure blending for nitrox mixing. The diver has requested a final mix of 36% and 230 bar. These are two simple facts that the blender requires to proceed. The cylinder in this example contains a residual gas of mix 32% at a pressure of 100 bar.

- **Required Mix** **Residual gas**

Starting parameters:

- **Pg = 230 bar; Pamb = 231 bar** **Pg = 100 bar; Pamb = 101 bar**
- **FO_2 = 36%; FN2 = 64%** **FO_2 = 32%; FN2 = 68%**

How much oxygen is required versus residual in the mix:

- **PO_2 = 231 × 0.36 = 83.16 bar;** **PO_2 = 101 × 0.32 = 32.32 bar**

How much nitrogen is required versus residual in the mix:

- **PN_2 = 231 × 0.64 = 147.84 bar;** **PN_2 = 101 × 0.68 = 68.68 bar**

How much oxygen needs to be added?:

How much oxygen is required to be added:

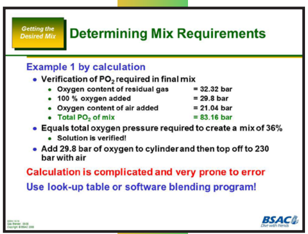
- **PO_2 = 83.16 – 32.32 = 50.84 bar of oxygen to achieve final mix**

How much nitrogen is required to get the final mix:

- **PN_2 = 147.84 – 68.68 = 79.16 bar of nitrogen required to achieve final mix**

N_2 determines amount of air & O_2 to be added

- **Air to be added = 79.16 / 0.79 = 100.2 bar**
- **O_2 content of air to be added = 100.2 x .21 = 21.04 bar**
- **Balance of 100 % O_2 to be added = 50.84 – 21.04 = 29.8 bar**



Determining Mix Requirements

Example 1 by calculation continued

- **Verification of PO_2 required in final mix**
  - **Oxygen content of residual gas = 32.32 bar**
  - **100 % oxygen added = 29.8 bar**
  - **Oxygen content of air added = 21.04 bar**
  - **Total PO_2 of mix = 83.16 bar**

  Total oxygen added in bar equals the sum of all the oxygen added.
- **Equals total oxygen pressure required to create a mix of 36%**

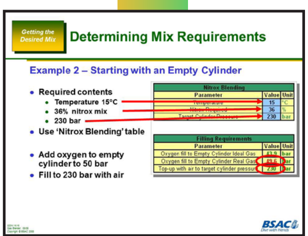
  At the outset it was established that nitrox 36 requires 83.16 bar of oxygen to be in the final composition.
  - **Solution is verified!**
- **Add 29.8 bar of oxygen to cylinder and then top off to 230 bar with air**

Calculation is complicated and very prone to error

There is a lot of room to make calculation errors when performing the calculation by hand.

Use look-up table or software blending program!

Use a simple look up table or computer application to avoid making mistakes.



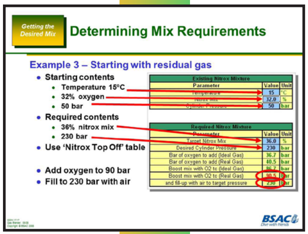
Determining Mix Requirements

Example 2 – Starting with an Empty Cylinder

- **Required contents**
  - **Temperature 15°C**
  - **36% nitrox mix**
  - **230 bar**
- **Use 'Nitrox Blending' table**

  Using the BSAC Gas Mixing Planner , select the 'Nitrox Blending' table.

Entering the required mix details will quickly generate the answer, i.e. fill the empty cylinder with 49.6 bar of oxygen and then top off to 230 bar with air.

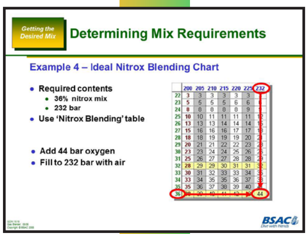


Determining Mix Requirements

Example 3 - Starting with residual gas

- **Starting contents**
  - **Temperature 15°C**
  - **32% oxygen**
  - **50 bar**
- **Required contents**
  - **36% nitrox mix**
  - **230 bar**
- **Use 'Nitrox Top Off' table**

Using the BSAC Gas Mixing Planner , select the 'Nitrox Top Off' table. Enter the starting contents and the required mix details will quickly generate the answer; i.e. fill the cylinder to 90.5 bar with oxygen and then top off to 230 bar with air.



Determining Mix Requirements

Example 4 – Ideal Nitrox Blending Chart

- **Required contents**
  - **36% nitrox mix**
  - **232 bar**
- **Use 'Nitrox Blending' table**

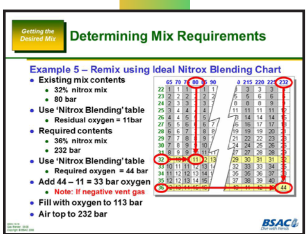
Using the BSAC Gas Mixing Planner select the 'Nitrox blending' table or use a print out of an ideal nitrox blending chart.

By simple looking up the mix and pressure, where the lines intercept informs the blender to first:

- **Add 44 bar oxygen**

And then,

- **Fill to 232 bar with air**



Determining Mix Requirements

Example 5 – Remix Nitrox Blending Chart

- **Residual mix contents**
  - **32% nitrox mix**
  - **80 bar**
- **Use 'Nitrox Blending' table**

Using the BSAC Gas Mixing Planner select the 'Nitrox blending' table or use a print out of an ideal nitrox blending chart. By simple looking up the mix and pressure, where the lines intercept informs the blender:

- **Residual oxygen = 11 bar**

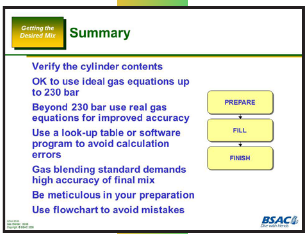
- **Required contents**
  - **36% nitrox mix**
  - **232 bar**
- **Use 'Nitrox Blending' table**

  Again, using the 'nitrox blending' table:
  - **Requires 44 bar of oxygen**

    Total oxygen required in the final mix.
- **Add 44 - 11 = 33 bar oxygen**

  Oxygen required to be added to obtain the target mix is 33 bar.
  - **Note: If negative vent gas**
- **Fill with oxygen to 113 bar**

  Possibly will need a booster pump to achieve this pressure.
- **Air top to 232 bar**



Summary

Reiterate the key points of the lesson using the summary interactively as a means to check that the students have understood them.

Verify the cylinder contents

Never trust the diver, double check the contents to obtain an accurate start point for blending.

OK to use ideal gas equations up to 230 bar

For nitrox blending, simple partial pressure calculations are relevant.

Beyond 230 bar use real gas equations for improved accuracy

Gas behaviour for high pressure blending requires real gas equations to be utilised to allow for accurate mixing.

Use a look-up table or software program to avoid calculation errors

Blending calculations are long winded and therefore prone to error. Use a appropriate blending program or look up table to minimise errors.

Gas blending standard demands high accuracy of final mix

A new British Standard defines higher tolerances for dive gas mix measurement. The standard has been applied by the major gas suppliers. It is currently only a recommendation for end users.

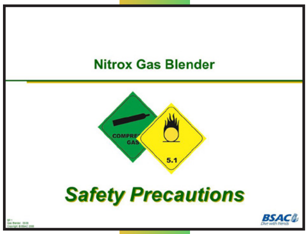
Be meticulous in your preparation

Follow a defined operating procedure to minimise errors.

Use flowchart to avoid mistakes

A flowchart has been produced to avoid making systematic errors. It is all too easy to make mistakes and then be viewed as negligent.

Allow time for the students to ask questions.



SAFETY PRECAUTIONS

Lesson Objectives

Guide duration: 35 mins.

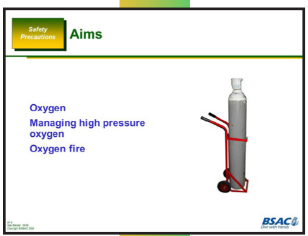
To provide a full understanding of the issues and safety precautions for the handling of high pressure oxygen.

Achievement targets

At the end of this lesson students should know

- Understand the management of oxygen
- Understand the safety precautions for handling oxygen

Oxygen, although not flammable in itself, supports combustion, i.e. oxidation, and a high percentage of oxygen makes almost everything burn faster and easier than in air. All common metals will burn in pure oxygen at the proper temperatures. This lesson addressed the precautions the blender should follow to avoid an incident and what should be done if such an incident occurs.



Aims

Oxygen

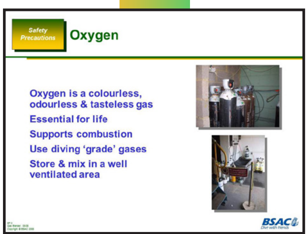
Review the properties of oxygen and storage requirements.

Managing high pressure oxygen

Understand the need to ensure that components exposed to oxygen are in oxygen service.

Oxygen fire

Actions to take if there is an oxygen fire.



Oxygen

Oxygen is a colourless, odourless & tasteless gas

Oxygen is a difficult gas to detect in closed spaces. Oxygen that has been bled or leaks from the storage system will accumulate creating a hazard.

Essential for life

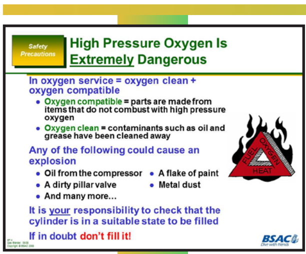
Humans breathe normoxic air and it is a key input for the metabolic process. Too much oxygen is toxic to humans and too little potentially life threatening.

Supports combustion

Oxygen is one of the key ingredients to start a fire, i.e. Air - Fuel - heat. Removing anyone of the three elements stops the fire.

Use diving 'grade' gases

Suppliers in the UK supply oxygen and helium to BS 8478:2006. Overseas, diving grade oxygen or helium needs to be requested locally.



High pressure oxygen is extremely dangerous

Store & mix in a well ventilated area

The chosen blending facility must be well ventilated to prevent oxygen build up and be clean of contaminates that may act as fuel to start a fire.

High pressure oxygen is extremely dangerous

Careful cleaning is essential to prevent oxygen fires. Organic contaminants and fine particles burn violently in pure oxygen and are the kindling chain that starts a fire.

Any system coming into direct contact with high pressure oxygen should be in:

In Oxygen service = oxygen clean + oxygen compatible

Oxygen service requires that two fundamental steps are achieved:

- **Oxygen compatible = parts are made from items that do not combust with high pressure oxygen**
- **Oxygen clean = contaminants such as oil and grease have been cleaned away**

Any of the following could cause an explosion

Potential sources of fuel for a fire include:

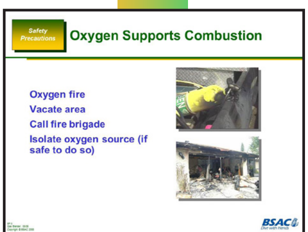
- **Oil from the compressor**
- **A dirty pillar valve**
- **A flake of paint**
- **Metal dust**
- **And many more...**

It is your responsibility to check that the cylinder is in a suitable state to be filled

The cylinder should be appropriately labelled with an up-to-date oxygen service certificate.

If in doubt don't fill it!

If you have any doubts about the cylinder that you are going to fill, do not hesitate to state that as the blender you are uncomfortable filling it with high pressure oxygen. It is your life that is being put in danger.



Oxygen Supports Combustion

Oxygen fire

In an oxygen system fire (oxygen-fuel-ignition) oxygen cannot be removed, it may, as a result of adiabatic compression become its own ignition energy, the fuel being part of the delivery system. Once an oxygen fire is initiated, depending upon the materials, the oxygen continues to fan the fire because oxygen is the oxidiser and lowers the ignition temperatures of materials.

Vacate area

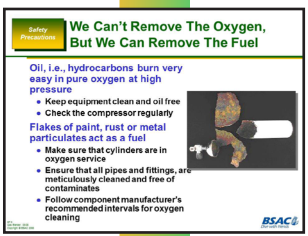
The first action is to ensure the blenders personal safety.

Call fire brigade

Oxygen fires are highly dangerous. Leave it to the professionals to extinguish. Ensure that the fire brigade are fully briefed on what they are confronting.

Isolate oxygen source (if safe to do so)

Never place yourself in danger. If there is a safety valve to isolate the oxygen and starve the fire and it is safe to operate then close it promptly.



We can't remove the oxygen, but we can remove the fuel

Oil, i.e., hydrocarbons burn very easy in pure oxygen at high pressure

- **Keep equipment clean and oil free**

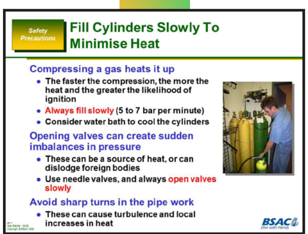
  It is imperative that oxygen systems be cleaned as individual articles, preferably prior to assembly. Manufactured products should preferably be cleaned by a qualified technician periodically.

- **Check the compressor regularly**

  Compressors should be checked as a minimum when the filters are changed, typical every 16-20 hours. Follow manufacturers specified maintenance and service interval guidelines.

Flakes of paint, rust or metal particulates act as a fuel

Many materials which would not be expected to burn in air can do so vigorously when exposed to heat in high pressure oxygen. Keeping all equipment that will be exposed to high pressure oxygen scrupulously clean is therefore an essential safety measure.



Fill cylinders slowly to minimise heat

Compressing a gas heats it up

Guy-Lussac's law as described in the introduction explained this effect.

- **The faster the compression the more the heat and the greater the likelihood of ignition**

  The temperature of the gas inside a cylinder rises during the filling process as a step function, i.e. typical inside a minute reaches the maximum temperature, then approximately remains constant for a time (around 4 minutes) and then slowly drops.

- **Always fill slowly (5 to 7 bar per minute)**

  The flow into a cylinder should be controlled and slow. General rule of filling with oxygen is 'slow, slow and slower'!

- **Consider water bath to cool the cylinders**

  Water baths in addition to keep the cylinder cool during the blending process act as a shock absorber for any mechanical failures.

Opening valves can create sudden imbalances in pressure

In poorly designed systems, valves that are opened too quickly may cause sonic flow of the gas pressure. This flow can produce adiabatic compression at a restriction and can also be a source of ignition.

- **These can be a source of heat, or can dislodge foreign bodies**

  Another possible source of ignition is particle impingement. High gas velocities can entrain the particulates that are present in most systems, for example, in high pressure hose. The particles actually produce sparking when they impact the internal system.

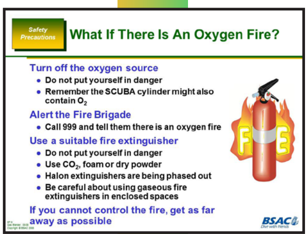
- **Use needle valves, and always open valves slowly**

  Needle valves are designed to enable fine operational control.

Avoid sharp turns in the pipe work

- **These can cause turbulence and local increases in heat**

  Sharp turns act as a barrier to high velocity gas flow, the impact of the gas with the bend may be sufficient to generate substantial temperatures as a result of adiabatic compression.



What if there is an oxygen fire?

Turn off the oxygen source

This will starve the fire and reduce its ferocity.

- **Do not put yourself in danger**

  Self preservation, put your safety first!

- **Remember the SCUBA cylinder might also contain O2**

  If possible, isolate the dive cylinder.

Alert the Fire Brigade

- **Call 999 and tell them there is an oxygen fire**

  An oxygen fire is one of the most dangerous fires to control and finally extinguish. The fire brigade will be putting there lives in great danger, so furnish them with as much detail as possible.

Use a suitable fire extinguisher

Ideally, the user of a fire extinguisher should be trained. Ensure that you follow the instructions for safe use.

- **Do not put yourself in danger**
- **Use CO_2, foam or dry powder**
- **Halon extinguishers are being phased out**
- **Be careful about using gaseous fire extinguishers in enclosed spaces**

If you cannot control the fire, get as far away as possible

Standards and Markings

The appropriate standards governing the safety of breathing gases and breathing air are BS 8478 and BS EN 12021 appropriate extracts are included in your Student Manual as an Appendix.

Colour coding of cylinders varies by country and manufacturer current UK colour are illustrated for

- **Oxygen**
- **Helium**
- **Nitrogen**
- **Argon**

Mixed Gases are more appropriately identified by labeling including the warning diamonds

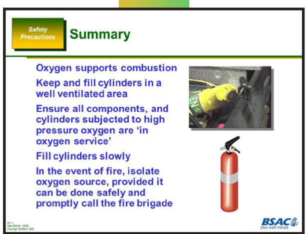
- **Green compressed gas**
- **yellow flammable 5.1**

Labelling

Labelling of dive cylinders may include:

- **Cylinder test date**
- **Oxygen service date**
- **Gas Contents**

We will check markings and labelling during the Practical session



Summary

Reiterate the key points of the lesson using the summary interactively as a means to check that the students have understood them.

Oxygen supports combustion

The oxygen fire triangle consists of oxygen, ignition and fuel. High pressure oxygen can also be the cause of ignition as a result of adiabatic compression.

Keep and fill cylinders in a well ventilated area

Oxygen will initial layer at the bottom of a room becoming a potential issue if exposed to high temperatures, for example, the cylinder jacket on the compressor.

Ensure all components, and cylinders subjected to high pressure oxygen are in 'oxygen service'

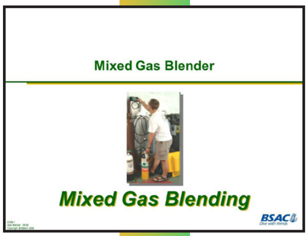
Ensure components exposed to high pressure oxygen are clean and in oxygen service.

Fill cylinders slowly

Slow, slow and slower! Filling rate for oxygen should be around 5-7 bar per minute. This minimises heat generation.

In the event of fire, isolate oxygen source, provided it can be done safely and promptly call the fire brigade

Allow time for the students to ask questions.



MIXED GAS BLENDING

Lesson Objectives

Guide duration: 35 mins.

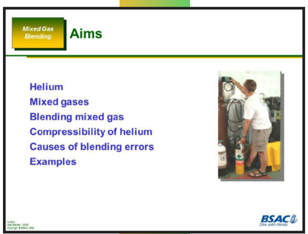
To establish the additional procedures to blend mixed gas mixes.

Achievement targets

At the end of this lesson students should know

- Understand the properties of helium
- Understand the different mixes produced using helium
- Understand the compressibility of helium
- Understand the key causes of mix gas blending errors
- Understand how to calculate the gas pressures for blending mixed gas

The lesson prepares a qualified nitrox blender to safely and accurately use helium to blend mixed gas.



Aims

Helium

The fundamental properties of helium and its effects on the diver.

Mixed gases

The different variations of mixed gas blends based on helium are identified.

Blending mixed gas

The basic principles of blending with helium.

'Non-ideal' behaviour of helium

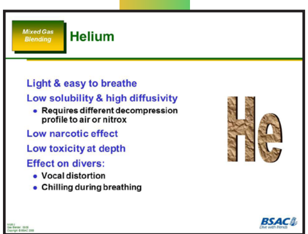
Understanding the behaviour of helium when compressed is fundamental to understanding why it is more complex to blend.

Causes of blending errors

Key sources of blending errors and methods to minimise the errors are identified.

Examples

Four mixed gas examples are provided based on different residual conditions.



Helium

Helium is a non-toxic, colourless, odourless, tasteless, inert and lightweight gas. It is an inert monatomic gas, atomic weight of 4.

Helium is also relatively expensive due to its rarity. Although most of the Earth's helium can be found in the atmosphere, the economic cost of extracting it is extremely high due to its low concentration in the air. Instead, it is obtained from some natural gas fields during extraction of methane. Most helium-rich reserves are in the USA and Canada. The cost of helium is expected to rise dramatically in the next 25 years as sources are depleted. Some hyperbaric chambers incorporate a reclamation system to recover up to 98% of the gas for re-use.

Light & easy to breathe

Its lower density makes it easier to breathe than nitrogen at the same pressure.

Low solubility & high diffusivity

As helium is a smaller monatomic molecule than nitrogen, it enters the tissues faster than nitrogen. Helium also leaves the tissue more rapidly in theory, but also gets ‘stuck’ if it gets in too deep too quickly. Helium decompression is not necessarily shorter than for nitrogen.

- **Requires different decompression profile to air or nitrox**

  While helium is extremely useful in combating the adverse effects of nitrogen and oxygen at extreme depths, it’s not without its problems. Because it is a lighter, faster gas, divers on-gas and off-gas helium more quickly than nitrogen. Paradoxically helium requires a little more decompression time with short dives than air, but less decompression time on long dives than air depending on safety/risk of profile. For some profiles, this requires slower ascents or deeper decompression stops to keep the helium from off-gassing too rapidly and causing DCI.

Low narcotic effect

This is the principal reason for using helium. It is less narcotic than nitrogen and has a (theoretical based on lipid solubility) measured narcotic effect of 0.23 times that of nitrogen.

Low toxicity at depth

Although an inert gas, it does have recognised and notable effects on the body when divers experience helium at high partial pressures.

Effect on divers:

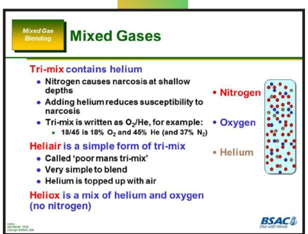
- **Vocal distortion**

  Helium has the effect of causing distorted speech.

- **Chilling during breathing**

  Helium’s thermal conductivity is six times greater than that of nitrogen. This means that a diver breathing heliox or tri-mix will lose body heat via breathing six times faster than someone breathing compressed air or nitrox, making them more susceptible to hypothermia.

Mixed Gases



Tri-mix contains helium

- **Nitrogen causes narcosis at shallow depths**

  Nitrogen narcotic (toxicity) tolerance, or more truthfully an ‘adaptation’ of sorts, can be built up to narcosis after repeated exposures at depth. The mixed gas diver is able to manage the nitrogen narcosis.

- **Adding helium reduces susceptibility to narcosis**

  By adding helium, the mixed gas diver is able to reduce the percentage of nitrogen in the final mix thereby reducing the overall narcotic effect.

- **Tri-mix is written as 02/He, for example:**

  - **18/45 is 18% 02 and 45% He (and 37% N2)**

    The example, 18/45 illustrates the simple convention used for defining a tri-mix gas. The logic is based on the following rule:

    First number, i.e., 18 defines the oxygen %

    The second number, i.e., 45 defines the helium %

    The balance is nitrogen (100 - 18 - 45) equals 37%, is generally not expressed.

Heliair is a simple form of tri-mix

Heliair is popular as it is the cheapest from of mixed gas. Heliair has viability as a diving gas for a very limited operational range.

- **Called 'poor mans tri-mix'**

  Cheaper to blend as there is no pure oxygen added to the cylinder.

- **Very simple to blend**

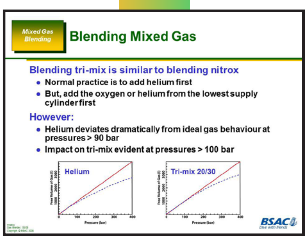
  Simple operational process for the blender.

- **Helium is topped up with air**

  Helium is added and cooled to ambient conditions, then air is pumped directly on top until the required pressure is reached.

Heliox is a mix of helium and oxygen (no nitrogen)

This is an expensive mix to create as it adds helium to pure oxygen and requires a booster pump to reach high pressures. The mix is used occasionally by mixed gas divers and requires dedicated decompression tables.



Blending Mixed Gas

Blending tri-mix is similar to blending nitrox

The principals of blending remain the same. The normal operational procedure follows:

- **Normal practice is to add helium first**

  Due to its very high compressibility helium is generally added first as it is the most difficult component to manage.

- **But, add the oxygen or helium from the lowest supply cylinder first**

  If decanting directly from supply cylinders, it is very important to confirm that you can reach the desired pressures for the desired mix. Sometimes, the oxygen should be added first as the helium pressure is much higher in the supply cylinder and oxygen pressure too low to add on top of the helium.

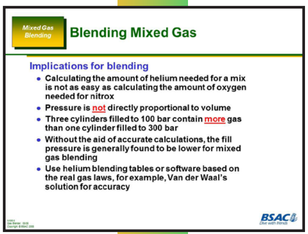
However:

- **Helium deviates dramatically from ideal gas behaviour at pressures > 90 bar**

  The compressibility curve illustrates how far pure helium deviates from the ideal gas laws. Use real gas behaviour to calculate fill pressures.

- **Impact on tri-mix evident at pressures > 100 bar**

  For tri-mix rely on software programmes/look-up tables to calculate the desired mix.



Blending Mixed Gas

Implications for blending

- **Calculating the amount of helium needed for a mix is not as easy as calculating the amount of oxygen needed for nitrox**

  The characteristics of helium are such that they deviate from the 'ideal' gas relationship at a much lower pressure than those for oxygen and nitrogen.

- **Pressure is not directly proportional to volume**

  Ideal gas laws are not applicable above 100 bar without using fudge factors.

- **Three cylinders filled to 100 bar contain more gas than one cylinder filled to 300 bar**

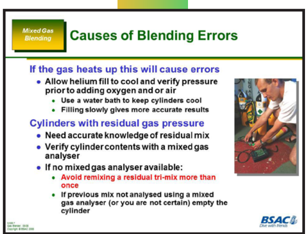
  The sum of the number of molecules added together to reach 100 bar in three identical cylinders exceeds the number of molecules required to fill one of the cylinders to 300 bar.

- **Without the aid of accurate calculations, the fill pressure is generally found to be lower for mixed gas blending**

  This is due to helium's non-ideal behaviour affecting the pressure of the mix.

- **Use helium blending tables or software based on the real gas laws, for example, Van der Waal's solution for accuracy**

  Real gas equations need to be used to blend accurately.



Causes of Blending Errors

If the gas heats up this will cause errors

It is virtually impossible to avoid the gas heating up during filling, which will lead to significant errors if not managed.

- **Allow helium fill to cool and verify pressure prior to adding oxygen and or air**
  - **Use a water bath to keep cylinders cool**
  - **Filling slowly gives more accurate results**

Cylinders with residual gas pressure

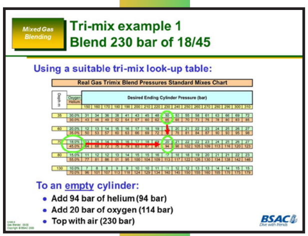
- **Need accurate knowledge of residual mix**

  Remixing is extremely difficult if the blender does not have an accurate knowledge of the residual mix. If an oxygen analyser is available it is extremely difficult to calculate the helium content accurately (compound errors) during subsequent fills. Errors greater than 10 percent are not uncommon.

- **Verify cylinder contents with a mixed gas analyser**

  The ideal tool is a helium analyser to accurately measure the helium content of the mix.

- **If no mixed gas analyser available:**
  - **Avoid remixing a residual tri-mix more than once**
  - **If previous mix not analysed using a mixed gas analyser (or you are not certain) empty the cylinder**



Tri-mix example 1 Blend 230 bar of 18/45

Using a suitable tri-mix look-up table:

For example, using the BSAC Gas Mixing Planner, select the 'Real Tri-mix Blending Chart' worksheet.

Identify the required mix and desired pressure on the chart and round-up.

To an empty cylinder:

First step:

- **Add 94 bar of helium (94 bar)**

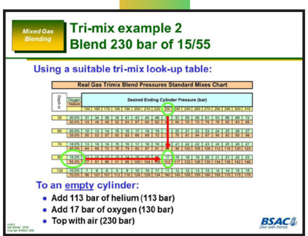
  Add and verify the pressure of helium added by allowing the cylinder to cool, then:

- **Add 20 bar of oxygen (114 bar)**

  Add oxygen and verify pressure by allowing to cool, then finally:

- **Top with air (230 bar)**

  Check final pressure and analyse the mix.



Tri-mix example 2 Blend 230 bar of 15/55

Using a suitable tri-mix look-up table:

Use the BSAC Gas Mixing Planner (or suitable application), select the 'Real Tri-mix Blending Chart' worksheet.

Identify the required mix and desired pressure on the chart and round-up.

To an empty cylinder:

First step:

- **Add 113 bar of helium (113 bar)**

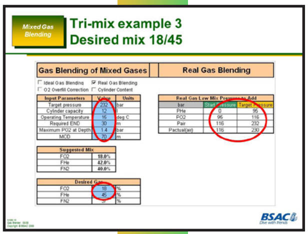
  Add and verify the pressure of helium added by allowing the cylinder to cool, then:

- **Add 17 bar of oxygen (130 bar)**

  Add oxygen and verify pressure by allowing to cool, then finally:

- **Top with air (230 bar)**

Check final pressure and analyse the mix.



Tri-mix example 3 Desired mix 18/45

This example uses the BSAC Gas Mixing Planner by selecting the 'Mixed gas blending' worksheet to calculate a desired mix.

The blender should select real gas blending, enter the ambient temperature of say 15°C and complete the desired gas fields by entering 18% oxygen and 45% helium.

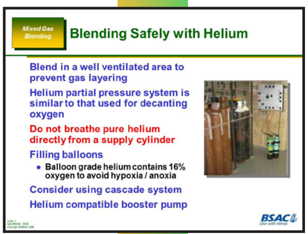
The other fields may be entered provided the mixed gas diver supplies relevant data to enable the blender to determine or verify a mix. It is the responsibility of the mixed gas diver to provide the desired mix and fill pressure.

The table now instructs the blender to fill the cylinder by:

First adding 95 bar of helium,

Then fill the cylinder to 116 bar with pure oxygen,

And finally top with air to 230 bar



Blending safely with helium

Blend in a well ventilated area to prevent gas layering

Helium being very light will layer at the top of any enclosed space and potentially create a hypoxic breathing environment.

Helium partial pressure system is similar to that used for decanting oxygen

Minimum equipment consists of a supply cylinder of diving grade helium, a decanting whip and a SCUBA cylinder. This is an identical requirement to decanting oxygen. The filling whip does not necessarily need to be in oxygen service, but practically it is normally the same filling whip used for decanting oxygen.

Do not breathe pure helium directly from a cylinder

There is no oxygen present in the mix. Anyone who breathes helium will very quickly become unconscious.

Filling Balloons

Helium used for filling balloons consists of a very different gas composition to diving grade helium.

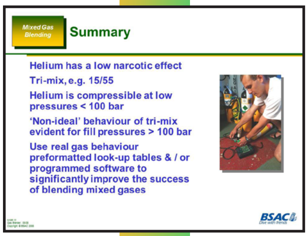
- **Balloon grade helium contains 16% oxygen to avoid hypoxia / anoxia**

Consider using cascade system for filling

A simple solution consisting of two or more to more supply gas cylinders to use the gas efficiently.

Helium compatible booster pump

When considering the purchase or use of a booster pump check that it is helium compatible.



Summary

Reiterate the key points of the lesson using the summary interactively as a means to check that the students have understood them.

Helium has a low narcotic effect

The low narcotic effect of helium enables the diver to manage the overall narcotic effect of the gas and define a comfortable level for diving.

Tri-mix, e.g. 15/55

15 defines the oxygen %, 55 defines the helium %

Helium is compressible at low cylinder pressures < 100 bar

Helium is highly compressible which makes it difficult to accurately mix.

‘Non-ideal’ behaviour of tri-mix evident for fill pressures > 100 bar

Oxygen compensates for the high compressibility of helium for low pressure mixes, but for pressures greater than 100 bar tri-mix is highly compressible.

Use real gas behaviour pre-formatted look-up tables and or programmed software to significantly improve the success of blending mixed gases

Do not rely on ideal gas law calculations for accurate blending unless as a blender you have learnt the fudge factors to apply to your particular blending system. Use real gas blending software to greatly simplify the process. Accurate calculations aids accurate mixing.

Allow time for the students to ask questions.

NITROX GAS BLENDING WORKSHOP

Workshop Objectives

The workshop objectives are to apply the information learned in the theory lessons in practice. It comprises two elements:

- familiarity with, and understanding of, the actual equipment involved
- practical nitrox blending experience.

Equipment Needed

The Instructor will require the following;

- Compressor or air bank supplying 'clean air'.

  This means that a secondary filter, if required, must be fitted to the system prior to the clean air whip or connection point.
- Blending whip.

  The blending whip will need to be in oxygen service and include the following components as a minimum: Bull nose interface (for 'J' cylinders), DIN (and/or A clamp) interface (SCUBA cylinders), bleed valve, adapter to connect to 'clean air' outlet (bull nose – adapter), accurate pressure gauge (either analogue (minimum diameter 10-15 cm) or digital (accuracy 1 bar).
- Nitrox Blending Flow chart (see Appendix A).
- Gas Blending log (see Appendix C).
- Ideal Nitrox Blending Chart (see Appendix F).
- Computer installed with blending software.
- 'J' or adequate sized supply cylinder of diving grade oxygen .
- All diving cylinders to be both in current test and oxygen service.
- Oxygen analyser.

Workshop Prerequisites

To progress with the practical elements the student must:

- Be able to competently operate and use a compressor (where students need to be taught this skill additional time must be allowed on the course to achieve the necessary competence and confidence).
- Have completed the theory section of the course.

Instructor Guidance

The course lead instructor must be happy with the safety and suitability of the blending facility/equipment.

Course instructors should familiarize themselves with the type of facility/equipment to be used, see Appendix D.

Course instructors are recommended to emphasise the sections of the course that most apply to the facility/equipment in use at the branch, shop or dive centre.

Instructors are reminded that the objective of the course is to ensure that, on completion, the students can safely and reliably blend gas with the equipment available. They should also have sufficient knowledge to adapt the techniques taught to other equipment they are likely to use in the future.

BLENDING SYSTEM OVERVIEW

Lesson Objectives

Introduce and explain the component parts of the blending system in use for the course. The students should be able to identify and understand the function of the critical components in the system they will be using. In addition, where practical, instructors should advise on 'typical' systems and how they relate to the equipment in use on the course.

Instructors should ensure that any safety issues that relate to the installation are also explained and understood by the students.

Achievement Targets

At the end of the lesson the students should be able to;

- Identify the key components of the blending facility.
- Understand the function of the components.
- Understand and abide by any safety issues relating to the system.

Lesson Contents

The lesson deals with:

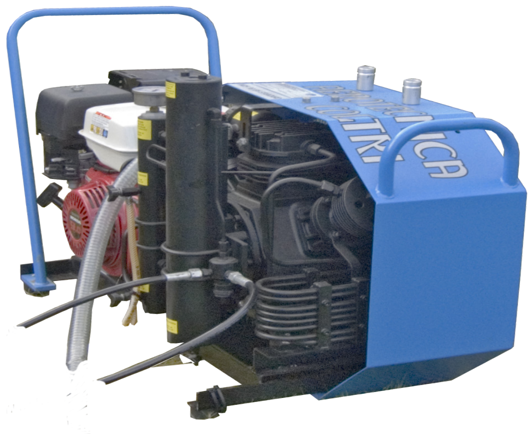
- Identifying the individual components, their function and operation.
- Familiarity with connecting the blending whip (or static system) to the 'clean compressed air'.
- Familiarity with connecting the blending whip (or static system) to the supply cylinders of oxygen and helium, if appropriate.
- All safety related issues of dealing with the installation, associated equipment and working environment.

Explanation of the Blending Equipment.

Instructors should identify the following elements, explain their function and correct operation. The student should take the opportunity to point out any safety related issues with each individual component as it is explained. This will be reinforced as the lessons progress.

Ideally instructors should be fully conversant with the equipment they are using. If not, now is the time that they should ensure that they are fully familiar with the system prior to progressing to the handling and blending of compressed gas.

Compressor and Clean air system



Whilst this is not a compressor course, it may be necessary to review the safe operation of the compressor.

This would include the following:

- Compressor stop and emergency stop switches.
- Compressor on switch.
- Compressor running hours meter. The instructor should reinforce the theory lecture with the importance of accurate logging of compressor operating hours and compressor maintenance. With special emphasis on filter and lubricant hours.
- Compressor purge taps. This should include the procedure for purging the compressor of water in each of the compressor stages, and the frequency at which this should be done.
- Starting procedure. Compressor start up procedure.
- Shutdown procedure. Compressor shut down procedure.
- Identifying filters and specifically the last filter, i.e. the clean air filter.
- Identifying the clean air whip or interface point.
- Demonstrating the connection of the blending whip (or static system) to the compressor clean air output. This should include ensuring that the connection points are clean from particulates, contamination and grease.

Air bank

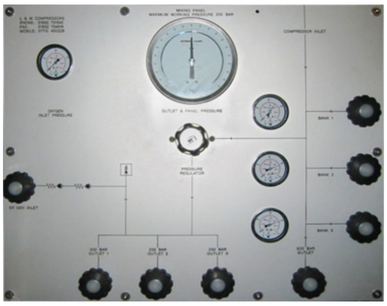
- Understanding the layout.
- Understanding how to isolate the complete air bank from the compressor.
- Understanding how to isolate sections of the air bank.
- Understanding how to decant from the air bank.
- 'J' cylinders.

The instructor should ensure that the students can:

- Confirm and identify the correct 'J' cylinder. Identify the type (purity / grade) of gas supplied by the cylinder.
- Understand the fire risk associated with handling cylinders.
- Understand how to safely move a 'J' cylinder. The normal practice to roll them on their base if they are required to be moved a short distance.

The correct use of ‘J’ cylinder trolleys, for moving cylinders over long distances.

- Understand the safety implications of a falling cylinder or damaged valve.
- Ensure that the ‘J‘ cylinders are safely secured. There must be no risk that the ‘J’ cylinder can fall or roll unexpectedly. The normal procedure is to ensure that the cylinder is secured to the wall.
- Understand the need to use the correct tools to open/close and connect to ‘J’ cylinders.
- Understand and Identify a ‘bull nose’ connection.
- Connect the blending whip (or static system) to the J cylinder. This should include ensuring that the connection points are clean from dirt contamination and grease.
- Understand the fire risks of handling oxygen in a confined area.
- Blending systems – there are two likely variations. A static installation using a full mixing panel, or a portable blending whip. The component parts are similar. It is the degree of complexity that varies.



‘Whip’

The instructor should ensure that the students:

- Understand that the whip should be in ‘oxygen service’. Suitable for high pressure operation.

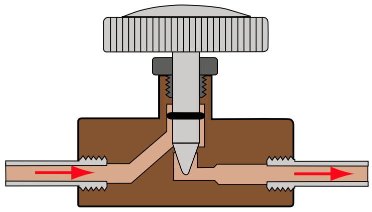
‘Pressure Gauge’

The instructor should ensure that the students understand:

- The pressure gauge operation.
- In the case of electronic gauges (digital) that they understand how to zero them and read them.

- In the case of analogue gauges, how to read them accurately (using the mirrored back to avoid parallax error).
- How to handle, pack and transport the gauge to avoid damage (especially the analogue gauges).

'Needle Valve'



The instructor should ensure that the students understand:

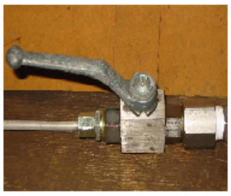
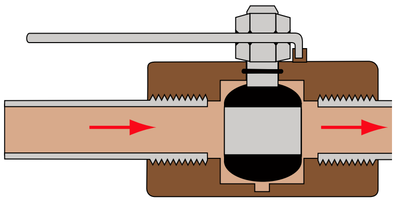
- How to operate the needle valve and its function. They should also understand NOT to over tighten the valve due to the risk of damage.
- On static systems a blending panel may be in use. The Instructor should explain the connections to the panel. The function of each needle valve.

'Bleed Valve'

The instructor should ensure that the students understand:

- How to operate the 'bleed valve' for the blending whip.
- 'Static Blending Systems '

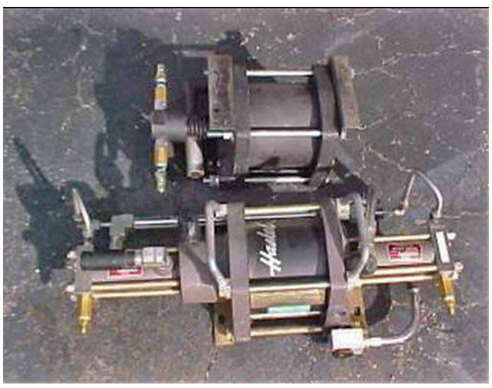
Whilst it is expected that a single blending whip will be in use, some systems may have a static blending panel. In addition to the above, instructors should identify and explain any emergency shut off valves fitted (quarter turn) and their function.

In addition instructors should explain that these should not be reopened on a fully pressurised system. That all compressed gases should be isolated (closed) first and where possible lines purged prior to reopening.

If possible a portable blending whip should also be available and its function demonstrated.

Booster Pumps'



Whilst of extreme expense, booster pumps are often available in shops or static installation and are becoming more common in branch environments.

- If a booster pump is fitted its correct operation should be explained.
- It is strongly recommended that using a booster pump is avoided until basic blending skills and operation of the blending equipment have been fully understood.

Skill Performance Standards

At the end of the lesson the students should have achieved the following:

Be able to confidently and competently identify the key components of the blending facility.

Be able to describe the function of the components accurately.

Should be totally conversant and fully understand the safety issues relating to using the blending system before them.

PRACTICAL BLENDING - NITROX

Lesson Objectives

Practical demonstration and practice of the blending of nitrox mixes.

Develop familiarity of the blending facility in use.

For those upgrading a nitrox blending ticket to mixed gas blender, allows a demonstration of competence and to gain familiarity with the blending facility.

Achievement Targets

At the end of the lesson the students should have demonstrated;

- An understanding of the blending equipment in use.
- Demonstration of competence in calculation of custom nitrox mixes, using both partial pressure tables and computer tools.
- Demonstration of accurate mixing of nitrox, from:
    - o An empty SCUBA cylinder
    - o Remixing a partially SCUBA used cylinder

      This exercise should require a bleed of excess gas to achieve the required mix.
- Demonstrate accurate analysis of nitrox using an oxygen analyser.

Lesson Contents

The lesson deals with:

- Inspection of the cylinder prior to blending.
- Calculation of the required gases to achieve the specified mix using both tables and computer software.
- Blending the specified mix.
- Correctly labelling and documenting the blended gas.

The students should carry out all the following stages to blend a different nitrox mix for each of the following:

- An empty cylinder
- Remixing a partially used cylinder

  Including the need to vent residual gas to achieve the required mix.

1. Pre-blending procedures - Inspection.

Instructors are expected to demonstrate once, and offer corrective tuition where required. The student should have ample opportunity to demonstrate and practise each element on subsequent blending operations.

Instructors should demonstrate the inspection of the diving cylinder prior to proceeding further.

The inspection should include:

- General condition and suitability of the cylinder.

  The instructor should emphasise that they are looking for corrosion or damage to the cylinder. Areas of potential interesting include areas hidden from view, i.e. under the cylinder boot.
- Cylinder test stamp.

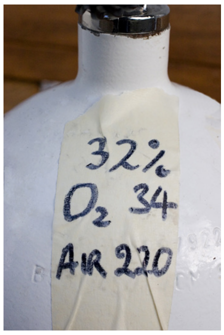
- Cylinder specification (maximum working pressure).

- Cylinder oxygen service label

  Emphasise the need to check that the cylinder is suitable for partial pressure filling (pure oxygen).

- Cylinder is correctly labeled for the use as a nitrox cylinder.
- Analysis of the current oxygen % inside the cylinder and noting it on the cylinder.
- Confirmation of the current cylinder gas pressure.

2. Pre-blending procedures – Calculation.



For nitrox blending the students are required to demonstrate that they can use the partial pressure table and verify the require mix with a computer based blending tool.

- Calculate the required gas quantities to achieve a specified mix in an empty cylinder.
- Label the cylinder with the required pressures (see illustration below) and final target mix.

3. Blending Procedure - Oxygen.

- Connect the blending whip to the oxygen 'J' cylinder.

  Ensure that the valve and fitting are clean and free from contamination.

- Connect the blending whip to the SCUBA cylinder.

  Ensure that the valve and fitting are clean and free from contamination.

- Check and confirm the starting pressure.
- Add oxygen at 5-7 bar per minute

  Instructors to ensure that oxygen is added SLOWLY!

- Overfill oxygen a little (5-10 bar)
- Close SCUBA cylinder and oxygen 'J' cylinder (and / or feed on static system).
- Leave SCUBA cylinder to cool

  If a number of cylinders are to be blended it is recommended that the other cylinders have their oxygen contents added prior to continuing to allow the gas to cool.

- Recheck oxygen pressure – if incorrect top up. Once correct strike through tape.

  Striking through the O2 pressure confirms that the oxygen fill procedure is complete and air is the next gas to be added to achieve the target mix.

- Prepare to add compressed air.

- On a portable system this will involve closing both the diving cylinder and 'J' cylinder valves, venting the whip, moving the whip to the clean air feed.
- On a static system this will require shutting off the oxygen supply to the blending panel and opening the supply from the clean air.

4. Blending Procedure – Compressed air.

- Connect the blending whip to the 'clean' air supply.

  Ensure that the valve and fitting are clean and free from contamination.
- Connect the blending whip to the SCUBA cylinder.

  Ensure that the valve and fitting are clean and free from contamination.
- Check and confirm the starting pressure.
- Add compressed air at 5-7 bar per minute

  From a fixed air storage bank this rate is easily controlled. If filling directly from a compressor however, controlling the fill rate may not be possible, it will be dictated by the compressor output. Keeping the gas cool during filling is not just a consideration of the accuracy of the final mix, but also of minimising fire risk. Heat is one of the three elements of the 'fire triangle', the more there is the great the potential fire risk. Attempts to 'throttle' the fill rate by using the SCUBA cylinder pillar valve should not be attempted as, among other reasons, no pressure gauge in the system will then be able to accurately reflect the cylinder pressure. When filling from a compressor therefore , SCUBA cylinders should be submerged in a water bath to keep them cool. Where this is not practical it may be necessary to fill in stages, allowing the cylinder to cool in the intervening periods, to limit the temperature rise. Where the latter is necessitated, instructors should allow extra time for his to be carried accomplished.
- Once a large proportion of the air has been added the rate can be increased.

  Heating of the cylinder/compressed gas adversely effects the accuracy of the mix.
- Over fill the SCUBA cylinder slightly to allow for 'cool back'

  Experience will assist in gauging this correctly, however this should NOT be taken beyond the working pressure of the cylinder, only beyond the target fill pressure. Compressor mounted gauges should not be relied upon to achieve an accurate value. Being subject to vibration they unlikely to maintain the required calibration accuracy and are generally of too coarse a scale to be read to the required accuracy.
- Leave air to cool

  If a number of cylinders are to be blended it is recommended that the other cylinders are filled with air prior to continuing to allow the gas to cool. If cylinders have become overwarm during filling, such as when adding air directly from a compressor, additional time should be allowed to ensure that the cylinders have cooled adequately.
- Recheck air pressure – if incorrect top up. Once correct strike through tape.
- Close the SCUBA cylinder, isolate the clean air feed prior to venting the whip and disconnecting
- Analyse the oxygen percentage.

  There can be an inaccuracy at this point if the gas has been added slowly and layering has occurred (although theory states this cannot happen it does in practice), agitate the gas by rolling the cylinder.

5. Blending Procedure - Documentation.

- Analyse the oxygen percentage.

  Ensure that the gas has mixed properly.
- Copy the cylinder serial number onto the Gas Blending log sheet with the details of the blender and

the mix.

- Label the cylinder with the Mix, MOD and date.
- On collection of the cylinder the diver is to re-analyse the mix and include this on the blending log alongside the divers' signature and nitrox qualification details.

6. Blending Procedure - Shutdown.

- Ensure the oxygen cylinder is closed.
- Note the 'J' cylinder pressure on the record card.

  It is recommended that a card is fitted to the cylinder neck with the remaining pressure.
- Shutdown the compressor following the compressor shutdown procedure.
- Record the compressor operation hours on the log sheet.
- Store the blending whip, taking care to protect the gauge and fittings.

7. Repeat exercise

- Starting with a cylinder containing residual nitrox.

Skill Performance Standards

At the end of the lesson the students should have achieved the following:

Be able to confidently and competently identify the key components of the blending facility.

Be able to describe the function of the components accurately.

Be able to demonstrate competence and confidence in the calculation of custom nitrox mixes, using both partial pressure tables and computer software.

Demonstration confidence and competence in the accurate mixing of nitrox to within ±1 percent of the target mix, from:

1) An empty cylinder
2) A partially used SCUBA cylinder

Be able to confidently and competently demonstrate the accurate analysis of nitrox using an oxygen analyser.

MIXED GAS BLENDING WORKSHOP

Course Objectives

The workshop objectives are to apply the information learned in the theory lessons in practice. It comprises two elements:

- familiarity with, and understanding of, the actual equipment involved
- practical mixed gas blending experience.

Equipment Needed

The Instructor will require the following;

- Compressor or air bank supplying 'clean air'.

  This means that a secondary filter, if required, must be fitted to the system prior to the clean air whip or connection point.
- Blending whip.

  The blending whip will need to be in oxygen service and include the following components as a minimum: bull nose interface (for 'J' cylinders), DIN (and/or A clamp) interface (SCUBA cylinders), bleed valve, adapter to connect to 'clean air' outlet (bull nose – adapter), accurate pressure gauge (either analogue (minimum diameter 10-15 cm) or digital (accuracy 1 bar).
- Mixed gas blenders flow chart (see Appendix B).
- Gas Blending log (see Appendix C).
- Computer installed with blending software.
- 'J' or adequate sized supply cylinder of diving grade oxygen .
- All diving cylinders to be both in current test and oxygen service.
- Oxygen analyser.

In addition for mix gas blending module:

- Real mixed gas blending chart (see Appendix G).
- 'J' or adequate sized supply cylinder of diving grade helium.
- Helium analyser – (strongly recommended).

Workshop Prerequisites

To progress with the practical elements the student must:

- Have satisfactorily completed the nitrox section of a combined nitrox / mixed gas course

  or

  Hold a BSAC Nitrox Blender qualification or an acceptable equivalent from another agency
- Have completed the theory section of the mixed gas course.
- Be able to competently operate and use a compressor (where students need to be taught this skill additional time must be allowed on the course to achieve the necessary competence and confidence).

Instructor Guidance

The course lead instructor must be happy with the safety and suitability of the blending facility/equipment.

Course instructors should familiarize themselves with the type of facility/equipment to be used, see

Appendix D.

Instructor are recommended to emphasise the sections of the course that most apply to the facility/ equipment in use at the branch, shop or dive centre.

Course instructors are reminded that the objective of the course is to ensure that on completion of the course the students can safely and reliably blend gas with the equipment available. They should also have sufficient knowledge to adapt the techniques taught to other equipment they are likely to use in the future.

PRACTICAL BLENDING – MIXED GAS

Lesson Objectives

Practical demonstration and practice in the blending of mixed gases.

Achievement Targets

At the end of the lesson the students should have demonstrated:

- An understanding of the blending equipment in use.
- Demonstration of competence in the calculation of custom mixed gases, using either the partial pressure tables or computer software.
- Demonstration of accurate mixing of mixed gases, from:
    - An empty cylinder
    - Remixing a partially used cylinder
- Demonstrate accurate analysis of diving gases using oxygen and helium analysers.

Lesson Contents

The lesson deals with:

- Inspection of the cylinder prior to blending.
- Calculation of the required gases to achieve the specified mix using both tables and compatible computer software.
- Blending the specified mix.
- Correctly labelling and documenting the blended gas

The students should carry out all the following stages to blend a different mixed gas mix for each of the following:

- An empty SCUBA cylinder
- Remixing a partially used SCUBA cylinder

1. Pre-blending procedures - Inspection.

Instructor are expected to demonstrate once, and offer corrective tuition where required. The student should have ample opportunity to demonstrate and practice each element on subsequent blending operations.

Instructors should demonstrate the inspection of the SCUBA cylinder prior to proceeding further.

The inspection should include:

- General condition and suitability of the cylinder.

  Instructors should emphasis that they are looking for corrosion or damage to the cylinder. Areas of potential interest include areas hidden from view, i.e. under the cylinder boot.

- Cylinder test stamp.

- Cylinder specification (maximum filling pressure).

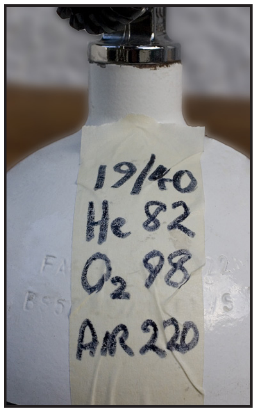
- Cylinder oxygen service label.

  Emphasise the need to check that the cylinder is suitable for partial pressure filling with pure oxygen.

- Cylinder is correctly labeled for use as a mixed gas cylinder.
- Analysis of the current O2 % inside the cylinder.
- Analysis of the current helium % inside the cylinder. If an analyser is not available, only one remix is advised.
- Confirm the current cylinder gas pressure.

2. Pre-blending procedures - Calculation.

The student is required to use either partial pressure look up tables or computer software. It is not recommended to use both together, unless they are derived from the same application, for example, the BSAC spreadsheet. The accuracy of the computed pressures will differ slightly from application to application depending on the originators method of calculation and inputted constants. This is not an exact science, but certainly a more accurate method than basing the calculations on the Ideal gas laws.



Note; When using the BSAC spreadsheet, on opening a dialogue box will appear giving the choice of whether to enable the embedded macros or not. It is essential that the macros are ENABLED if all the necessary functionality is to be available.

- Calculate the required gas quantities to achieve a specified mix in an empty cylinder.
- Label the cylinder with the required pressures and final target mix.

3. Blending Procedure - Helium.

- Connect the blending whip to the helium J cylinder.

  Ensure that the valve and fitting are clean and free from contamination.

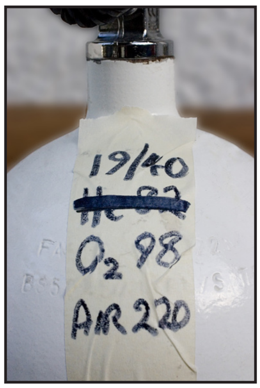
- Connect the blending whip to the SCUBA cylinder.

  Ensure that the valve and fitting are clean and free from contamination.

- Check and confirm the starting pressure.
- Add helium slowly to avoid heating.
- Overfill helium a little (5-10 bar).
- Close SCUBA cylinder and helium J cylinder (and or feed on static system).
- Leave SCUBA cylinder to cool

  If a number of cylinders are to be blended it is recommended that the other cylinders are filled with Helium fills prior to continuing to allow the gas to cool.

- Recheck helium pressure – if incorrect top up. Once correct strike through



tape.

Striking through the helium pressure confirms that the helium fill procedure is complete and oxygen is the next gas to be added in the filling process.

- Prepare to add oxygen.
  - On a portable system this will involve closing both the SCUBA cylinder and helium J cylinder valves, venting the whip, moving the whip to the oxygen 'J' cylinder.
  - On a static system this will require shutting off the helium supply to the blending panel and opening the supply from the oxygen supply.

4. Blending Procedure - Oxygen.

- Connect the blending whip to the oxygen J cylinder.

  Ensure that the valve and fitting are clean and free from contamination.
- Connect the blending whip to the SCUBA cylinder.

  Ensure that the valve and fitting are clean and free from contamination.
- Check and confirm the starting pressure.
- Add oxygen at 5-7 bar per minute.

  Instructors are to ensure that oxygen is added SLOWLY!
- Overfill oxygen a little (5-10 bar)
- Close SCUBA cylinder and oxygen 'J' cylinder valves (and or feed on static system).

- Leave SCUBA cylinder to cool

  If a number of cylinders are to be blended it is recommended that the other cylinders have their oxygen contents added prior to continuing to allow the gas to cool.
- Recheck oxygen pressure – if incorrect top up. Once correct strike through tape.

  Striking through the oxygen pressure confirms that the oxygen fill procedure is complete and air is the next gas to be added to achieve the target mix.
- Prepare to add compressed air.
  - On a portable system this will involve closing both the diving cylinder and J cylinder valve, venting the whip, moving the whip to the clean air feed.
  - On a static system this will require shutting off the oxygen supply to the blending panel and opening the supply from the clean air.

5. Blending Procedure – Compressed air.

- Connect the blending whip to the 'clean' air supply.

  Ensure that the valve and fitting are clean and free from contamination.
- Connect the blending whip to the SCUBA cylinder.

  Ensure that the valve and fitting are clean and free from contamination.
- Check and confirm the starting pressure.
- Add compressed air at 5-7 bar per minute.

  From a fixed air storage bank this rate is easily controlled. If filling directly from a compressor however, controlling the fill rate may not be possible, it will be dictated by the compressor output. Keeping the gas cool during filling is not just a consideration of the accuracy of the final mix, but also of minimising fire risk. Heat is one of the three elements of the 'fire triangle', the more there is the great the potential fire risk. Attempts to 'throttle' the fill rate by using the SCUBA cylinder pillar valve should not be attempted as, among other reasons, no pressure gauge in the system will then be able to accurately reflect the cylinder pressure. When filling from a compressor therefore , SCUBA cylinders should be submerged in a water bath to keep them cool. Where this is not practical it may be necessary to fill in stages, allowing the cylinder to cool in the intervening periods, to limit the temperature rise. Where the latter is necessitated, instructors should allow extra time for his to be carried accomplished.

- Once a large proportion of the air has been added the rate can be increased.

  Heating of the cylinder/compressed gas adversely effects the accuracy of the mix.

- Over fill the SCUBA cylinder slightly to allow for 'cool back'

  Experience will assist in gauging this correctly, however this should NOT be taken beyond the working pressure of the cylinder, only beyond the target fill pressure. Compressor mounted gauges should not be relied upon to achieve an accurate value. Being subject to vibration they unlikely to maintain the required calibration accuracy and are generally of too coarse a scale to be read to the required accuracy.

- Leave air to cool

  If a number of cylinders are to be blended it is recommended that the other cylinders are filled with air prior to continuing to allow the gas to cool. If cylinders have become overwarm during filling, such as when adding air directly from a compressor, additional time should be allowed to ensure that the cylinders have cooled adequately.

- Recheck cylinder pressure – if incorrect top up. Once correct strike through tape.
- Close the SCUBA cylinder and isolate the clean air feed prior to venting the whip and disconnecting
- Analyse oxygen percentage.

  There can be an inaccuracy at this point if the gas has been added slowly and layering has occurred (although theory states this cannot happen it does in practice). Agitate the gas by rolling the cylinder before analysing.

- Analyse the helium percentage.

  Note – if no analyser is available the oxygen percentage MUST match that intended by calculation, within ± 1%. IF NOT THE GAS MUST BE VENTED and REMIXED!

6. Blending Procedure - Documentation.

- Analyse the oxygen percentage.
- Analyse the helium percentage.

  Ensure the gas has mixed properly.

- Copy the cylinder serial number on to the Gas Blending log sheet with the details of the blender and the mix.
- Label the cylinder with the Mix, MOD and date.
- On collection of the cylinder the diver is to re-analyse the contents and include this on the Gas Blending Log alongside the diver's signature and mixed gas qualification details.

7. Blending Procedure - Shutdown.

- Ensure the oxygen and helium cylinders are closed.
- Record the 'J' cylinder pressures on the record card.

  It is recommended that a card is fitted to the cylinder neck with the remaining pressure.

- Shutdown the compressor following the compressor shutdown procedure.

- Record the compressor operation hours on the log sheet.
- Store the blending whip, taking care to protect the gauge and fittings.

8. Repeat exercise

- Starting with a SCUBA cylinder containing residual mixed gas.

  Depending upon the pressures of the residual gas mix and those of the supply gases, if a booster pump is not available it may not be possible to simply add gas to the SCUBA cylinder. In this case students should be guided through working out what mix can be achieved with the pressures available or working out what pressure they need to bleed the SCUBA cylinder down to in order to achieve the required mix.

Skill Performance Standards

At the end of the lesson the students should have achieved the following:

Be able to confidently and competently identify the key components of the blending facility.

Be able to describe confidently the function of the system components.

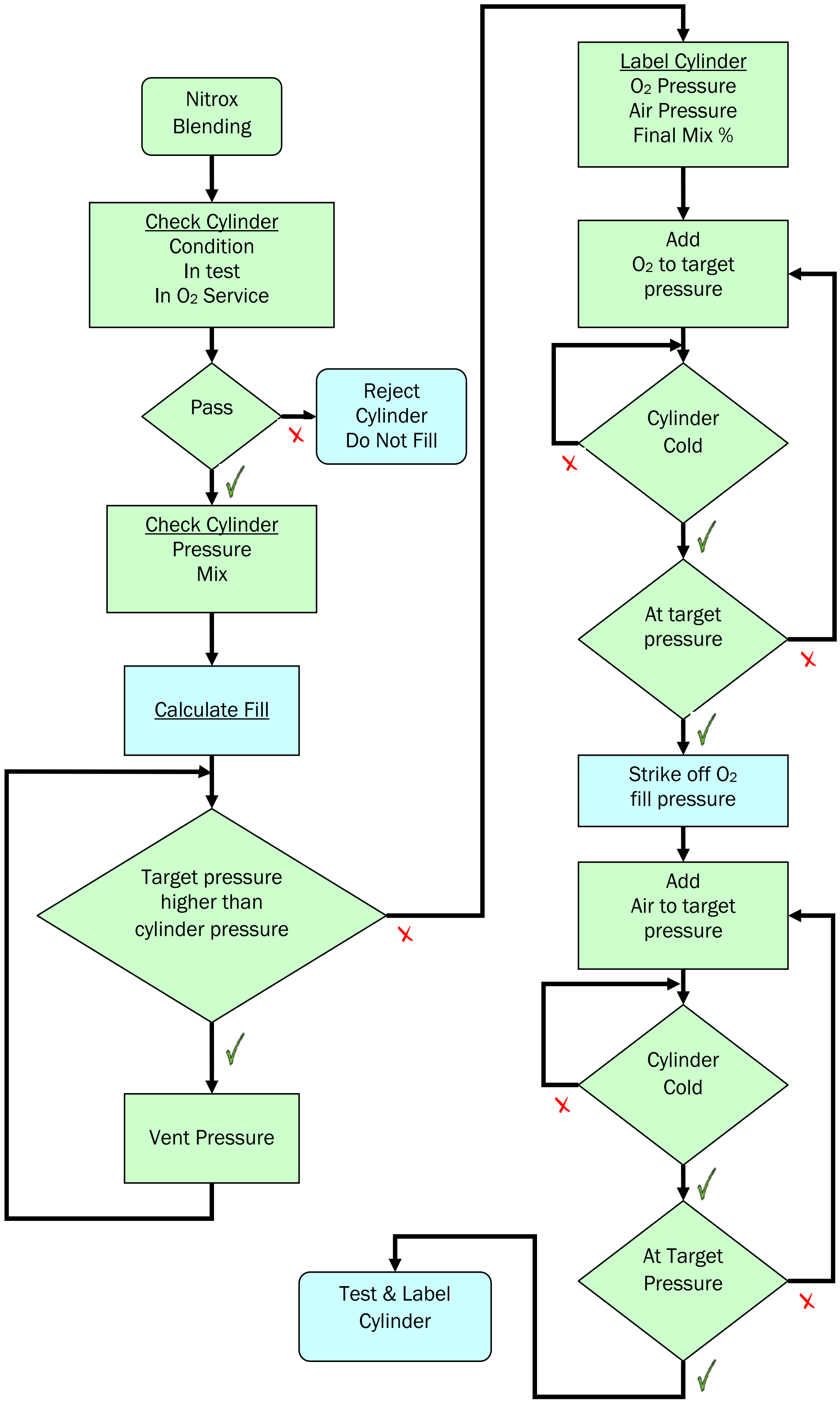
Be able to confidently and competently calculate custom mixed mixes, using either partial pressure tables or computer software.

Be able to confidently and competently achieve mixing accuracies to within ±1 percent of the target mix for oxygen and ±2% for helium, from:

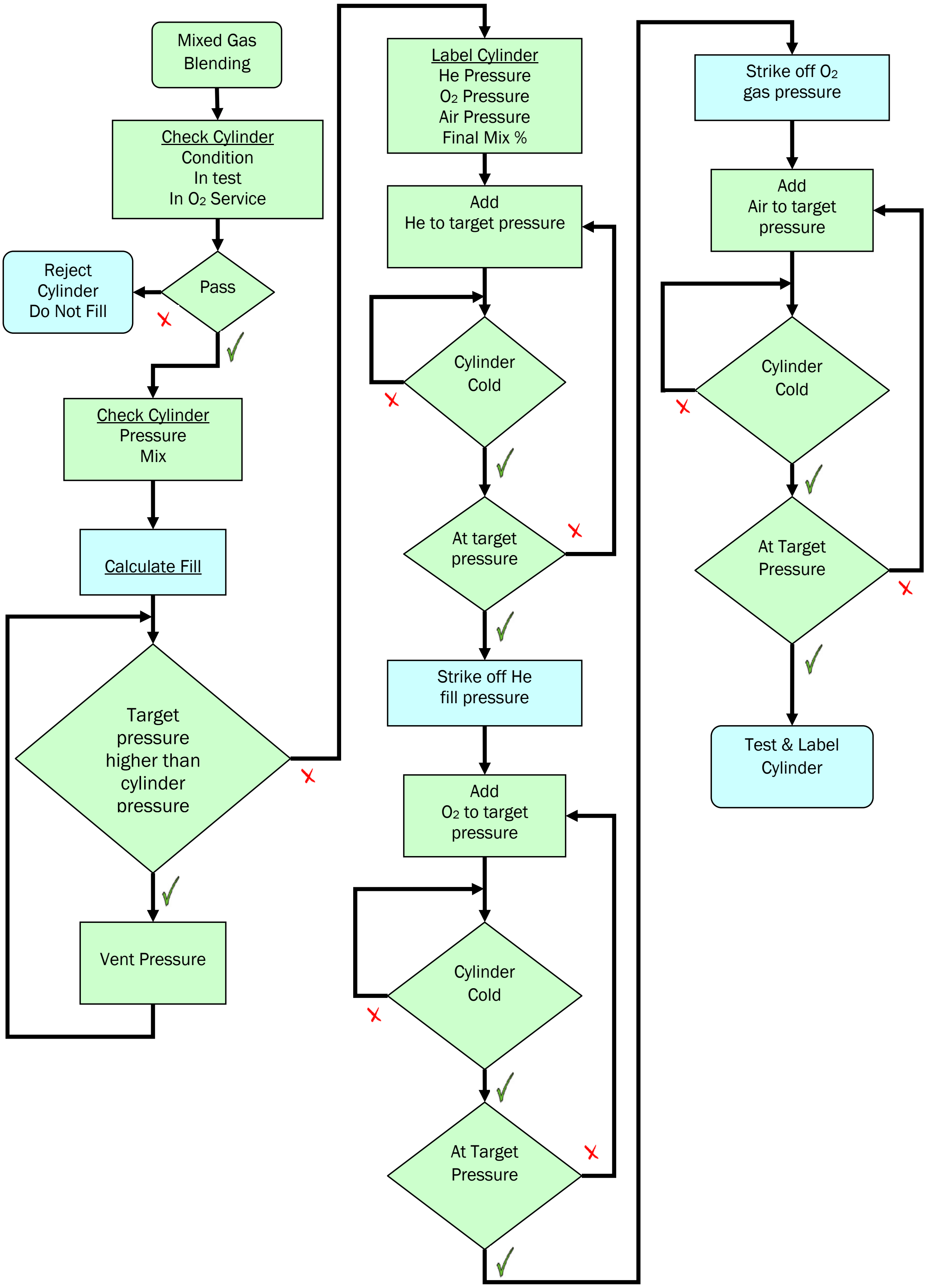
1) An empty SCUBA cylinder
2) A partially used SCUBA cylinder

Be able to confidently and competently accurately analyse diving gases using an oxygen and helium analyser, if available.

APPENDIX A
NITROX BLENDING FLOWCHART



APPENDIX B
MIXED GAS BLENDING FLOWCHART



APPENDIX C
GAS BLENDING LOG SHEET

Gas Blending Log							
BLENDER					DIVER		
Cylinder Serial No	Req'd % Mix	Date	Name	Signature	Signature	Qualification & No	% Mix

APPENDIX D
SYSTEM INSPECTION

This check list is designed to aid the instructor and user in confirming the safety and suitability of a proposed blending facility for producing nitrox and mixed gases.

Environment

- Clean, free from oil, grease and other sources of contamination
- Well ventilated

Clean Air

- Maintained compressor
    - Service log
    - Operating hours log
    - Contamination free compressor inlet
- Filter system
    - Logged filter life
    - ‘Second’ (clean air) filter
- Air bank
- Maximum available air pressure
- Maximum intended blending pressure

J Cylinders

- Storage
    - Secure and stable
    - Well ventilated
- Oxygen
    - Diving grade oxygen
- Helium
    - Diving grade helium

Blending System

1. Portable (or whip)

- High pressure oxygen service whip
- Needle valve
- Pressure gauge
    - Digital (accuracy 1 bar, resolution ±0.5%)

    Or
    - Analogue (minimum diameter 10 - 15 cm)
- Bullnose fitting

APPENDIX D
SYSTEM INSPECTION

- Bullnose/DIN adapter
- DIN fitting

2. Static (Panel)

- Oxygen service (maintained piping)
- High pressure oxygen whips
- Needle valve
- Isolator valves
- Pressure gauge
    - o Digital (accuracy 1 bar)

    Or

    - o Analogue (minimum diameter 10 - 15 cm)
- Bullnose fitting
- DIN fitting

Booster Pump

- Oxygen service

Documentation

- Compressor log
- Compressor service Log
- Gas Blending log

APPENDIX E
BS 8478 COMMENTARY

There is a British Standard, BS8478:2006 Breathing Gases, which specifies requirements and test methods for the composition and purity of breathing gases, other than compressed air, for use in diving and hyperbaric applications.

The standard is applicable to the following categories of gas mixtures:

- Breathing oxygen;
- Oxygen and nitrogen mixtures (known as nitrox);
- Oxygen and helium mixtures (known as heliox);
- Oxygen, helium and nitrogen mixtures (known as tri-mix).

The standard is not applicable to compressed breathing gases for other applications (medical or altitude).

Note 1 – The composition and purity of compressed air is specified in BS EN 12021.

Note 2 – Compressed air for use with nitrox or tri-mix, i.e. ‘clean air’, is considered to be nitrox and therefore comes under the remit of BS 8478 not BS 12021.

The standard covers:-

- Freedom from particulate contamination, both the maximum allowable size of particulate contamination and the degree of contamination.
- Freedom from odour
- Composition of breathing oxygen (see table 1.)
- Composition of nitrox (see table 2)
- Composition of oxygen and helium mixtures (see table 3)
- Composition of oxygen, helium and nitrogen mixtures (see table 4)
- Analyses and measuring requirements
- Labelling.

Summary

The tables 1-4 basically define the quality of the gas. The accuracy of the measuring of the mix is that specified for a commercial manufacturer and supplier of gas.

When blending gases for diving we have a wider accuracy tolerance because of the nature of the decompression software we use.

Generally we expect to have:-

- the oxygen to within 1% of that specified.
- the helium to within 2% of that specified.

If the gas is outside these parameters then a new decompression profile is required.

APPENDIX E
BS 8478 COMMENTARY

Component	Concentration at 1.013 bar and 20° C
Oxygen (%)	>99.5
Water ($mg \cdot m^{-3}$)	≤5
Carbon dioxide (ppm)	≤5
Carbon monoxide (ppm)	≤1
Oil ($mg \cdot m^{-3}$)	<0.01
Methane (ppm)	≤30
Total volatile non-substituted hydrocarbons (vapour or gas) as methane equivalent (ppm)	≤50
Total chlorofluorocarbons and halogenated hydrocarbons (ppm)	≤2
Total other non-toxic gases (including argon and other group 18 noble gases) (%)	<0.5

Table 1 – Composition of breathing Oxygen

Component	Concentration at 1.013 bar and 20° C
Oxygen (%)	
Mixtures containing <40% by volume	Stated [A] ±0.5 [B]
Mixtures containing ≥40% by volume	Stated [A] ±1.0 [B]
Nitrogen (%)	Remainder
Water ($mg \cdot m^{-3}$)	≤5
Carbon dioxide (ppm)	≤500
Carbon monoxide (ppm)	≤3
Oil ($mg \cdot m^{-3}$)	<0.01
Methane (ppm)	≤30
Total volatile non-substituted hydrocarbons (vapour or gas) as methane equivalent (ppm)	≤50
Total other non-toxic gases (including argon and other group 18 noble gases) (%)	<1
[A] Percentage as stated by the supplier [b] Tolerance value is a percentage of the total gas mixture	

Table 2 – Composition of oxygen and nitrogen mixtures.

APPENDIX E
BS 8478 COMMENTARY

Component	Concentration at 1.013 bar and 20° C
Oxygen (%)	
Mixtures containing ≤10% by volume	Stated [A)] ±0.25 [B)]
Mixtures containing >10% to ≤20% by volume	Stated [A)] ±0.5 [B)]
Mixtures containing >20% by volume	Stated [A)] ±1.0 [B)]
Helium (%)	Remainder
Water ($mg{\cdot}m^{-3}$)	≤5
Carbon dioxide (ppm)	≤5
Carbon monoxide (ppm)	≤1
Oil ($mg{\cdot}m^{-3}$)	<0.01
Methane (ppm)	≤30
Total volatile non-substituted hydrocarbons (vapour or gas) as methane equivalent (ppm)	≤50
Hydrogen (ppm)	≤10
Total other non-toxic gases (including argon and other group 18 noble gases) (%)	<1
[A)] Percentage as stated by the supplier [b)] Tolerance value is a percentage of the total gas mixture	

Table 3 – Composition of oxygen and helium mixtures.

APPENDIX E
BS 8478 COMMENTARY

Component	Concentration at 1.013 bar and 20° C
Oxygen (%)	
Mixtures containing ≤10% by volume	Stated [A] ±0.25 [B]
Mixtures containing >10% to ≤20% by volume	Stated [A] ±0.5 [B]
Mixtures containing >20% by volume	Stated [A] ±1.0 [B]
Helium (%)	
Mixtures containing ≤20% by volume	Stated [A] ±0.5 [B]
Mixtures containing >20% by volume	Stated [A] ±1.0 [B]
Nitrogen (%)	Remainder
Water ($mg{\cdot}m^{-3}$)	≤5
Carbon dioxide (ppm)	≤300
Carbon monoxide (ppm)	≤3
Oil ($mg{\cdot}m^{-3}$)	<0.01
Methane (ppm)	≤30
Total volatile non-substituted hydrocarbons (vapour or gas) as methane equivalent (ppm)	≤50
Hydrogen (ppm)	≤10
Total other non-toxic gases (including argon and other group 18 noble gases) (%)	<1
[A] Percentage as stated by the supplier [b] Tolerance value is a percentage of the total gas mixture	

Table 4 – Composition of oxygen, helium and nitrogen mixtures.

APPENDIX E
BS EN 12021 COMMENTARY
DIVERS' BREATHING AIR

Component	Concentration at 1.013 bar and 20° C
Oxygen % by volume (dry air)	21 ±1%
Lubricant content (droplets or mist) (mg.m-3)	0.5
Carbon dioxide (ppm)	500
Carbon monoxide (ppm)	≤15
The air shall be without significant odour or taste.	
There shall be no free liquid water.	
The maximum water content of the air measured at:	≤30
- a compressor system outlet for filling cylinders (mg.m-3)	25
- a cylinder outlet, cylinder pressure from 40 to 200 bar (mg.m-3)	50
- a cylinder outlet, cylinder pressure >200 bar (mg.m-3)	35

Table – Composition of divers' breathing air.

Recommended exposure limits

It is recommended in the National Foreword to BS EN 12021 that all contaminants should be kept to as low a level as possible, preferably below 10% of the UK 8-hour Time Weighted Average (TWA) Workplace Exposure Limits (WELs).

Frequency of tests

A competent person should test the quality of the air supplied for breathing apparatus at least once every three months, and more frequently when the quality of the air supplied cannot be assured.

Competent Person

A 'competent person' is a person having a combination of training, knowledge and experience such that the person can do the job required in a safe and efficient manner, using the test apparatus provided for the task. The duty holder will have to decide who the 'competent person' will be.

APPENDIX F
IDEAL NITROX BLENDING CHART

Ideal State Nitrox Blending Chart (30 - 145 bar)

CYLINDER PRESSURE (BAR)

	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110	115	120	125	130	135	140	145
22	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2
23	1	1	1	1	1	1	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	4	4
24	1	1	2	2	2	2	2	2	3	3	3	3	3	4	4	4	4	4	5	5	5	5	5	6
25	2	2	2	2	3	3	3	3	4	4	4	4	5	5	5	5	6	6	6	6	7	7	7	7
26	2	2	3	3	3	3	4	4	4	5	5	5	6	6	6	7	7	7	8	8	8	9	9	9
27	2	3	3	3	4	4	5	5	5	6	6	6	7	7	8	8	8	9	9	9	10	10	11	11
28	3	3	4	4	4	5	5	6	6	7	7	8	8	8	9	9	10	10	11	11	12	12	12	13
29	3	4	4	5	5	6	6	7	7	8	8	9	9	10	10	11	11	12	12	13	13	14	14	15
30	3	4	5	5	6	6	7	7	8	9	9	10	10	11	11	12	13	13	14	14	15	15	16	17
31	4	4	5	6	6	7	8	8	9	9	10	11	11	12	13	13	14	15	15	16	16	17	18	18
32	4	5	6	6	7	8	8	9	10	10	11	12	13	13	14	15	15	16	17	17	18	19	19	20
33	5	5	6	7	8	8	9	10	11	11	12	13	14	14	15	16	17	17	18	19	20	21	21	22
34	5	6	7	7	8	9	10	11	12	12	13	14	15	16	16	17	18	19	20	21	21	22	23	24
35	5	6	7	8	9	10	11	12	12	13	14	15	16	17	18	19	19	20	21	22	23	24	25	26
36	6	7	8	9	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
37	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
38	6	8	9	10	11	12	13	14	15	16	17	18	19	20	22	23	24	25	26	27	28	29	30	31
39	7	8	9	10	11	13	14	15	16	17	18	19	21	22	23	24	25	26	27	28	30	31	32	33
40	7	8	10	11	12	13	14	16	17	18	19	20	22	23	24	25	26	28	29	30	31	32	34	35
45	9	11	12	14	15	17	18	20	21	23	24	26	27	29	30	32	33	35	36	38	39	41	43	44
50	11	13	15	17	18	20	22	24	26	28	29	31	33	35	37	39	40	42	44	46	48	50	51	53
55	13	15	17	19	22	24	26	28	30	32	34	37	39	41	43	45	47	49	52	54	56	58	60	62
60	15	17	20	22	25	27	30	32	35	37	39	42	44	47	49	52	54	57	59	62	64	67	69	72
65	17	19	22	25	28	31	33	36	39	42	45	47	50	53	56	58	61	64	67	70	72	75	78	81
70	19	22	25	28	31	34	37	40	43	47	50	53	56	59	62	65	68	71	74	78	81	84	87	90
75	21	24	27	31	34	38	41	44	48	51	55	58	62	65	68	72	75	79	82	85	89	92	96	99
80	22	26	30	34	37	41	45	49	52	56	60	63	67	71	75	78	82	86	90	93	97	101	105	108

APPENDIX F
IDEAL NITROX BLENDING CHART

Ideal State Nitrox Blending Chart (145 - 232 bar)

	CYLINDER PRESSURE (BAR)																	
	145	150	155	160	165	170	175	180	185	190	195	200	205	210	215	220	225	232
22	2	2	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3
23	4	4	4	4	4	4	4	5	5	5	5	5	5	5	5	6	6	6
24	6	6	6	6	6	6	7	7	7	7	7	8	8	8	8	8	9	9
25	7	8	8	8	8	9	9	9	9	10	10	10	10	11	11	11	11	12
26	9	9	10	10	10	11	11	11	12	12	12	13	13	13	14	14	14	15
27	11	11	12	12	13	13	13	14	14	14	15	15	16	16	16	17	17	18
28	13	13	14	14	15	15	16	16	16	17	17	18	18	19	19	19	20	21
29	15	15	16	16	17	17	18	18	19	19	20	20	21	21	22	22	23	23
30	17	17	18	18	19	19	20	21	21	22	22	23	23	24	24	25	26	26
31	18	19	20	20	21	22	22	23	23	24	25	25	26	27	27	28	28	29
32	20	21	22	22	23	24	24	25	26	26	27	28	29	29	30	31	31	32
33	22	23	24	24	25	26	27	27	28	29	30	30	31	32	33	33	34	35
34	24	25	26	26	27	28	29	30	30	31	32	33	34	35	35	36	37	38
35	26	27	27	28	29	30	31	32	33	34	35	35	36	37	38	39	40	41
36	28	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44
37	29	30	31	32	33	34	35	36	37	38	39	41	42	43	44	45	46	47
38	31	32	33	34	36	37	38	39	40	41	42	43	44	45	46	47	48	50
39	33	34	35	36	38	39	40	41	42	43	44	46	47	48	49	50	51	53
40	35	36	37	38	40	41	42	43	44	46	47	48	49	51	52	53	54	56
45	44	46	47	49	50	52	53	55	56	58	59	61	62	64	65	67	68	70
50	53	55	57	59	61	62	64	66	68	70	72	73	75	77	79	81	83	85
55	62	65	67	69	71	73	75	77	80	82	84	86	88	90	93	95	97	100
60	72	74	77	79	81	84	86	89	91	94	96	99	101	104	106	109	111	115
65	81	84	86	89	92	95	97	100	103	106	109	111	114	117	120	123	125	129
70	90	93	96	99	102	105	109	112	115	118	121	124	127	130	133	136	140	144
75	99	103	106	109	113	116	120	123	126	130	133	137	140	144	147	150	154	159
80	108	112	116	119	123	127	131	134	138	142	146	149	153	157	161	164	168	173

APPENDIX G

REAL MIXED GAS BLENDING CHART STANDARD MIXES

Real Gas Trimix Blend Pressures Standard Mixes Chart

Depth m	Oxygen / Helium	150	160	170	180	190	200	210	220	230	240	250	260	270	280	290	300	310
		Desired Ending Cylinder Pressure (bar)																
35	30.0%	31	34	36	38	41	43	45	48	50	53	55	58	61	63	66	69	72
	30.0%	43	46	49	52	54	57	60	62	65	68	70	73	75	78	80	83	85
60	20.0%	12	13	14	15	16	17	18	19	19	20	21	22	23	24	25	26	27
	35.0%	50	53	57	60	63	66	69	72	75	78	81	84	87	90	93	95	98
70	18.0%	13	14	14	15	16	17	18	19	20	21	22	22	23	24	25	26	27
	45.0%	64	68	72	75	79	83	87	91	94	98	102	105	109	113	116	120	123
80	15.0%	11	12	12	13	14	15	15	16	17	18	18	19	20	21	21	22	23
	55.0%	77	81	86	91	95	100	104	109	113	117	122	126	130	134	138	142	146
130	10.0%	7	8	8	9	9	10	10	11	11	12	12	13	13	14	14	15	15
	70.0%	96	101	107	113	118	124	129	134	140	145	150	155	160	165	170	175	179

APPENDIX H
OXYGEN PARTIAL PRESSURE TABLE

Oxygen Partial Pressure Table

Nitrox mix

	21	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	52	54	56	58	60
1	0.23	0.24	0.26	0.29	0.31	0.33	0.35	0.37	0.40	0.42	0.44	0.46	0.48	0.51	0.53	0.55	0.57	0.59	0.62	0.64	0.66
2	0.25	0.26	0.29	0.31	0.34	0.36	0.38	0.41	0.43	0.46	0.48	0.50	0.53	0.55	0.58	0.60	0.62	0.65	0.67	0.70	0.72
3	0.27	0.29	0.31	0.34	0.36	0.39	0.42	0.44	0.47	0.49	0.52	0.55	0.57	0.60	0.62	0.65	0.68	0.70	0.73	0.75	0.78
4	0.29	0.31	0.34	0.36	0.39	0.42	0.45	0.48	0.50	0.53	0.56	0.59	0.62	0.64	0.67	0.70	0.73	0.76	0.78	0.81	0.84
5	0.32	0.33	0.36	0.39	0.42	0.45	0.48	0.51	0.54	0.57	0.60	0.63	0.66	0.69	0.72	0.75	0.78	0.81	0.84	0.87	0.90
6	0.34	0.35	0.38	0.42	0.45	0.48	0.51	0.54	0.58	0.61	0.64	0.67	0.70	0.74	0.77	0.80	0.83	0.86	0.90	0.93	0.96
7	0.36	0.37	0.41	0.44	0.48	0.51	0.54	0.58	0.61	0.65	0.68	0.71	0.75	0.78	0.82	0.85	0.88	0.92	0.95	0.99	1.02
8	0.38	0.40	0.43	0.47	0.50	0.54	0.58	0.61	0.65	0.68	0.72	0.76	0.79	0.83	0.86	0.90	0.94	0.97	1.01	1.04	1.08
9	0.40	0.42	0.46	0.49	0.53	0.57	0.61	0.65	0.68	0.72	0.76	0.80	0.84	0.87	0.91	0.95	0.99	1.03	1.06	1.10	1.14
10	0.42	0.44	0.48	0.52	0.56	0.60	0.64	0.68	0.72	0.76	0.80	0.84	0.88	0.92	0.96	1.00	1.04	1.08	1.12	1.16	1.20
11	0.44	0.46	0.50	0.55	0.59	0.63	0.67	0.71	0.76	0.80	0.84	0.88	0.92	0.97	1.01	1.05	1.09	1.13	1.18	1.22	1.26
12	0.46	0.48	0.53	0.57	0.62	0.66	0.70	0.75	0.79	0.84	0.88	0.92	0.97	1.01	1.06	1.10	1.14	1.19	1.23	1.28	1.32
13	0.48	0.51	0.55	0.60	0.64	0.69	0.74	0.78	0.83	0.87	0.92	0.97	1.01	1.06	1.10	1.15	1.20	1.24	1.29	1.33	1.38
14	0.50	0.53	0.58	0.62	0.67	0.72	0.77	0.82	0.86	0.91	0.96	1.01	1.06	1.10	1.15	1.20	1.25	1.30	1.34	1.39	1.44
15	0.53	0.55	0.60	0.65	0.70	0.75	0.80	0.85	0.90	0.95	1.00	1.05	1.10	1.15	1.20	1.25	1.30	1.35	1.40	1.45	1.50
16	0.55	0.57	0.62	0.68	0.73	0.78	0.83	0.88	0.94	0.99	1.04	1.09	1.14	1.20	1.25	1.30	1.35	1.40	1.46	1.51	1.56
17	0.57	0.59	0.65	0.70	0.76	0.81	0.86	0.92	0.97	1.03	1.08	1.13	1.19	1.24	1.30	1.35	1.40	1.46	1.51	1.57	1.62
18	0.59	0.62	0.67	0.73	0.78	0.84	0.90	0.95	1.01	1.06	1.12	1.18	1.23	1.29	1.34	1.40	1.46	1.51	1.57	1.62	
19	0.61	0.64	0.70	0.75	0.81	0.87	0.93	0.99	1.04	1.10	1.16	1.22	1.28	1.33	1.39	1.45	1.51	1.57	1.62		
20	0.63	0.66	0.72	0.78	0.84	0.90	0.96	1.02	1.08	1.14	1.20	1.26	1.32	1.38	1.44	1.50	1.56	1.62			
21	0.65	0.68	0.74	0.81	0.87	0.93	0.99	1.05	1.12	1.18	1.24	1.30	1.36	1.43	1.49	1.55	1.61				
22	0.67	0.70	0.77	0.83	0.90	0.96	1.02	1.09	1.15	1.22	1.28	1.34	1.41	1.47	1.54	1.60					
23	0.69	0.73	0.79	0.86	0.92	0.99	1.06	1.12	1.19	1.25	1.32	1.39	1.45	1.52	1.58						
24	0.71	0.75	0.82	0.88	0.95	1.02	1.09	1.16	1.22	1.29	1.36	1.43	1.50	1.56	1.63						
25	0.74	0.77	0.84	0.91	0.98	1.05	1.12	1.19	1.26	1.33	1.40	1.47	1.54	1.61							
26	0.76	0.79	0.86	0.94	1.01	1.08	1.15	1.22	1.30	1.37	1.44	1.51	1.58								
27	0.78	0.81	0.89	0.96	1.04	1.11	1.18	1.26	1.33	1.41	1.48	1.55	1.63								
28	0.80	0.84	0.91	0.99	1.06	1.14	1.22	1.29	1.37	1.44	1.52	1.60									
29	0.82	0.86	0.94	1.01	1.09	1.17	1.25	1.33	1.40	1.48	1.56										
30	0.84	0.88	0.96	1.04	1.12	1.20	1.28	1.36	1.44	1.52	1.60										
31	0.86	0.90	0.98	1.07	1.15	1.23	1.31	1.39	1.48	1.56											
32	0.88	0.92	1.01	1.09	1.18	1.26	1.34	1.43	1.51	1.60											
33	0.90	0.95	1.03	1.12	1.20	1.29	1.38	1.46	1.55												
34	0.92	0.97	1.06	1.14	1.23	1.32	1.41	1.50	1.58												
35	0.95	0.99	1.08	1.17	1.26	1.35	1.44	1.53	1.62												
36	0.97	1.01	1.10	1.20	1.29	1.38	1.47	1.56													
37	0.99	1.03	1.13	1.22	1.32	1.41	1.50	1.60													
38	1.01	1.06	1.15	1.25	1.34	1.44	1.54														
39	1.03	1.08	1.18	1.27	1.37	1.47	1.57														
40	1.05	1.10	1.20	1.30	1.40	1.50	1.60														
41	1.07	1.12	1.22	1.33	1.43	1.53															
42	1.09	1.14	1.25	1.35	1.46	1.56															
43	1.11	1.17	1.27	1.38	1.48	1.59															
44	1.13	1.19	1.30	1.40	1.51	1.62															
45	1.16	1.21	1.32	1.43	1.54																
46	1.18	1.23	1.34	1.46	1.57																
47	1.20	1.25	1.37	1.48	1.60																
48	1.22	1.28	1.39	1.51	1.62																
49	1.24	1.30	1.42	1.53																	
50	1.26	1.32	1.44	1.56																	

APPENDIX H
OXYGEN PARTIAL PRESSURE TABLE

Oxygen Partial Pressure Table

	Nitrox mix 62	64	66	68	70	72	74	76	78	80	82	84	86	88	90	92	94	96	98	100
1	0.68	0.70	0.73	0.75	0.77	0.79	0.81	0.84	0.86	0.88	0.90	0.92	0.95	0.97	0.99	1.01	1.03	1.06	1.08	1.10
2	0.74	0.77	0.79	0.82	0.84	0.86	0.89	0.91	0.94	0.96	0.98	1.01	1.03	1.06	1.08	1.10	1.13	1.15	1.18	1.20
3	0.81	0.83	0.86	0.88	0.91	0.94	0.96	0.99	1.01	1.04	1.07	1.09	1.12	1.14	1.17	1.20	1.22	1.25	1.27	1.30
4	0.87	0.90	0.92	0.95	0.98	1.01	1.04	1.06	1.09	1.12	1.15	1.18	1.20	1.23	1.26	1.29	1.32	1.34	1.37	1.40
5	0.93	0.96	0.99	1.02	1.05	1.08	1.11	1.14	1.17	1.20	1.23	1.26	1.29	1.32	1.35	1.38	1.41	1.44	1.47	1.50
6	0.99	1.02	1.06	1.09	1.12	1.15	1.18	1.22	1.25	1.28	1.31	1.34	1.38	1.41	1.44	1.47	1.50	1.54	1.57	1.60
7	1.05	1.09	1.12	1.16	1.19	1.22	1.26	1.29	1.33	1.36	1.39	1.43	1.46	1.50	1.53	1.56	1.60	1.63	1.67	1.70
8	1.12	1.15	1.19	1.22	1.26	1.30	1.33	1.37	1.40	1.44	1.48	1.51	1.55	1.58	1.62	1.66	1.69	1.73	1.76	
9	1.18	1.22	1.25	1.29	1.33	1.37	1.41	1.44	1.48	1.52	1.56	1.60	1.63	1.67						
10	1.24	1.28	1.32	1.36	1.40	1.44	1.48	1.52	1.56	1.60	1.64	1.68	1.72	1.76						
11	1.30	1.34	1.39	1.43	1.47	1.51	1.55	1.60	1.64											
12	1.36	1.41	1.45	1.50	1.54	1.58	1.63	1.67	1.72											
13	1.43	1.47	1.52	1.56	1.61	1.66														
14	1.49	1.54	1.58	1.63																
15	1.55	1.60	1.65																	
16	1.61																			

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