

# Portable respiratory support for emergency situations

## Can SCUBA Diving kit be easily adapted to provide it?

This team are looking to open source these ideas, check feasibility & get support to implement

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### Background

- Covid-19 is causing unprecedented need for ventilation, even with increased manufacture will demand be met? If hospitals are at capacity improvised sites may need to be used, without plumbed oxygen. **While we may not be at the point to need to think quite this laterally –we may yet reach it.** There are 3 levels of respiratory support solution discussed, and while they may not currently be suitable for a hospital, they may be ideas which could prove useful in extreme or mass recovery situations (e.g. use of Stadiums to house patients).

### Current Situation

- Engineer & experienced PADI SCUBA instructor (I.Jones) identified the possibility of adapting dive kit to create portable emergency respiratory support, he is investigating this with other engineers and divers.
- The basis of the idea is founded in the use of Nitrox for emergency dive situations to provide extra oxygen to a sick diver when the oxygen tanks run out in a remote location.
- Looking to open source these ideas, check feasibility & get support to implement** – in the ethos of when in WWII and manufacturing was flat out building spitfires - the UK government called on the furniture industry to make a plane that didn't stretch existing supply lines – they invented the Mosquito one of the fastest operational aircraft in the world in 1941. We hope to suggest a supporting source without impacting supply lines.

### Objective

- Suggest possible solutions for emergency respiratory support
- Extend provision of elevated oxygen to improvised hospitals using existing materials
- Augment the supply of O2 without adding to the burden of existing industrial plants.
- Convert SCUBA gear & industry to support medical response – use of Enriched air nitrogen 36% O2 gas supplied in compressed gas scuba tanks.
- Adaptation of common scuba gear, so that it could be sourced or donated to all 3 levels of respiratory support below

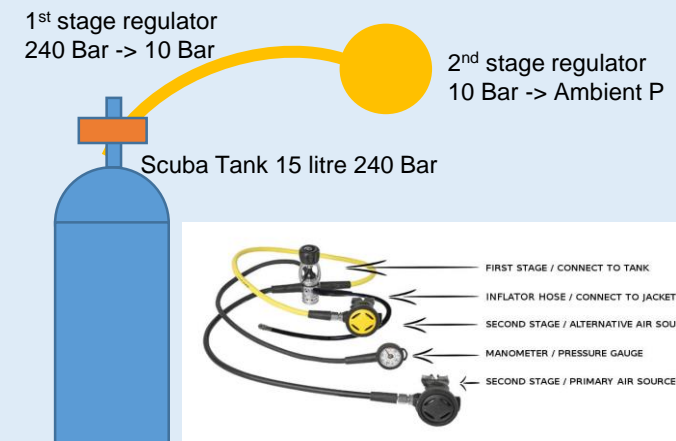
### Potential Solutions to explore – further detail on other slides

- Support for conscious breathing** - Design attachment to fit a medical mask to SCUBA rig for conscious breathing to increase the number of O2 sets available. Once designed & made – simple to adapt.
- Modify SCUBA equipment to be a CPAP** with 36% O2, independent of power & can provide elevated O2 levels. Once designed & made quick to implement.
- Full ventilator – longer term solution.** Use scuba tank & regulator adjusted for positive pressure with added in line module. Mechanical or Electromechanical solutions to consider.
- Completely alternative premise – negative pressure ventilation – iron lung** – could the technology from old Polio epidemics & iron lung technology be resurrected?

### Potential Benefits

- Portable & independent from plumbed hospital oxygen.
- Doesn't pull on existing supply lines. Reduces burden on commercial O2 plants, rental cylinder stocks and other manufacturers. Privately held equipment available today.
- Industry of Scuba technicians available to support to fill tanks & modify regulators.
- Use of Nitrox as a resource multiplier, even just free flow flow masks could help capacity.
- Can be made locally using same technology as Personal Oxygen Concentrators technology uses i.e. using Nitrogen membrane filters to concentrate and compress the Nitrox mix and store it in large volumes & delivered with existing equipment.
- Minimal training required for some solutions, 10 mins to learn regulator setup.

### SCUBA gear basic layout



**Sometimes what you're looking for is already there**

– Aretha Franklin

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# Supporting Information

**With thanks to the following (and others) for ideas**

Ian Jones CEng MIMechE (PADI, BSAC)  
Dr. Barry Doyle BEng PhD  
Susan Jones Meng CEng MIET MWES  
Verma Vitales BEng  
Others to follow

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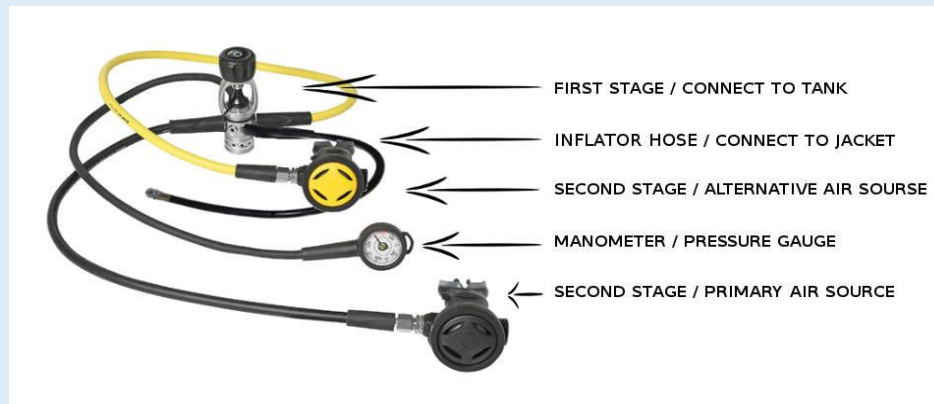
### Supporting information – Basic layout of SCUBA gear

#### SCUBA gear basic layout

1<sup>st</sup> stage regulator  
240 Bar -> 10 Bar

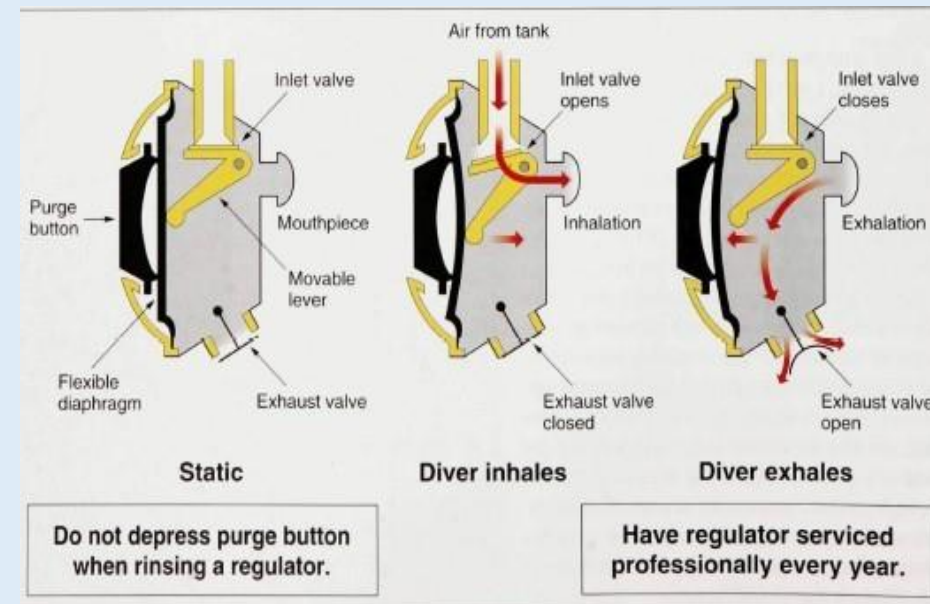
2<sup>nd</sup> stage regulator  
10 Bar -> Ambient P

Scuba Tank  
15 litre 240 Bar



#### Use of Scuba gear as a basis for respiratory support and designs – ideally with minimum modification

- Portability,
- Independence from plumbed in O<sub>2</sub> in a hospital,
- Wide availability,
- Entire industry of Scuba Techs (currently unemployed) who can support.



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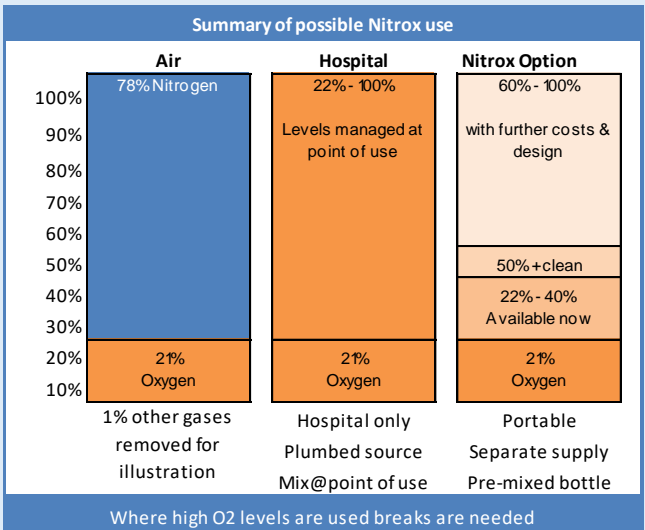
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### Supporting information – Use of Enriched Air Nitrox (EAN) aka Nitrox

Using Nitrox even just for free flow Masks could greatly increase the capability of giving Oxygen to massive numbers of people. It can be made locally using the same technology as Personal Oxygen Concentrators use i.e. using Nitrogen membrane filters to concentrate and compress the Nitrox mix and store it in large volumes & deliver with existing equipment.

#### Key Points

- i. **Nitrox is oxygen enriched air which is a mix of Nitrogen and Oxygen but with a higher oxygen percentage than air.** In hospitals when patients are breathing from an oxygen mask they are sometimes breathing a low flow of oxygen to raise the amount in their blood. e.g. they may be getting 4 lpm of Oxygen while their natural respiration rate is 10-12 lpm so they are getting about 40%-50% oxygen mix – rather than 100%.
  - Instead of using pure oxygen from a bottle (which could be rare). They may be able to use a pre-blended Nitrox mixture with adapted SCUBA equipment. They could still have up to 40%-50%, without drawing on the scarce supply of medical equipment, it would be stand alone (makeshift hospital without plumbed in O2), and using equipment that already exists in private hands. A 15 litre dive tank could last up to 5 hours at this flowrate (~3.5hrs for a 12litre lighter tank).
  - Any mix of Nitrox from 20% - 40% could be used, a typical diving mix is EAN36 i.e. 36% oxygen. In some cases higher oxygen rates could be achieved but these require more specialist equipment - not as readily available but they do exist. One method of producing Nitrox uses membranes that filter the air and concentrate the oxygen which would prevent drawing on scarce oxygen supplies.
- ii. **When O2 >40% touches anything it requires great care to use materials that are O2 Cleaned** (no greases / anything combustible) and O2 Compatible Materials (plastics, metals that can't combust). **However Nitrox 36% does not require special equipment**, it's low enough that risk of O2 saturated bedsheets should not be high.
- iii. **Minimal training** - A doctor could prescribe O2 mix required, then a Scuba-tech fills the tank to that %. They analyse it with a simple hand analyser used currently by every dive centre for Nitrox, and marks the tank. So the mix is pre-blended.
- iv. **To mix Nitrox many fill centres exist which use several methods** – The BEST is a nitrogen separating membrane (this technology is used at a small scale in Personal Oxygen Concentrators), which **can MAKE Nitrox from normal air enriching the air up to about 50% Nitrox WITHOUT STRETCHING EXISTING O2 infrastructure**. Even where this isn't available there is a whole industry of dive shops dedicated to filling peoples' dive tanks with Nitrox every weekend that is currently idle with plenty of capacity for thousands of people  
<http://www.nitroxmadeeasy.com/Methods.htm>
  - There are other ways to mix and blend nitrox that different dive shops will have set up. Where possible the best way is Oxygen Concentrating Filter Membrane as it doesn't need commercial oxygen. Please note that different methods will have different requirements.
  - Using Nitrox even just to drive free-flow Masks means that the capability of giving Oxygen to massive numbers of people is increased without needing to use up the capacity of commercial O2 Plants (BOC, Air Liquide etc.) that create pure O2 and only have a limited stock of Cylinders
- v. **Another option could be to look into the use of welding oxygen**



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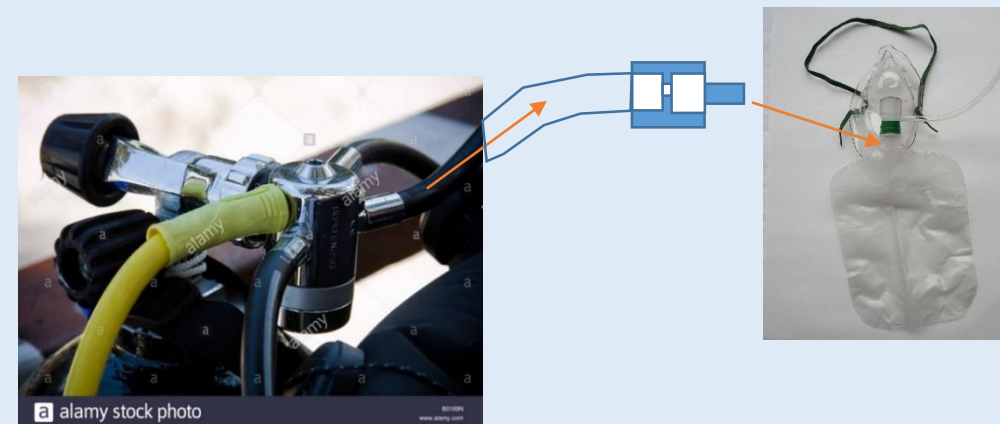
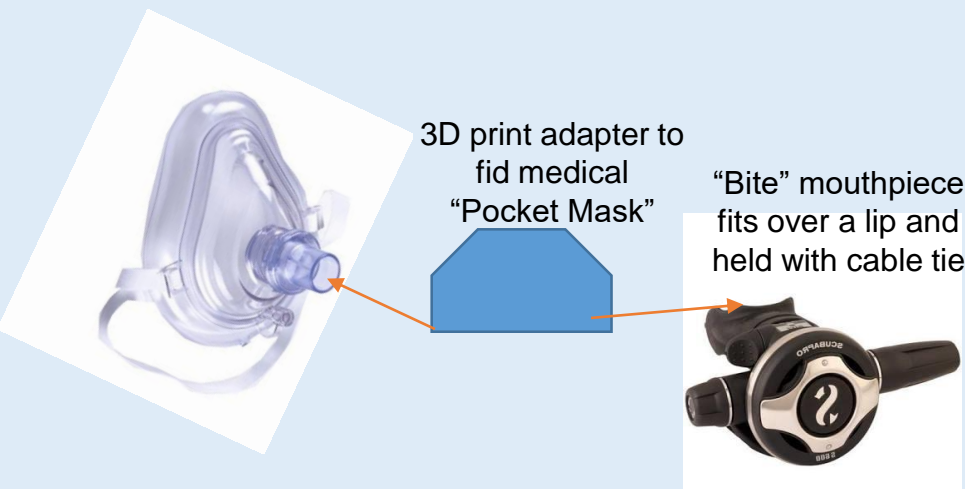
### Supporting information – Possible Solution 1 - **Support for conscious breathing**

To increase the number of O2 sets available design attachment to fit a medical mask to SCUBA rig for conscious breathing . Once designed & made – simple to adapt. Increase # of O2 sets for conscious breathing casualties – this is the simplest use and can be done in a day or two - Use of SCUBA rig plus some simple attachments to fit a medical mask instead our bite mouthpiece to Augment Oxygen constant flow units – e.g. in Makeshift hospitals such as hotels and even at home and independent of places with Plumbed in O2 or to extend the number of available O2 sets once Pure O2 tanks have run out.

### Key Points

**Provide Nitrox on demand** – 3D print adaptor to put pocket mask onto a 2<sup>nd</sup> stage scuba regulator. Patient breathes normally and gets 36% O2, BUT it doesn't waste it with constant flow so a single tank could last longer while automatically giving enough flow – For conscious casualties.  
This is super simple to make and could, in the time necessary to 3D print a small adaptor and cable tie it to the regulator – provide a unit.

**Constant flow of nitrox** – 3D print adaptor to put something in between 2nd stage. Either purge button of regulator kept down and then adjustable valve used to regulate flow OR a piece is made (e.g. orifice plate) to bolt into any of the ports on the 1st stage (10 Bar) to provide a variable constant flow to a mask. OR instead of a variable needle valve an orifice plate could be set for different flow rates and plugged in e.g. 10 lpm / 12 lpm / 15 lpm – This would be machined due to the pressure needed.



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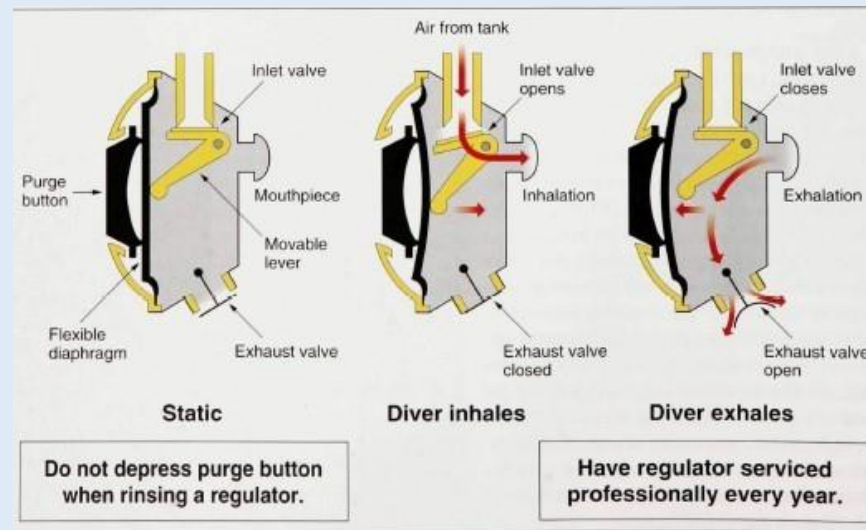
### Supporting information – Possible Solution 2 - **Modify SCUBA equipment to be a CPAP**

*With 36% O<sub>2</sub>, independent of power & can provide elevated O<sub>2</sub> levels. Once designed & made quick to implement.*

Modify SCUBA Rig to be a CPAP – Positive pressure flow, but also a CPAP that is independent of power AND can provide elevated O<sub>2</sub> levels which an electric CPAP can't do. Could be done with a simple adjustment to regulator, plus gluing the exhaust valve shut and adding a spring controlled back pressure exhaust valve. This could also be relatively quickly implemented in a few days once we work out how.

### Key Points

#### Current regulator



#### Possible Method

1. Adjust inlet pressure to be higher so valve free flows slightly, if out of mouth
2. Replace simple exhaust mushroom valve with a sprung valve – which can be adjusted for back pressure
3. Use adaptor shown in 3a to go to a CPAP mask and harness. – with mask off face free-flows, mask in place pressure builds up to exhaust level and reg seals (adjust both inlet and exhaust), user breathes in breathes in with about 8 to 20 cm H<sub>2</sub>S positive pressure.

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### Supporting information – Possible Solution 3 - Full ventilator – longer term solution

*Use scuba tank & regulator adjusted for positive pressure with added in line module. Mechanical or Electromechanical solutions to consider.*

Use scuba tank and regulator (1st stage, or possibly both stages, adjusted for positive pressure with a module added in line to make a full ventilator – Could be run off scuba cylinder (air, enriched air nitrox, oxygen (but requires O2 clean and O2 service materials).

## Key Points

### Mechanical Ventilator

Using Compressed air as sole power source develop from Positive pressure demand regulator resuscitator idea like Oxy-Viva3 / O2 But developed from this to include volume metering or a mechanical feedback system to dump pressure once inflated until lungs empty and ready to start again (exactly how unsure – pop-off valve or exhalation bag which when full triggers valve again ? – Portable, not reliant on plumbed Oxygen or Power. Based on this – <https://otwo.com/oxygen-therapy-resuscitation-kits/demand-valve-resuscitator/> ↓

### Electro Mechanical Ventilator

Add Modules to make Mech / Elec Ventilator – Uses portable compressed air / Nitrox / Oxygen – no need to pump uses compressed gas to ventilate – Electromechanical control module (Solenoid, pop-off valve, pressure sensor) uses 240V

## Demand Valve Resuscitator

Demand Valve  
Resuscitator



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