



Pulse Oxygen Systems in Aviation

All supplemental oxygen systems used to prevent hypoxia in aviation operations function by increasing the partial pressure of oxygen in a user's lungs to improve the level of blood oxygen saturation (SaO₂). Pulse oxygen systems offer an effective means to optimize system efficiency. This is important in order to reduce the size and weight of the oxygen system or to increase the time the system will offer protection.

Simple supplemental oxygen systems act to increase the concentration of oxygen in the air the user inhales throughout the inhalation cycle by mixing a constant flow of pure oxygen into the air the user is breathing, thus increasing the partial pressure of oxygen in the user's lungs. This type of delivery system utilizes oxygen in a very inefficient manner. Pulse oxygen systems achieve efficiency by increasing the partial pressure of oxygen in only the most effective parts of the lungs as opposed to the entire respiratory tract. Pulse oxygen systems deliver a "pulse" of oxygen during the initial portion of the inhalation cycle and, therefore, deliver the highest concentration of oxygen to the portions of the lungs that actually transfers oxygen into the blood. The balance of the inhalation cycle has a lower partial pressure of oxygen than the initial "pulse" and fills the portions of the lungs that do not transfer oxygen into the blood. This results in adequate oxygenation of the body while using less oxygen.

Hypoxia occurs when the oxygen saturation in the blood (SaO₂) falls below a particular level necessary to maintain physiological and cognitive abilities. The impacts can vary between individuals and is dependent on how low the SaO₂ actually drops and how long the condition remains. Typical impacts and symptoms of hypoxia are a feeling of well being or euphoria, degradation of motor coordination and vision and dampening of cognitive abilities to the point of being unable to follow very simple directions. If the SaO₂ drops low enough, injury or death can occur.

There are two key variables related to the partial pressure of oxygen being transferred from the lungs into the blood. The first is the percentage of oxygen or concentration of oxygen in the inspired gas. The second is the ambient pressure that drives the transfer of oxygen to the blood in the lungs. The partial pressure is affected and hypoxia can be induced by changes to either or both of these variables. Normal ambient air contains roughly 21% oxygen. Decreasing the concentration of oxygen in the inspired air will induce hypoxia. This can occur in confined spaces or contaminated environments. The ambient air pressure at sea level is roughly 760 mm Hg. Ambient air normally contains 21% oxygen and, therefore, the partial pressure of oxygen in the air at sea level is roughly 159 mm Hg (760 mm Hg x 21%). Decreasing the partial pressure of oxygen in the inspired air will also induce hypoxia. This occurs as the altitude above sea level is increased.

Supplemental oxygen is often used to prevent the effects of hypoxia and maintain SaO₂ levels. There are various delivery systems to provide supplemental oxygen. To better understand the differences between these systems, it is important to understand basic pulmonary physiology. The transfer of oxygen to the bloodstream occurs in the alveoli, which line the inner walls of the lung. Much of the volume of the inspired gas, referred to as tidal volume, remains in the trachea, bronchia, and other "dead spaces" in the lungs where oxygen transfer does not occur. The only oxygen that enters the bloodstream is the oxygen in the air that is in contact with the alveoli. The air in contact with the alveoli is generally the air that is first inspired during inhalation. The rest of the air



inspired during inhalation fills the “dead space” in the lungs, bronchia and trachea. Because of this, different delivery devices can result in different SaO₂ levels while consuming the same amount of oxygen.

When the mechanism of the transfer of oxygen from the inhaled gas to the bloodstream is understood, the inefficiencies of simple supplemental oxygen systems, which enrich all the inhaled air with oxygen, become apparent. It is well known that pulse dosing of oxygen significantly improves SaO₂ performance by delivering 100% oxygen, directly into the most efficient portions of the lungs in terms of oxygen transfer. For example, a continuous flow supplemental oxygen mask without a reservoir or re-breather bag delivers a mix of ambient air and supplemental oxygen in every breath. This improves the SaO₂ value of the individual, but because the same concentration of oxygen is added to the air delivered to the alveoli as to the respiratory “dead spaces”, a large amount of the supplemental oxygen, added to the inspired air, is not utilized by the body.

Pulse oxygen systems, because they deliver higher concentrations of oxygen to the air in contact with the alveoli than they deliver to the air entering the respiratory “dead spaces”, utilize supplemental oxygen far more efficiently. There are at least two different technologies employed to deliver a pulsed dose of oxygen. They are pneumatic pulse systems and electronic pulse systems.

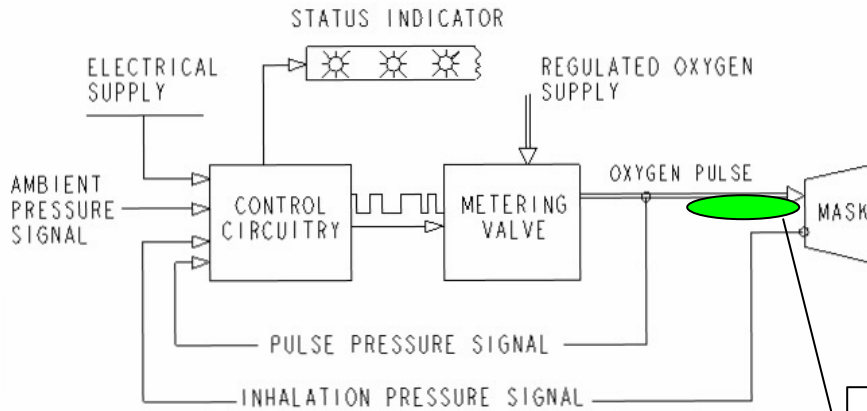
The first is extensively used in the aviation industry and may be familiar to everyone as the yellow cup passenger mask. Although this mask delivers a “constant flow” of oxygen, the mask is actually a phased dilution mask that delivers a pulse of 100% oxygen at the start of the inhalation cycle and delivers a small amount of oxygen mixed with ambient air for the balance of the inhalation. This is accomplished by using a reservoir bag to collect a relatively small amount of pure oxygen, which flows to the mask during the exhalation cycle, and by the phased opening of valves in the face mask to allow the accumulated 100% oxygen to enter the lungs first.

The second technology is electronic pulse systems first used in the medical fields. These systems work in a way similar to the pneumatic system but utilizing an electronically initiated pre-set pulse of oxygen during the first part of the inhalation and then stopping the oxygen flow to allow the balance of the inhalation to be ambient air. This is accomplished through electronically sensing the breathing cycle and timing the oxygen pulse to start with the start of inhalation.

Both the pneumatic pulsed oxygen systems and the electronically pulsed oxygen systems are far more efficient than simple constant flow supplemental oxygen systems. Pulsed systems allow the mass of oxygen supplied to an individual to be reduced, without reducing the blood oxygen saturation of the individual.



Electronic Pulse



Bolus of 100% oxygen delivered first to the mask and the balance of the inhalation cycle consists of ambient air

Pneumatic Pulse (Phased Dilution)

