

Time of Useful Consciousness

Time of useful consciousness (TUC) is defined as the amount of time an individual is able to perform flying duties efficiently in an environment of inadequate oxygen supply. It is the period of time from the interruption of the oxygen supply or exposure to an oxygen-poor environment to the time when useful function is lost, and the individual is no longer capable of taking proper corrective and protective action. It is not the time to total unconsciousness. The TUC has also been called Effective Performance Time (EPT). At the higher altitudes, the TUC becomes very short; considering this danger, the emphasis is on prevention rather than cure.

Medical analysis and variations

There are many individual variations of hypoxia, even within the same person. Generally, old age tends to reduce the efficiency of the pulmonary system, and can cause the onset of hypoxia symptoms sooner. Smoking drastically reduces oxygen intake efficiency, and can have the effect of reducing tolerance by 1,000-2,000 meters (approx. 3,000-6,000 feet). Hypoxia can be simulated in an altitude chamber. This can be useful for identifying individual symptoms of hypoxia, along with rough estimates of the altitude that causes problems for each person. Identifying symptoms is often helpful for self-diagnosis in order to realize when altitude should be reduced. Although the times in the table below are often called average TUCs, an average failure is meaningless to a person who has a shorter TUC.

The table below reflects various altitudes with the corresponding average TUC:

Altitude in Flight level	Time of Useful Consciousness	Altitude in meters	Altitude in feet
FL 150	30 min or more	4,572 m	15,000
FL 180	20 to 30 min	5,486 m	18,000
FL 220	5-10 min	6,705 m	22,000
FL 250	3 to 5 min	7,620 m	25,000
FL 280	2.5 to 3 mins	8,534 m	28,000
FL 300	1 to 3 mins	9,144 m	30,000
FL 350	30 sec to 60 sec	10,668 m	35,000
FL 400	15 to 20 sec	12,192 m	40,000
FL 430	9 to 15 sec	13,106 m	43,000
FL 500 and above	6 to 9 sec	15,240 m	50,000

These times have been established from observations over a period of years and are for an individual at rest. Any exercise will reduce the time considerably. For example, usually upon exposure to hypoxia at FL 250, an average individual has a TUC of 3 to 5 minutes. The same individual, after performing 10 deep knee bends, will have a TUC in the range of 1 to 1.5 minutes.

A rapid decompression can reduce the TUC by up to 50 percent caused by the forced exhalation of the lungs during decompression and the extremely rapid rate of ascent

http://en.wikipedia.org/wiki/Time_of_Useful_Consciousness

Explosive Decompression

The discussion here has focussed only on exposure to vacuum. However, in general the action of being exposed to vacuum will also involve a rapid decompression. This event is generally known as "explosive decompression," and apart from the simple effect of vacuum on the body, the explosive decompression event itself will be hazardous. As noted, explosive decompression will be particularly bad if the decompression subject attempts to hold his or her breath during decompression.

In *The USAF Flight Surgeon's Guide*, Fischer lists the following effects due to mechanical expansion of gases during decompression.

1. Gastrointestinal Tract During Rapid Decompression.

One of the potential dangers during a rapid decompression is the expansion of gases within body cavities. The abdominal distress during rapid decompression is usually no more severe than that which might occur during slower decompression. Nevertheless, abdominal distention, when it does occur, may have several important effects. The diaphragm is displaced upward by the expansion of trapped gas in the stomach, which can retard respiratory movements. Distention of these abdominal organs may also stimulate the abdominal branches of the vagus nerve, resulting in cardiovascular depression, and if severe enough, cause a reduction in blood pressure, unconsciousness, and shock. Usually, abdominal distress can be relieved after a rapid decompression by the passage of excess gas.

2. The Lungs During Rapid Decompression.

Because of the relatively large volume of air normally contained in the lungs, the delicate nature of the pulmonary tissue, and the intricate system of alveolar airways for ventilation, it is recognized that the lungs are potentially the most vulnerable part of the body during a rapid decompression. Whenever a rapid decompression is faster than the inherent capability of the lungs to decompress (vent), a transient positive pressure will temporarily build up in the lungs. If the escape of air from the lungs is blocked or seriously impeded during a sudden drop in the cabin pressure, it is possible for a dangerously high pressure to build up and to overdistend the lungs and thorax. No serious injuries have resulted from rapid decompressions with open airways, even while wearing an oxygen mask, but disastrous, or fatal, consequences can result if the pulmonary passages are blocked, such as forceful breath-holding with the lungs full of air. Under this condition, when none of the air in the lungs can escape during a decompression, the lungs and thorax becomes over-expanded by the excessively high intrapulmonic pressure, causing actual tearing and rupture of the lung tissues and capillaries. The trapped air is forced through the lungs into the thoracic cage, and air can be injected directly into the general circulation by way of the ruptured blood vessels, with massive air bubbles moving throughout the body and lodging in vital organs such as the heart and brain. The movement of these air bubbles is similar to the air embolism that can occur in SCUBA diving and submarine escape when an individual ascends from underwater to the surface with breath-holding. Because of lung construction, momentary breath-holding, such as swallowing or yawning, will not cause sufficient pressure in the lungs to exceed their tensile strength.

3. Decompression Sickness.

(also known as "Bends")

Because of the rapid ascent to relatively high altitudes, the risk of decompression sickness is increased. Recognition and treatment of this entity remain the same as discussed elsewhere in this publication.

4. Hypoxia.

While the immediate mechanical effects of rapid decompression on occupants of a pressurized

cabin will seldom be incapacitating, the menace of subsequent hypoxia becomes more formidable with increasing altitudes. The time of consciousness after loss of cabin pressure is reduced due to offgassing of oxygen from venous blood to the lungs. Hypoxia is the most immediate problem following a decompression.

5. Physical Indications of a Rapid Decompression.

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- (a) Explosive Noise. When two different air masses make contact, there is an explosive noise. It is because of this explosive noise that some people use the term explosive decompression to describe a rapid decompression.
- (b) Flying Debris. The rapid rush of air from an aircraft cabin on decompression has such force that items not secured to the aircraft structure will be extracted out of the ruptured hole in the pressurized compartment. Items such as maps, charts, flight logs, and magazines will be blown out. Dirt and dust will affect vision for several seconds.
- (c) Fogging. Air at any temperature and pressure has the capability of holding just so much water vapor. Sudden changes in temperature or pressure, or both, change the amount of water vapor the air can hold. In a rapid decompression, temperature and pressure are reduced with a subsequent reduction in water vapor holding capacity. The water vapor that cannot be held by the air appears in the compartment as fog. This fog may dissipate rapidly, as in most fighters, or not so rapidly, as in larger aircraft.
- (d) Temperature. Cabin temperature during flight is generally maintained at a comfortable level; however, the ambient temperature gets colder as the aircraft flies higher. If a decompression occurs, temperature will be reduced rapidly. Chilling and frostbite may occur if proper protective clothing is not worn or available.
- (e) Pressure.

Cabin Decompression and Hypoxia

by Mark Wolff -- Source: PIA Air Safety Publication

At the hypobaric chamber at the RAAF base in Edinburgh several hundred air force pilots each year get to check out their reactions to depressurization and the effects of hypoxia.

The chamber is set to an altitude of 25,000 feet, which gives a time of useful consciousness of around three to five minutes.

Up to ten pilots at a time sit in the chamber tensely-waiting for the depressurization, which starts at 8,000 feet and moves to 25,000 feet in just 10 seconds. Each clutches a checklist of tasks they are to perform. Each is determined to remain conscious and capable for as long as possible.

After about two minutes one of the subjects is asked to repeat back a number. Inevitably the subject is unable to do so. In fact, most don't remember being asked.

Trying to go through the checklist the pilots tend to exhibit one of two kinds of behaviour; they are either "page flickers" or "fixators". The page flickers will just sit there mindlessly flipping through the checklists while the fixators will just stare at one page. They are "passengers in their own bodies". These two quite different behavioural responses to rapid depressurization hint at the variation in individual responses to lack of oxygen, or hypoxia.

Hypoxia is a threat to safety for all pilots operating pressurised aircraft and for unpressurised aircraft that fly at an altitude of 10,000 feet or above --- the legal ceiling above which oxygen must be used by flight crew members in unpressurised aircraft.

Some individuals with reduced lung function will become hypoxic well below this level. This includes people with emphysema, industrial lung disease, certain forms of anaemia, ischaemic heart disease and even mild degrees of heart failure.

If you smoke, you may have already reduced your oxygen intake by a significant factor. Avoid smoking before and during flight.

The Nature of Hypoxia:

The term hypoxia translates from the Latin to mean below normal (hypo) oxygen (oxia). It is a physiological state in which tissues are deprived of adequate oxygen, and organs such as the brain, eyes, ears, lungs and heart are adversely affected.

When an aircraft undergoes rapid decompression above around 35,000 feet, the time of useful consciousness for crew may be 30 seconds or less, depending on the altitude (see table).

Time of Useful Consciousness	
Altitude (feet)	Consciousness
15,000	30 minutes or more
18,000	20-30 minutes
22,000	5-10 minutes
25,000	3-5 minutes
28,000	2.5-3 minutes
30,000	1-3 minutes
35,000	30-60 seconds
40,000	15-20 seconds
45,000	9-15 seconds
50,000	6-9 seconds
Pressure and Altitude	

Altitude (feet)	Pressure		Temperature °C
	hpa	lb/in ²	
0	1013.25	14.70	+15.0
5,000	843.1	12.23	+5.1
10,000	696.8	10.11	-4.8
15,000	571.8	8.29	-14.7
20,000	465.6	6.75	-24.6
25,000	376.0	5.45	-34.5
30,000	300.9	4.36	-44.4
35,000	238.4	3.46	-54.2
40,000	147.5	2.72	-56.5

At lower altitudes the time of useful consciousness maybe longer, but subtle effects may still impair your functioning. The more rapid the decompression, the faster the symptoms of hypoxia will appear.

Crew surprise and perhaps lack of familiarity with decompression can contribute to dangerous delays in appropriate response. Research by the US Air Force shows 80 per cent of pilots with no experience of decompression wait as long as 15 seconds to respond correctly to a loss of cabin pressure.

Because of the insidious effects of hypoxia on judgement and reasoning, the correct response to loss of cabin pressure is always to don the oxygen mask - immediately. That's the only way you can be sure that you will make the right choices.

The death of US golfer Payne Stewart in October 1999 and two recent Australian incidents - one in a RAAF King Air and the other in a civilian King Air - have put the spotlight on the issue of hypoxia. While the RAAF incident is known to have involved hypoxia, we may never know the contributing factors to the civilian accidents.

In the RAAF incident, shortly after the aircraft was levelled at the planned cruising level of FL250, the right-hand seat passenger noticed that the pilot was acting erratically while manipulating the Global Positioning System (GPS). Soon after, the pilot slumped over the controls and turned a curious shade of blue.

Fortunately the passenger (who was a pilot but was not endorsed on type) was able to take control of the aircraft. He descended and, after having some trouble locating the communications panel, declared an emergency. He was extremely lucky - he should first have donned his own oxygen mask to ensure he was able to function correctly.

Preliminary reports from US investigators reveal the cockpit voice recorder on Payne Stewards aircraft contained no voices, but that there were sounds consistent with various alarms (cabin altitude / low pressure, stall warnings). Speculation is that the accident may have been related to decompression early in the flight and that the pilots and passengers may have been incapacitated by the low level of oxygen. Pilots of military aircraft assigned to follow the Learjet after it failed to respond to ATC transmissions and climbed above its assigned altitude said the windows were covered with ice and that there was no sign of flight control movement.

The flight ended when the aircraft dived into the ground at the time that the Learjet's fuel supply would have been exhausted.

Symptoms and Signs:

The symptoms of hypoxia are similar to alcohol. Like alcohol, there can be a personality change.

The first signs include both mental and physical effects. Mentally there can be a loss of judgement, self-criticism and short-term memory. This can be accompanied by an increase in reaction time and a kind of mental "tunnel vision" similar to the fixation on the GPS unit experienced by the RAAF King Air pilot. You may even become euphoric.

The physical effects include muscular incoordination and an impairment of colour, night and peripheral vision. Hearing also deteriorates. You may experience hot flushes and turn bluish at the extremities (cyanosis). Rapid breathing or hyperventilation is one of the early physical signs. But because hypoxia impairs judgement, you may not notice loss of vision and hearing or other physical or mental signs. It's the opposite of "You don't know what you've got until you lose it". More like, "You don't know what you've lost until you get it back".

Simple tasks become extraordinarily difficult and performance fails. As hypoxia continues, you become semiconscious. After you lose consciousness entirely, you have only minutes to live, depending on the altitude. There are many factors which affect the tolerance to hypoxia. The faster the rate of ascent, the quicker the onset.

Apart from smoking and lung disease, you may be more susceptible if you are ill, stressed, unfit, fatigued, under the influence of drugs or are suffering from a hangover. There is a high degree of individual variation in the response to hypoxia. Some people may hyperventilate and turn blue immediately; others may not. In a small number of individuals, unconsciousness may occur before any other symptom. (See footnotes for [variability of symptoms](#))

Recovery Procedures:

Don your oxygen mask immediately, select 100 percent oxygen if you have differential settings, then descend to 10,000 feet or below, terrain permitting. You may find that you feel worse immediately after putting your oxygen mask on. Do not take it off. This is called the oxygen paradox and you will feel better after about one minute.

Breathe at a normal rate and depth. Declare an emergency, and land as soon as possible. After recovery from an episode of hypoxia, some symptoms may persist. These include headache, fatigue and lethargy.

Note that if you have been in an aircraft which has been decompressed, you should not fly again the same day because you will increase your risk of decompression illness. Decompression illness (or the bends) can be incapacitating, particularly if nitrogen bubbles enter the brain.

You should also use oxygen if you detect fumes or smoke. Again, set the oxygen at 100 per cent in order to prevent any toxins from the fumes or smoke entering the system.

Prevention:

The key to prevention is twofold. First, you need to follow your flight manual prompts to accurately set and monitor cabin pressure. As soon as the cabin pressure drops below recommended levels you should take preventative action.

If warning systems indicate problems with cabin pressure, you must immediately don your oxygen mask and descend if terrain permits. It pays to know your equipment, because it can take some time to put the oxygen mask on. Make sure you know how to use the masks, practise using them, and time yourself in putting them on.

There are traps with checklists which you must guard against. You should understand your pressurization and oxygen systems, and fill in the gaps in your checklists so that you are sure of what to do in an emergency. For example, if you are over ocean and have an uncontained engine failure which leads to depressurization, you will want 20,000 feet or so to retain range. But do you have enough oxygen? Do you know how to calculate that?

Sixty per cent of corporate jet depressurizations are caused by uncontained engine failures. Most others are caused by doors or windows departing the aeroplane. Even if you set up and use checklists properly, things can still go wrong.

A checklist is a skill based action which means it is a stored pattern of preprogrammed activity. The greater the skill level, the greater the chance of "strong, but wrong" error. All it takes is a change to a well practised routine and a missed attentional check. The intention may be correct, but the action may be wrong.

You could get it wrong through inattention, jisti action or preoccupation. That's why checklists need to be monitored carefully as they are the last line of defence.

If you are halfway through a checklist, and are interrupted, go back to the beginning and start again. Be sure, however, not to introduce new errors by operating things like switches which have already been activated correctly.

The one thing that you should not do first is to start working out what's gone wrong. That is, you should not be problem solving and planning on line. This is hard to do. If you know the aircraft well and you have a pressurization warning going off, but the cabin pressure indicator seems OK, you should not be trying to work out which is correct. You must immediately put on the oxygen mask, descend and then look to problem solving.

The reason you should not work the problem early is that hypoxia interferes with your ability to solve problems and limits your time of useful consciousness. Get the oxygen right first, then ponder your situation. If you go into problem solving mode you will lose valuable time. You should take the course of least regret.

From a human factors point of view, once you notice a pressurization warning, you need to quickly don your oxygen mask. So your well-practised rule should always be:

- Pressurization warning.
- Don mask.
- Descend (terrain permitting).
- Solve the problem.

Footnotes:

Variability of Symptoms: Larger aircraft are not immune. Cabin alerts are fallible and hypoxia symptoms are insidious and variable.

Even if cabin altitude alerts function correctly, time of useful consciousness may be less than expected for a given altitude. In 1995, a US Navy P3C departing Japan suffered a rapid decompression to cabin altitude of 24,000 feet in 10 seconds.

Despite the captain's immediate directions, it took the flying pilot some time to don oxygen equipment and initiate descent. He then had difficulty remembering the emergency descent procedure. The non-flying pilot made several radio calls without response, before others realised she had not replaced her headset after donning her smoke mask.

The flight engineer became fixated with the uncorrectable pressurization problem and the captain placed his mask on him. The captain, sitting behind the flying pilot, noticed that his fingernails were blue and decided to check the crew aft. They had differing symptoms:

- One member felt light-headed, experienced tingling, started to walk aft but had to sit down.
- A spare pilot noticed the pressure change, discussed rapid decompression and hypoxia with another member, felt light headed and lost colour vision. He felt nervous as he had no oxygen mask.
- The navigator felt tingling and was disoriented. He noticed misting in the cabin, became claustrophobic, hyperventilated and fixated on his station.
- Another crewman felt his ears pop, felt cold, dizzy, confused, disoriented and sat down until another member administered oxygen.
- Another felt cold, short of breath and suffered an upset stomach.
- Another attempted to grab a walkaround oxygen bottle but became confused and remembers searching for a toolbox key for a ratchet to unfasten the wall bracket.
- One passenger became nervous, laid down, began shaking and had blurred vision.
- Another passenger saw the misting, thought there was a fire, turned blue, had ear pain and noticed everything in slow motion.
- The spare flight engineer was fascinated when the coffee pot lid exploded and coffee sprayed everywhere. He walked to the flight station, became exhausted, disoriented, saw bright flashing lights and had to be administered oxygen.
- Another passenger started cleaning the spilled coffee, felt ill, couldn't figure out how to open the toilet door and vomited on himself.

Following this incident, the US Navy recommended "Don Oxygen Mask" as the first item in the Rapid Decompression and Cabin Pressure Light On emergency checklists.

<http://www.theairlinepilots.com/medical/decompressionandhypoxia.htm>