Flying After Conducting an Aircraft Excessive Cabin Leakage Test

Stephen Houston; Elizabeth Wilkinson

INTRODUCTION: Aviation medical specialists should be aware that commercial airline aircraft engineers may undertake a 'dive equivalent' operation while conducting maintenance activities on the ground. We present a worked example of an occupational risk assessment to determine a minimum safe preflight surface interval (PFSI) for an engineer before flying home to base after conducting an Excessive Cabin Leakage Test (ECLT) on an unserviceable aircraft overseas.

METHOD: We use published dive tables to determine the minimum safe PFSI.

RESULTS: The estimated maximum depth acquired during the procedure varies between 10 and 20 fsw and the typical estimated bottom time varies between 26 and 53 min for the aircraft types operated by the airline. Published dive tables suggest that no minimum PFSI is required for such a dive profile.

DISCUSSION: Diving tables suggest that no minimum PFSI is required for the typical ECLT dive profile within the airline; however, having conducted a risk assessment, which considered peak altitude exposure during commercial flight, the worst-case scenario test dive profile, the variability of interindividual inert gas retention, and our existing policy among other occupational groups within the airline, we advised that, in the absence of a bespoke assessment of the particular circumstances on the day, the minimum PFSI after conducting ECLT should be 24 h.

KEYWORDS: pressurization, engineer, aircraft, dive, decompression sickness, sinus barotrauma.

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Aviation medical specialists should be aware that commercial airline aircraft engineers may undertake a 'dive equivalent' operation while conducting a particular maintenance activity called an Excessive Cabin Leakage Test (ECLT). As an in-house airline medical department we were asked, 'How long after conducting an ECLT overseas is it safe for an engineer to fly home to base?' We present a worked example of a risk assessment to determine the minimum safe preflight surface interval (PFSI) before flying home to base for an engineer after conducting an ECLT. To do this, in line with other occupational risk assessments, we identify the hazard, consider who might be exposed, evaluate the risk, and then decide upon appropriate control measures.

An ECLT is a procedure conducted while the aircraft is on the ground to make sure the fuselage pressurized areas are intact and to check there are no large leaks. The primary pressure source is the Auxiliary Power Unit (APU), but engine bleed air or an external ground source may be used.[1,2] During the test the aircraft's fuselage is pressurized up to 4 psi above ambient pressure on the Boeing and up to 8.8 psi above ambient pressure on the Airbus aircraft types we operate.[1,2] Absolute pressure in the cabin of an aircraft parked at sea level during the test would be up to 14.7 + 4 = 18.7 psi for Boeing types and up to 14.7 + 8.8 = 23.5 psi for Airbus types [standard atmospheric pressure (ATA) at sea level is 14.7 psi]. Typically the test is conducted with two engineers on the flight-deck. No other person should be on board. 4 psi and 8.8 psi pressures are approximately equivalent to that exerted by 10 and 20 ft of sea water (fsw), respectively. The engineers are effectively conducting a dive to a depth up to 20 ft.

In commercial aviation the ECLT is mandated after certain major scheduled maintenance which requires the replacement of the aircraft doors or windows. This would typically happen once every few years. However, the test may also be required on an ad hoc basis when there is a technical problem with the

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cabin pressurization system or to discover the source of a leak. During the test the location of a leak may be identified audibly because any leak usually makes a sound like the reed in a clarinet. These ad hoc checks are infrequent, but may for example need to be conducted if an aircraft becomes unserviceable overseas. After conducting the test the engineer may then need to fly back home to base. It is well recognized that flying after diving increases the risk of decompression sickness (DCS).[9]

METHOD

Typically, ear pain and sinus barotrauma occur as divers encounter rapidly changing pressures during the first few feet of a dive.[10] During the ECLT, to minimize the risk of ear pain and sinus barotrauma, the cabin rate of descent is not allowed to exceed -500 ft/min. Persons who have an upper respiratory tract infection, ear ache, or sinus problems should not be on the aircraft during the test.

On the Boeing aircraft types that we operate this continues until the cabin pressure becomes stable at 4 psi (about 10 fsw) above ambient atmospheric pressure. With this rate of descent it will take about 16 min to achieve this pressure differential. The pneumatic source is then turned off and the pressure measured several times over the next 5-10 min to obtain the 'leak rate.' **Fig. 1** shows the cabin pressure leakage rate chart for a typical Boeing 747 aircraft.

On the Airbus aircraft types that we operate this continues until the cabin pressure becomes stable at 5.8 psi (about 13 fsw) above ambient atmospheric pressure for a minimum of 5 min and then continues until the cabin pressure becomes stable at 8.8 psi (about 20 fsw) above ambient atmospheric pressure. With a similar rate of descent it will take about 43 min to achieve this pressure differential. The pneumatic source is then turned off and the time taken for the pressure to drop from 8.5 psi to 7.5 psi is measured using a stopwatch in order to calculate the leakage rate, which must be less than an acceptable level. The pressure is then returned to sea level pressure, again at a rate not exceeding 500 ft/min.

The actual dive profile will vary on the day of the test and may be different between aircraft. The highest pressure above atmospheric to which engineers will be exposed will be determined by the procedure outlined in the Aircraft Maintenance Manual. The approximate dive profiles for an ECLT conducted upon the Boeing 747 and Airbus 380 are shown in **Fig. 2**. Tests using pressure differentials greater than about 4 psi values usually require removal of all pressure sensitive equipment from the aircraft; e.g., the crew masks have an aneroid capsule and to prevent high stress on the aneroid capsule it is recommended they be removed before a test at higher pressure differentials.

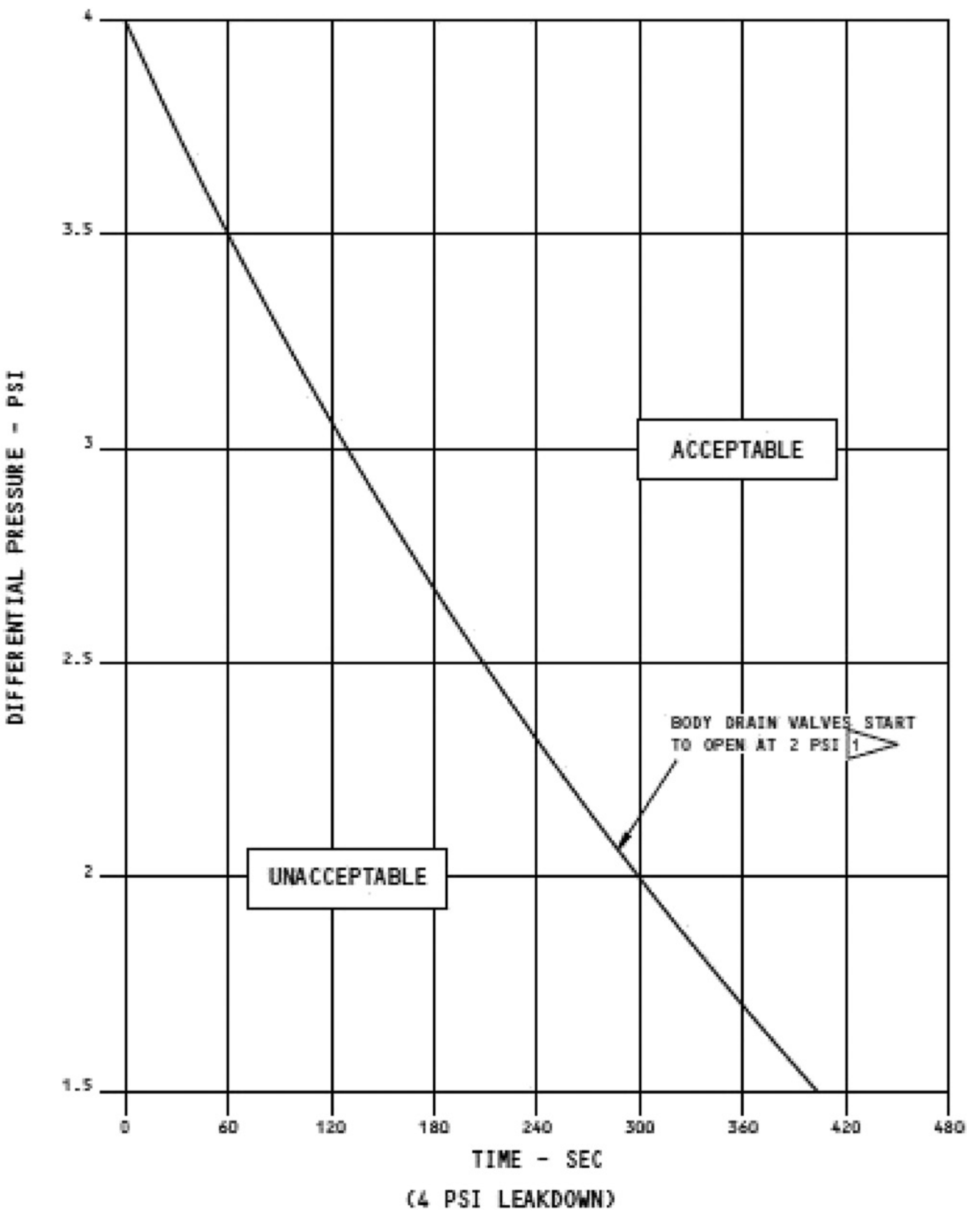

Fig. 1. Cabin pressure leakage rate chart. Pressure is measured several times over a 240–300 s period from the time the pressure source is turned off or until the pressure differential falls to 2.25 psi. If the pressure leakage rate (bleed down) is acceptable from time = 0 s to time = 240 s, the aircraft is acceptable.[1]

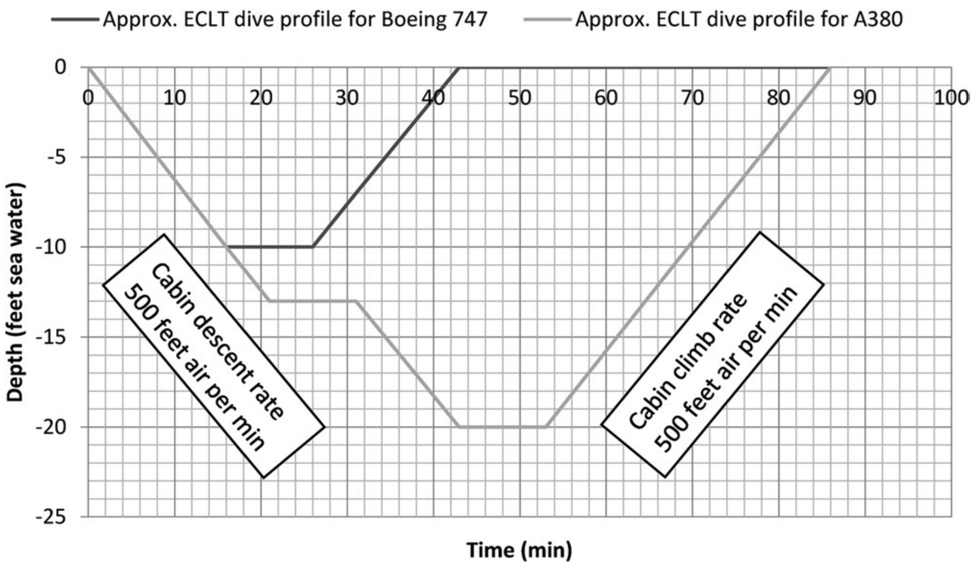

Fig. 2. Typical 'dive profile' for Boeing 747 and Airbus 380 ECLT.

RESULTS

The maximum depth acquired during the procedure varies between 10 and 20 fsw for the aircraft types operated by our airline. **Table I** shows the maximum pressure differential achieved during ECLT according to aircraft maintenance manual by type within the airline fleet. Bottom time is the total elapsed time from the time the diver leaves the surface to the time they leave the bottom. The bottom time varies between about 26 and 53 min for a typical ECLT dive profile within the airline.

Table II is an excerpt of the 'No-Decompression Limits and Repetitive Group Designators for No-Decompression Air Dives and Required Surface Interval Before Ascent to Altitude After Diving' tables of the U.S. Navy Diving Manual.[7] For any bottom time and depth, one can use this table to obtain the highest 'repetitive group designator.' The 'repetitive group designator' is a letter used to indicate the amount of residual nitrogen remaining in the diver's body following a previous dive. Using the highest 'repetitive group designator' obtained in the previous 24-h period it is then possible to read the required surface interval for the planned change in altitude. A dive to 10 fsw for a bottom time less than 57 min will have a repetitive group designator of A. A dive to 20 fsw for a bottom time less than 61 min will have a repetitive group designator of C. Although the cabin pressure in commercial aircraft varies somewhat with aircraft type and cruise altitude,[6] the nominal value used to compute the PFSI from dive tables is 8000 ft (2438 m). For this 'dive equivalent' maintenance activity the repetitive group designator is C or less. For repetitive group designator C there is no required surface interval before ascent to 8000 ft altitude according to the U.S. Navy Diving Manual tables.

Table I. Maximum Pressure Differential Achieved During ECLT According To Aircraft Maintenance Manual By Type Within The Airline Fleet.

AIRCRAFT TYPE	MAXIMUM DIFFERENTIAL PRESSURE DURING ECLT (psi)
Boeing 747	4.00
Boeing 777	4.00
Boeing 787	4.00
Boeing 767	4.00
Airbus 320	8.41
Airbus 380	8.80
Embraer 190/95	4.50

DISCUSSION

Ascent to altitude after a dive increases the likelihood a diver will develop DCS. The additional risk is maximal when the diver ascends immediately after surfacing; the additional risk subsequently declines as the surface interval between surfacing and ascent lengthens. Much effort has been spent to determine the 'safe' surface interval before flying. A paucity of experimental data and differing organizational needs have led to a wide variety of conflicting recommendations.[11,14]

Haldane composed the first 'decompression model' used to derive diving tables in 1908.[3] Though improved and refined over the years, his model forms the basis of modern dive tables. Haldane hypothesized that it was actually possible for divers to have tissues 'supersaturated' with nitrogen without the gas forming bubbles. This was thought to be true so long as the ratio of environmental pressure (i.e., the gas breathed) to tissue gas tension (i.e., the pressure exerted by the nitrogen) was 2:1 or less.[3] For example, this meant that it might be considered safe for a diver to ascend from a depth of 10 m of sea water (pressure of 2 ATA) to the surface (1 ATA) without developing DCS. Flying after conducting an ECLT causes the engineer to ascend from an environmental pressure up to 8.8 psi above ambient (1.6 ATA) to a cabin altitude of 8000 ft (0.74 ATA). This ratio is above the ratio that might be considered safe (1.60:0.74 is more than 2:1). Further study on the subject of inert gas tissue loading led to the addition of many more refinements to the original Haldane model, allowing for greater safety margins. These refinements have been incorporated into modern dive tables such as those in the U.S. Navy Diving Manual consulted during our risk assessment. Using these tables we determined that in theory there is no required PFSI for an aircraft engineer wanting to fly home to base having just conducted the ECLT dive profile described above.

Cabin pressure during the flight home will vary somewhat depending upon the aircraft type and cruise altitude.[6] The nominal value used to compute the PFSI from dive tables is 8000 ft (2438 m). Peak cabin altitudes provide a better reflection of the magnitude of the decompression stress during the

Table II. Excerpt from "No-Decompression Limits and Repetitive Group Designators for No-Decompression Air Dives and Required Surface Interval Before Ascent to Altitude After Diving" Tables of the U.S. Navy Diving Manual.[7]

		REPETITIVE GROUP DESIGNATION											
DEPTH (fsw)	**NO-STOP LIMIT**	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**
0	Unlimited	57	101	158	245	426	*						
15	Unlimited	36	60	88	121	163	217	297	449	*			
20	Unlimited	26	43	61	82	106	133	165	205	256	330	461	*

	INCREASE IN ALTITUDE (ft)									
REPETITIVE GROUP DESIGNATOR	**1000**	**2000**	**3000**	**4000**	**5000**	**6000**	**7000**	**8000**	**9000**	**10,000**
A	0:00	0:00	0:00	0:00	0:00	0:00	0:00	0:00	0:00	0:00
B	0:00	0:00	0:00	0:00	0:00	0:00	0:00	0:00	0:00	1:42
C	0:00	0:00	0:00	0:00	0:00	0:00	0:00	0:00	1:48	6:23
D	0:00	0:00	0:00	0:00	0:00	0:00	0:00	1:45	5:24	9:59
E	0:00	0:00	0:00	0:00	0:00	0:00	1:37	4:39	8:18	12:54
F	0:00	0:00	0:00	0:00	0:00	1:32	4:04	7:06	10:45	15:20
G	0:00	0:00	0:00	0:00	1:19	3:38	6:10	9:13	12:52	17:27
H	0:00	0:00	0:00	1:06	3:10	5:29	8:02	11:04	14:43	19:18
I	0:00	0:00	0:56	2:45	4:50	7:09	9:41	12:44	16:22	20:58
J	0:00	0:41	2:25	4:15	6:16	8:39	11:11	14:13	17:52	22:27
K	0:30	2:03	3:47	5:37	7:41	10:00	12:33	15:35	19:14	23:49
L	1:45	3:18	5:02	6:52	8:56	11:15	13:48	16:50	20:29	25:04

* Highest repetitive group that can be achieved at this depth regardless of bottom time.

flight home.[8] During a reappraisal of altitude exposures during commercial flight, peak cabin altitudes have been measured as high as 8549 ft (2606 m) and peak cabin altitudes greater than 8000 ft were measured in approximately 10% of total flights.[6] Furthermore, in the real world the actual dive profile may be different between aircraft types and the bottom time (total elapsed time from the time the diver leaves the surface to the time he leaves the bottom) will vary day-to-day. The highest Repetitive Group Designation that can be achieved at 20 fsw regardless of bottom time is L (marked * in Table II). This is reached when the bottom time exceeds 461 min. The required PFSI for L is 16 h 50 min for ascent to 8000 ft and 20 h 29 min for ascent to 9000 ft (the worst possible combination of variables in the real world). These variables must be considered within the risk assessment. In addition, there is little robust evidence indicating the minimum safe PFSI between diving and high altitude exposure.[11,14] Guidelines were initially issued by the 39th Undersea and Hyperbaric Medical Society Workshop in 1989.[12] The workshop suggested a minimum PFSI of 12 h after up to a 2 h no-stop dive.[12] Following this the Divers Alert Network (DAN) initially proposed the general recommendation to wait 24 h after recreational diving, which was then changed to at least 12 h after a single no-stop dive and more than 12 h after repetitive dives, decompression dives, and multiday diving.[13] Published results of a series of chamber trials conducted by DAN between 1992 and 1999 found no incidence of DCS for surface intervals longer than 11 h after single no-stop dives and DCS incidence decreases as the PFSI increases.[13,15] A recently published study used in-flight echocardiography to examine subjects flying home after a diving holiday. The study found the majority of divers did not develop bubbles during altitude exposure after a PFSI of 24 h but in certain individuals, 'bubblers,' the inert gas that accumulates during exposure to increased hyperbaric pressure may remain in the tissues for longer than the estimated safe interval of 24 h.[5] In accordance with guidance issued by the FAA Civil Aerospace Medical Institute, cabin crew and pilots within our airline must not undertake a no-stop dive within 24 h before a rostered duty.[4]

Diving tables suggest that no minimum PFSI is required for the typical ECLT dive profile within the airline; however, having conducted a risk assessment, which considered peak altitude exposure during commercial flight, the worst-case scenario test dive profile, the variability of interindividual inert gas retention, and our existing policy among other occupational groups within the airline, we advised that, in the absence of a bespoke assessment of the particular circumstances on the day, the minimum PFSI after conducting ECLT should be 24 h.

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