MINISTRY FOR
INNOVATION AND TECHNOLOGY
TRANSPORTATION SAFETY BUREAU

FINAL REPORT

2015-011-4P
Incident

Budapest Liszt Ferenc International Airport (LHBP)
10 December 2014

Airbus A320-214
LY-VEW

The sole objective of the technical investigation is to reveal the causes and circumstances of aviation accidents and incidents, to initiate the necessary technical measures and make recommendations in order to prevent similar cases in the future. It is not the purpose of this activity to apportion blame or liability.

This document is the translation of the Hungarian version of the Final Report. Although efforts have been made to translate it as accurately as possible, discrepancies may occur. In this case, the Hungarian is the authentic, official version.

General information

This investigation was carried out by Transportation Safety Bureau on the basis of

- Regulation (EU) No 996/2010 of the European Parliament and of the Council of 20 October 2010 on the investigation and prevention of accidents and incidents in civil aviation and repealing Directive 94/56/EC,
- Act XCVII of 1995 on aviation,
- ICAO Annex 13 identified in the Appendix of Act XLVI. of 2007 on the declaration of the annexes to the Convention on International Civil Aviation signed in Chicago on 7th December 1944,
- Act CLXXXIV of 2005 on the technical investigation of aviation, railway and marine accidents and incidents (hereinafter referred to as Kbvt.),
- NFM Regulation 70/2015 (XII.1) on technical investigation of aviation accidents and incidents, as well as on detailed investigation for operators,
- In absence of other relevant regulation in the Kbvt., in accordance with Act CXL of 2004 on the general rules of administrative authority procedure and service,

The competence of the Transportation Safety Bureau of Hungary is based on Government Decree № 278/2006 (XII. 23.), and, as from 01 September 2016, on Government Decree № 230/2016. (VII.29.) 23) on assignment of a transportation safety organisation and on the dissolution of Transportation Safety Bureau with legal succession.

Pursuant to the aforesaid laws,

- The Transportation Safety Bureau of Hungary shall investigate aviation accidents and serious aviation incidents.
- Transportation Safety Bureau Hungary may investigate aviation incidents and irregularities which – in its judgement – could have led to more accidents with more serious consequences in other circumstances.
- The Transportation Safety Bureau of Hungary is independent of any person or entity which may have interests conflicting with the tasks of the investigating organization.
- In addition to the aforementioned laws, the ICAO Doc 9756 and the ICAO DOC 6920 Manual of Aircraft Accident Investigation are also applicable.
- This Report shall not be binding, nor shall an appeal be lodged against it.
- The original of this Report was written in the Hungarian language.

Incompatibility did not stand against the members of the IC. The persons participating in the technical investigation did not act as experts in other procedures concerning the same case and shall not do so in the future.

The IC shall safe keep the data having come to their knowledge in the course of the technical investigation. Furthermore, the IC shall not be obliged to make the data – regarding which the owner of the data could have refused its disclosure pursuant to the relevant act – available for other authorities.

This Final Report was based on the Draft Report which prepared by the IC and sent to all affected parties (as stipulated by the relevant regulation) for comments.

Table of Contents

Definitions and Abbreviations

ACE	*Aeroplex of Central Europe Ltd.*
AD	*Airworthiness Directive*
Allotrope	*Allotropes are possible versions of the same chemical element which have the same physical state but different molecular or crystalline structures.*
AOT	*Alert Operators Transmission*
ARP	*Airport Reference Point*
Autocatalysis	*A chemical reaction in which one of the products of the process itself acts as catalyst for that reaction.*
BEA	*Bureau d'Enquêtes et d'Analyses pour la Sécurité de l'Aviation Civile /* *Bureau of Enquiry and Analysis for Civil Aviation Safety*
BFU	*Bundesstelle für Flugunfalluntersuchung /* *Federal Bureau of Aircraft Accident Investigation*
C-check	*Periodical aircraft maintenance performed in hangar environment* *(Base maintenance)*
EASA	*European Aviation Safety Agency*
IC	*Investigating Committee*
ICAO	*International Civil Aviation Organization*
Kbvt.	*Act CLXXXIV of 2005 on the technical investigation of aviation, railway and marine accidents and incidents and other transportation occurrences*
LHBP	*ICAO Code of Budapest Liszt Ferenc International Airport*
LT	*Local Time*
MET	*Ministry of Economics and Transport*
MIT	*Ministry for Innovation and Technology*
MND	*Ministry of National Development*
micron	*micrometre* ($1\mu m = 10^{-6}$ m)
MOT CIAAI	*Ministry of Transport* *Chief Investigator of Aircraft Accident and Incident (Lithuania)*
N_2	*Nitrogen gas*
NTA AA	National Transport Authority Aviation Authority, Hungary *(till 31 December 2016)*
NTSB	*National Transportation Safety Board (USA)*

O_2	*Oxygen gas*
P/N	*Part Number*
Part-145	*An aircraft maintenance organisation approved according to the requirements stipulated in Part-145, Regulation (EC) № 2042/2003*
psig	*Pound per square inch, gage / (1 psig = 6894.8 N/m^2 (Pa); 1 bar = 14.5 psi)*
RIL	*Retrofit Information Letter*
Service Life	*A period of time during which some equipment is installed in an airplane*
Shelf Life	*A period of time during which some equipment is stored.*
Tin pest	*An allotropic, autocatalytic transformation of the element tin. If the tin with tetragonal crystalline structure (white tin) is cooled below 13.2 °C then, through a very low recrystallization process, it transforms into a substance with diamond-shaped crystals (grey tin). The term 'pest' refers to the fact that, when the powder of the end-product of the transformation contacts intact white tin, the typical symptoms of the tin pest appear and start to spread out of the point of contact.*
TSB	*Transportation Safety Bureau of Hungary*
Useful Life	*A specified period of time within which certain equipment may be used in an airworthy airplane. Useful Life = Shelf Life + Service Life*
UTC	*Coordinated Universal Time*
α-tin	*Alpha-phase (grey) tin*
β-tin	*Beta-phase (white) tin*

Introduction

Occurrence category		Incident
Aircraft	Manufacturer	Airbus
	Type	A320-214
	Registration	LY-VEW
	Operator	Avion Express
Event	Date and time	10 December 2014
	Location	Budapest Liszt Ferenc International Airport (LHBP) (Figure 1)
Extent of damage to the aircraft involved in the incident:		None

Figure 1: Location of the occurrence in Hungary

Reports and notifications

The occurrence was reported to the duty service of TSB by the Deputy Director for Quality Center of Aeroplex of Central Europe Ltd. (hereinafter: “ACE”) on 12 January 2015.

TSB Hungary notified:

- the person on duty at National Transport Authority Aviation Authority, on 13 January 2015,
- the investigating organisation of the state of the aircraft manufacturer (BEA), the investigating organisation of the state of the aircraft operator (MOT CIAAI), European Aviation Safety Agency (EASA) and International Civil Aviation Organisation (ICAO), on 15 January 2015,
- the investigating organisation of the state of the assembly line of the oxygen generator container (BFU), on 16 January 2015

– the investigating organisation of the state of the manufacturer of the oxygen generator (NTSB), on 29 January 2015.

Investigation Committee

The Head of TSB assigned the following Investigating Committee (hereinafter: IC) for the investigation of the occurrence:

Investigator-in-Charge	**Ferenc Kamasz**	Accident Investigator
Member	**Endre Szilágyi**	Accident Investigator
Member	**Gergely Maróti**	Accident Investigator

Endre Szilágyi, Investigator, left TSB Hungary during the investigation, therefore Gábor Erdősi, Investigator, was appointed as member of the IC.

Overview of the investigation

Following the notification of the occurrence, the IC surveyed the oxygen equipment maintenance workshop of ACE on 14 January 2015. The IC viewed the oxygen generators (P/N: 117042-03 and P/N: 117042-04) which ACE had not been able to activate earlier and took photos of such generators. The maintenance staff at the oxygen shop of ACE attempted to activate two oxygen generators in the presence of the IC: one with P/N 117042-03, and one with P/N 117042-4, but the chemical reaction required for generating oxygen did not take place after the actuation pin was removed. The IC seized the two tested generators.

On 15 January 2015, the IC contacted B/E Aerospace, the manufacturer of the generators, who had already in progressed an inspection due to earlier similar cases. The IC received information from B/E Aerospace relating to the chemical composition of the oxygen generators, which made identification of the malfunction possible.

Airbus Company, manufacturer of the airplane, contacted TSB on 16 January 2015.

Airbus Company sent their actions taken relating to the case, as well as the Investigation Summary № 3500-15-049 Rev: B, prepared by B/E Aerospace to TSB on 20 July 2016, which the IC used in preparing its final report.

TSB Hungary sent the Draft Report on the investigation to the BEA, the EASA, the Litvanian accident investigation bureau, the Hungarian civil aviation authority and the ACE on 24 April 2018.

The organisations answered they had no proposal for modification to the Draft Report.

Synopsis

During the C-check ordered by the operator of the airplane 23 chemical oxygen generators were dismounted from the airplane and taken to the oxygen equipment maintenance unit of ACE for the purpose of disposal. At that time, the respective ages of the oxygen generators were within the useful life (15 years).

The maintenance staff at the oxygen shop of the maintenance organisation started to activate the oxygen generators in accordance with the scheduled maintenance process, and found that none of the oxygen generators worked. After disposing of 12 oxygen generators, the maintenance staffs suspended the process and informed ACE Quality Directorate who thereafter informed TSB Hungary on the occurrence.

Being aware of the combination of the oxygen generators and on the basis of the information from B/E Aerospace, the IC concluded that malfunction of the equipment had occurred due to premature recrystallization of a component (tin) in the oxygen generators.

By issuing the ADs to be discussed in detail herein, EASA has reduced the life limit for which the oxygen generators already produced may be installed in airworthy airplane, and thus, the IC finds that no safety recommendation needs to be issued relating to the occurrence.

1. Factual Information

1.1. Course of events

On 10 December 2014, during the C-check ordered by the operator of the airplane, Avion Express, removed 23 chemical oxygen generators from the type Airbus A320-214 (registration: LY-VEW). The dismounted units were taken to the oxygen equipment maintenance workshop of ACE, the airplane maintenance organisation, for the purpose of disposal.

The oxygen generators were manufactured between May 2000 and July 2000, and thus, the respective ages of the oxygen generators were 5 to 7 months within the useful life (15 years) at that time.

The maintenance staff at the oxygen shop started to activate the oxygen generators and found that none of the oxygen generators worked. Pulling out the activating pin did not start oxygen production in the devices: no gas flowed out through the manifold. The housing of the oxygen generators did not heat up, and the yellow indicator on the housing also did not become black.

After disposing of 12 oxygen generators, the maintenance staff suspended the process and informed ACE Quality Directorate who thereafter informed TSB Hungary about the occurrence.

On 14 January 2015, the maintenance staff at the oxygen shop of ACE attempted to activate two oxygen generators in the presence of the IC: one with P/N 117042-03, and one with P/N 117042-4, but neither equipment was serviceable.

ACE contacted B/E Aerospace, manufacturer of the components, and sent them the rest of the (non-activated) oxygen generators for further inspection.

1.2. Injuries to persons

No one was injured as an outcome of the occurrence.

1.3. Damage to aircraft

The airplane was not damaged as an outcome of the occurrence.

1.4. Other damage

The IC was not informed on any other damage during the period of the investigation.

1.5. Maintenance Staff data

Irrelevant to the case.

1.6. Aircraft data

1.6.1. General data

Class	Fixed-wing aircraft (MTOW>5700kg)
Manufacturer	Airbus
Type	A320-214
Year of manufacturing	1999
Serial number	1005
Registration	LY-VEW
State of registration	Lithuania
Operator	Avion Express

1.6.2. Conclusions airworthiness

The airplane had valid certificates at the time of the occurrence, discussion of the details is irrelevant to the case.

1.6.3. Data of the oxygen generators removed from the airplane

	Part Number	Core Lot No.	MFG Code	MFG Date	End of Useful Life
1	117042-03	239	014	May 2000	May 2015
2	117042-04	336	029	July 2000	July 2015
3	117042-03	239	014	May 2000	May 2015
4	117042-04	340	029	July 2000	July 2015
5	117042-03	239	014	May 2000	May 2015
6	117042-04	336	029	July 2000	July 2015
7	117042-03	239	014	May 2000	May 2015
8	117042-04	336	029	July 2000	July 2015
9	117042-03	239	014	May 2000	May 2015
10	117042-04	336	029	July 2000	July 2015
11	117042-03	247	020	May 2000	May 2015
12	117042-04	336	029	July 2000	July 2015
13	117042-04	336	029	July 2000	July 2015
14	117042-03	247	020	May 2000	May 2015
15	117042-04	336	029	July 2000	July 2015
16	117042-03	247	020	May 2000	May 2015
17	117042-04	336	029	July 2000	July 2015
18	117042-03	247	020	May 2000	May 2015
19	117042-04	336	029	July 2000	July 2015
20	117042-03	239	014	May 2000	May 2015
21	117042-04	336	029	July 2000	July 2015
22	117042-03	247	020	May 2000	May 2015
23	117042-04	336	029	July 2000	July 2015

The dates of manufacturing of the oxygen generators range from May 2000 to July 2000; their useful life is 15 years, so their remaining useful life at the time of the occurrence (December 2014) was 5 to 7 months.

1.6.4. Description of the malfunctioned system, equipment data

The purpose of the oxygen system in the airplane is to provide oxygen to the passengers and the cabin crew in the case that the cabin altitude exceeds 14,000 ft, or if the flight crew activates the ”MASK MANUAL ON” push button located in the overhead control panel in the cockpit.

When the passenger oxygen system is activated, either automatically or manually, the doors of the containers of the oxygen generators installed above the passengers open (Figure 2), and the oxygen masks drop down in front of the passengers.

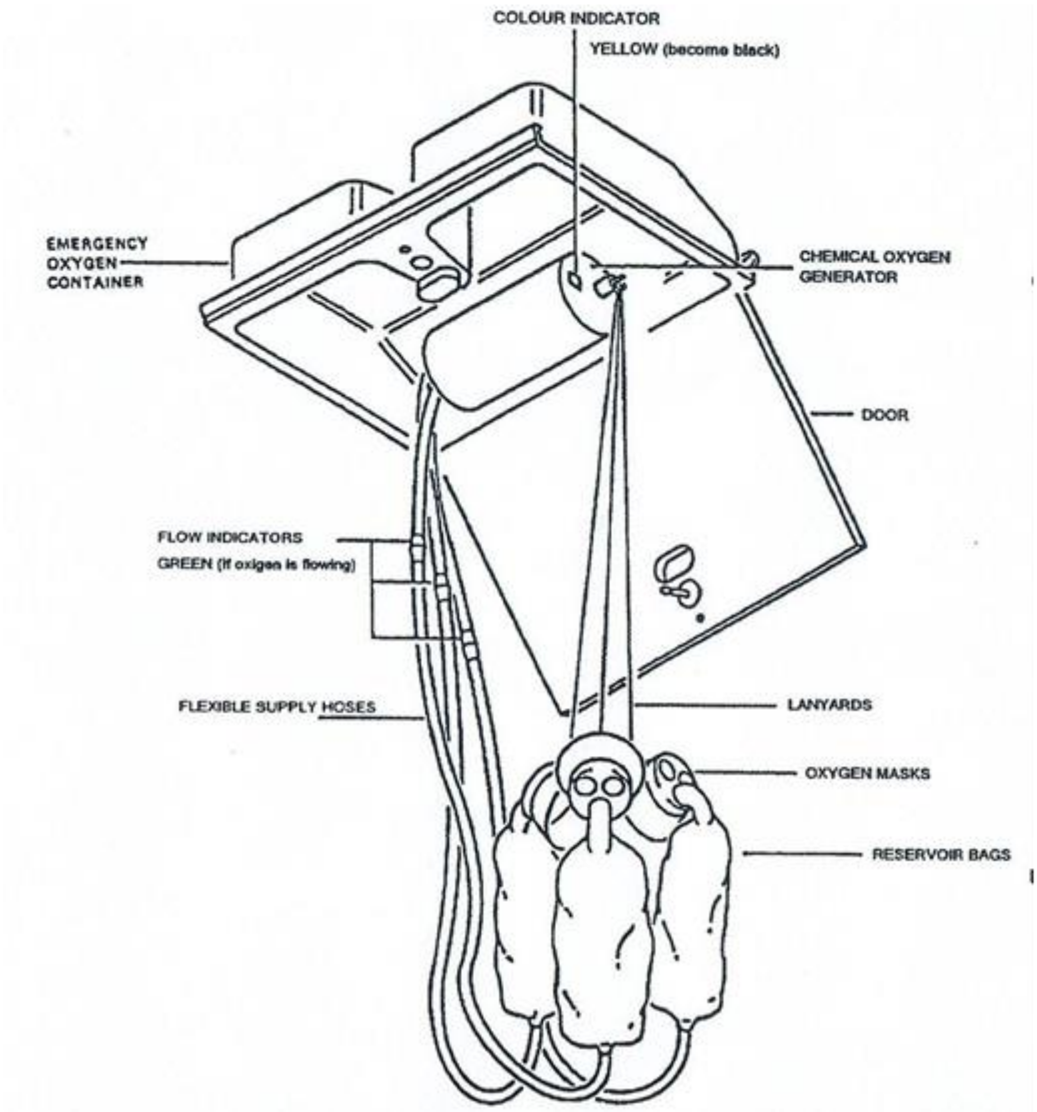


Figure 2: The passenger oxygen system after the door of the container has opened

When a person pulls one of the oxygen masks to themselves, the lanyard pulls the activating pin out of the oxygen generator, as a result of which the chemical reaction starts immediately, and oxygen gas is generated. The oxygen gas produced flows into the masks through the mask connections. The process goes on continuously for 15 minutes. That period is long enough for the flight crew to descend with the aircraft to an altitude where the pressure and composition of the external (atmospheric) air are suitable for the human organisation.

Figure 3 shows the arrangement of the components in the assembled oxygen container. Depending on its construction, a container may contain 2, 3, or 4 oxygen masks, each of which is connected to the oxygen generator through a flexible hose (the last character of the Part Number 117042-0x shows how many masks the given oxygen generator can supply with oxygen).

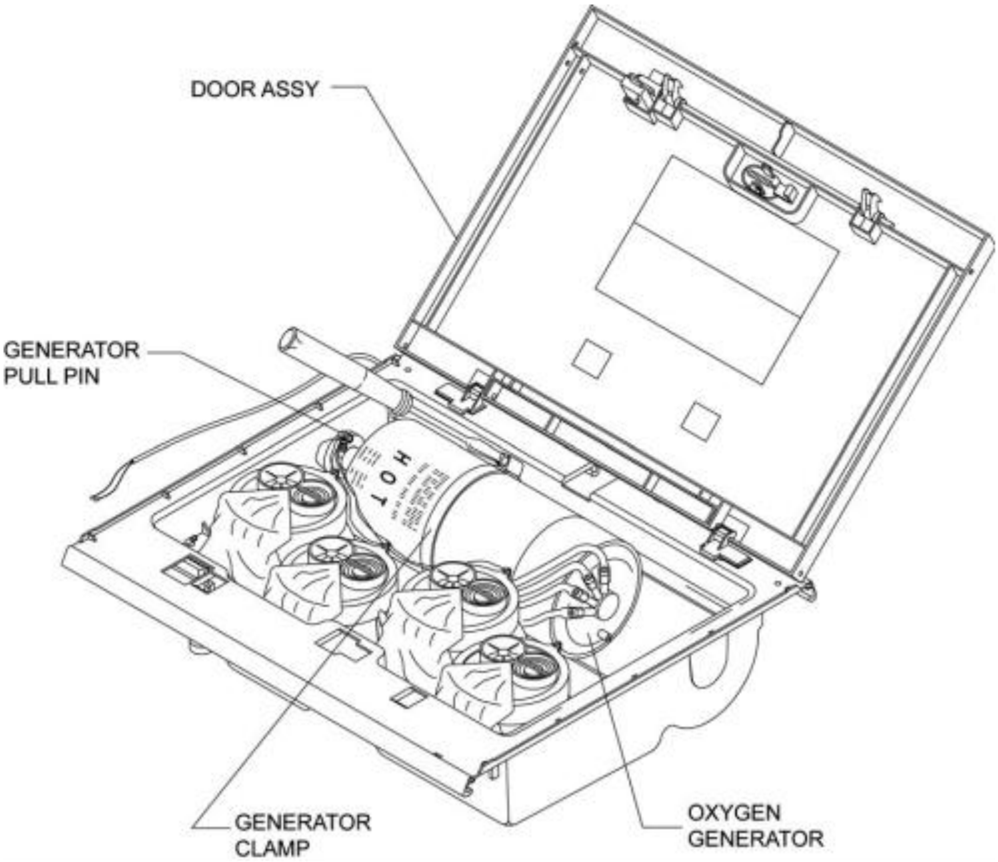


Figure 3: Arrangement of the oxygen masks in the container

Before expiry of the useful life of a chemical oxygen generator, it must be removed from the airplane and discarded.

Chemical components of the oxygen generator:

The generator contains substances in a solid form in a closed stainless steel vessel (Figure 4). The chemical composition of the generator changes during use: it is chemically transformed in the chemical reaction.

Chemical composition of the unused chemical oxygen generator:

Iron Powder....................................3 %
Tin Powder ....5 %
Calcium hydroxide........................1 %
Magnesium Oxide.........................1 %
Potassium Perchlorate...................2 %
Cobalt Oxide.................................1 %
Glass Powder ....2 %
Sodium Chlorate ....85 %

Chemical composition of the used chemical oxygen generator:

Sodium Chloride.........................74 %
Iron (metal and oxides).................7 %
Tin (metal and oxides) ....10 %
Calcium (chlorides and oxides).....2 %
Potassium Chloride.......................1 %
Cobalt Oxide.................................2 %
Glass Powder ....4 %

In addition to intensive heat production, oxygen gas is emitted from the generator during the chemical reaction, and consequently, the weight of the generator will change.

Part Number of generator	Weight, before use (grams)	Weight, after use (grams)
117042-02	242	150
117042-03	336	206
117042-04	455	278

The solid-state chemical components of the oxygen generator are in an internal insulated container:

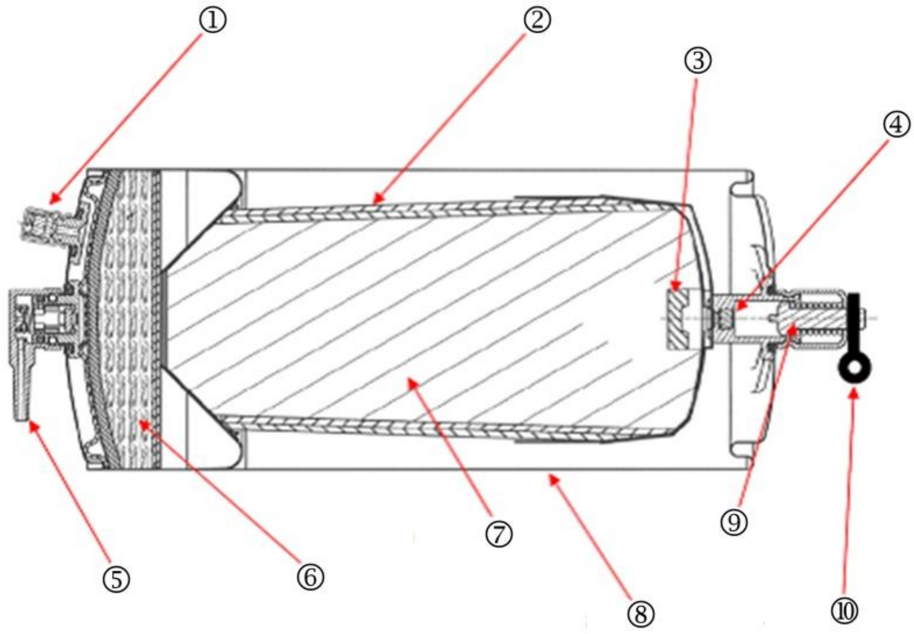


Figure 4: Internal layout of the chemical oxygen generator

① Relief valve;
② Insulation;
③ Primary pellet;
④ Pyrotechnic Primer;
⑤ Mask Connections;
⑥ Filter;
⑦ Chemical Core;
⑧ Solid state Vessel;
⑨ Striker Pin;
⑩ Actuation Pin

Operation of the oxygen generator:

The main constituent in the chemical core of the oxygen generator is Sodium Chlorate ($NaClO_3$) which itself stores oxygen. The initiation and regulation of the chemical reaction are ensured by metal powder fuel (tin and iron) and various catalysers. The chemical reaction is triggered in such manner that, as soon as the actuation pin is pulled out, a striker pin hits a pyrotechnic primer. The explosive heat energy of the primer is directed to the primary pellet, which catches fire and, in turn, ignites the core containing the chemical substances, and the chemical reaction starts. In addition to intensive heat production, the reaction causes the core to emit oxygen gas all along, which flows to the mask connections through a filter, and from there through the supply hoses to the oxygen masks.

1.7. Fire

Pulling out of the actuation pin of the oxygen generators was not followed by fire.

1.8. Survival aspects

No one was injured during the occurrence.

1.9. Tests and research

The oxygen generator is activated by pulling the lanyard of a mask, thus pulling the actuation pin out, which triggers the striker pin, which in turn initiates the chemical reaction, which goes on for 15 minutes.

The oxygen generator emits oxygen gas through the mask connections during the chemical reaction. The chemical reaction is accompanied by heat production, which heats up the vessel of the generator. During the chemical reaction, the colour of the heat-sensitive yellow indicator on the oxygen generator turns black, indicating that the oxygen generator has been used already, and it cannot be used in the airplane anymore.

Following the reporting of the occurrence, the maintenance staff at the oxygen shop of ACE attempted to activate two oxygen generators in the presence of the IC: one with P/N 117042-03, and one with P/N 117042-4. The generators failed to start oxygen production after the actuator pin was pulled out, no gas outflow was detected through the pipe manifold, the vessels of the oxygen generators did not heat up, neither did the yellow indicator on them discolour – no chemical reaction took place.

1.10. Organisational and management information

The operation of the airplane operator and maintenance organisation did not influence the occurrence and needs no discussion in detail.

1.11. Additional information

The duration of the useful life of the P/N 117042-XX oxygen generators is 15 years.

Useful Life = Shelf Life + Service Life, where Useful Life is the period of time within which the equipment may be used in an airworthy airplane. Shelf Life is that part of Useful Life which the equipment spends in storage. Service Life is that part of Useful Life which the equipment spends installed in the airplane.

The manufacturer of the oxygen generators (B/E Aerospace) had prior information on similar malfunctions, so they already had an investigation underway in order to reveal the cause at the time of the occurrence.

The oxygen generators with P/N 117042-XX are in service in the airplane types Airbus A300/A310, Airbus A318/A319/A320/A321, and Airbus A330/A340.

As a consequence of the occurrence under review and the cases investigated by B/E Aerospace, Airbus Company informed airplane operators on the malfunction by the following AOTs and RIL letters:

- AOT № A35W008-14 (18-DEC-2014) and RIL № WB35M14028325 (19 DEC 2014) for the operators of Airbus A300-600, A310, and AST,
- AOT № A35N006-14 (10-DEC-2014) and RIL № SA35M14027080 (11-DEC-2014) for the operators of Airbus A318, A319, A320, and A321,
- AOT № A35L007-14 (18-DEC-2014) and RIL № LR35M14028324 (19 DEC 2014) for the operators of Airbus A330, A340, A340-500, and A340-600.

Through the above AOTs and RIL letters, Airbus Company requested the operators to replace the oxygen generators manufactured in 2000 by June 2015 at latest, and those manufactured in 2001 by December 2015 at latest. In addition, they were also asked to activate the oxygen generators after removing and inform Airbus Company on the result in writing.

On 20 July 2016, the Airbus Company sent TSB the investigation report prepared by B/E Aerospace, and TSB used it when performing its own investigation and preparing its report.

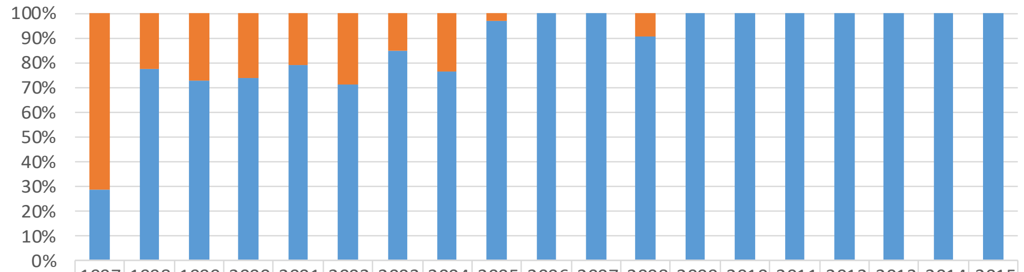
The pending investigations have revealed clearly that the malfunction of the oxygen generators was only occurred with older apparatuses, as the generators manufactured later worked reliably; thus, EASA issued the following ADs to limit the period of time for which the oxygen generators may be held in service in airworthy airplane:

- AD № 2015-0118 (24 June 2015) relating to the airplane types Airbus A300-600, A300-600ST, and A310,
- AD № 2015-0117 (24 June 2015) relating to the airplane types Airbus A318, A319, A320, and A321,
- AD № 2015-0119 (24 June 2015) relating to the airplane types Airbus A330 and A340.

The relevant ADs reduce the expected useful life of the oxygen generators from 15 to 10 years gradually, depending on their respective year of manufacturing. The transitional period implied by the AD ends at the beginning of 2019, i.e. all airworthy airplanes type Airbus A300/A310, Airbus A318/A319/A320/A321 and Airbus A330/A340 may have only such oxygen generators with P/N 117042-XX in place which are less than 10 years old.

1.12. Useful or effective investigation methods

B/E Aerospace inspected serviceability of 3815 oxygen generators with Part Number: 117042-XX manufactured between 1997 and 2015; the results of their study are shown in the diagram below:



	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Number Non-actuated	20	2	62	332	228	112	70	23	3	0	0	1	0	0	0	0	0	0	0
Number Pass	8	7	164	927	864	275	387	74	100	41	16	10	9	13	1	18	10	25	13

Number Pass   Number Non-actuated

The diagram shows that there were lots of unserviceable units among the oxygen generators manufactured between 1997 and 2004, while almost 100 % of the units manufactured between 2005 and 2015 were serviceable.

2. Analysis

Airplane operators reported B/E Aerospace the unserviceability of over 900 oxygen generators with Part Number:117042-XX. According to such reports, it was impossible to activate the generators after removal from the airplane: the production of oxygen gas failed to start after the actuator pin was pulled out.

The age of each oxygen generator involved was over 10 years but under the specified useful life of 15 years.

In the case of the malfunctioned oxygen generators formally investigated by B/E Aerospace, the primary pellet, which should initiate the chemical reaction, showed the burn mark caused by the heat energy of the pyrotechnic primer, but, due to insufficient intensity, such heat energy failed to propagate in the chemical core. The reaction stopped, that is why no oxygen gas was generated.

Analysis of the chemical core found that up to 64% of the tin fuel had oxidized. The presence of tin oxide was found during analysis of elemental tin.

The inspection found that, in the case of tin oxidation up to 50%, the self-sustaining chemical reaction started both in the primary pellet and in the top layer of the chemical core, with simultaneous oxygen generation. The process of oxygen generation was incomplete in cases of tin oxidation of 60% or above.

Tin oxide is not used to manufacture the oxygen generators, nor could it enter the chemical core after manufacturing. Consequently, tin oxide must have been generated through oxidation of the tin powder inside the chemical core of the oxygen generators with time.

The non-actuation mechanism of the generator can be summarised as follows:

1. the striker pin hits the pyrotechnic primer after the actuation pin is pulled out;
2. the small burst of energy produced by the pyrotechnic primer triggers a self-sustaining chemical reaction in the primary pellet;
3. as a portion of the tin fuel in the primary pellet has been oxidised, the primary pellet can produce only a lower amount of heat energy during the chemical reaction;
4. as a portion of the tin fuel in the chemical core has also been oxidised, the self-sustaining process would have needed higher temperature to start, and thus, the self-sustaining process failed to start;
5. oxygen gas generation failed to start due to the failed chemical reaction.

B/E Aerospace inspected serviceability of 3815 oxygen generators with P/N: 117042-XX manufactured between 1997 and 2015; the results of their study are discussed more in detail in Section 1.12.. Nearly all (99.5%) tested non-actuated generators manufacturing dates were between 1997 and 2004.

It can be concluded that, in general, oxygen generators with older manufacture dates became unserviceable with time.

Inspection of the possibility that moisture got into the oxygen generator and caused oxidation:

During normal operation, the airplane cabin pressure will vary between the pressure at ground level and at 10,000 feet altitude, creating an approximate 4.6 psi pressure differential between the sealed generator and the cabin. B/E Aerospace have performed multiple cycle tests on several generators, supposing that, as an effect of pressure change, moisture is able to flow into the chemical core of the generator when the generator returns to the circumstances of ground-level pressure.
However, no leakage was observed through the seals of the generators, so the manufacturer concluded that this factor was not a likely cause of tin oxidation in the chemical core.

Investigation of the oxygen concentration inside the generator:

At the end of the manufacturing process, on the solid state vessel (canister) of the oxygen generator was performed a pressure test with oxygen gas up to 30 psi and monitored for leakage to see whether the airtightness of the canister meets the requirements specified in the manufacturing technology.

Measurements performed by B/E Aerospace show that the concentration of oxygen gas inside the generator at the typical atmosphere ranges between 40% to 60% oxygen as the generator is produced.

This value decreased to 21% within one year since the manufacturing date. The oxygen concentration in older generators (those generators 13 years of age and older) was less than 21% and averaged around 17 % to 18%. Figure 5 shows the process of the change.

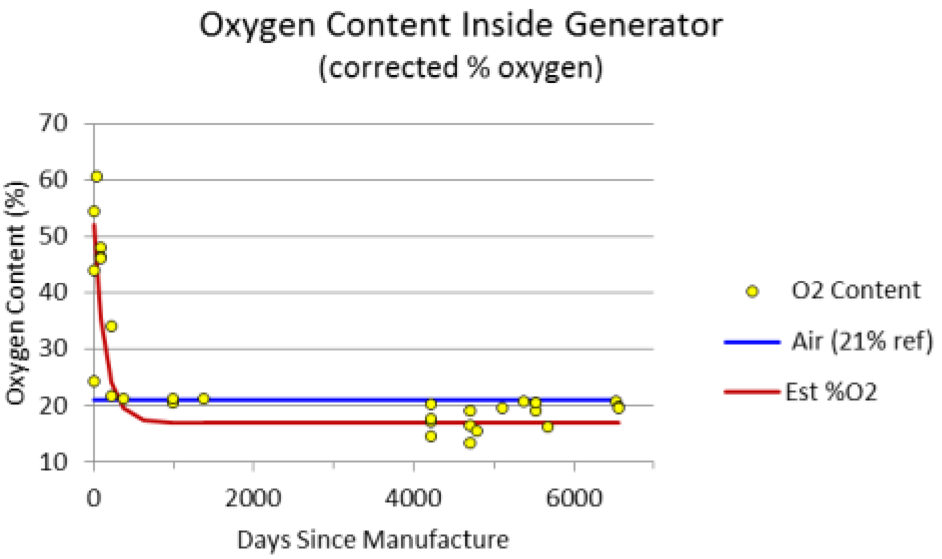


Figure 5: Changes in Oxygen content inside the generator with time

When it came to chemical analysis, tin oxidation looked the most likely. This supposition proved to be true by multiple measurements on multiple generators. For this reason, B/E Aerospace measured oxygen diffusion in order to understand the change in oxygen concentration. During the test, the generators were filled with 100% oxygen and 100% nitrogen, and oxygen gas concentration was monitored inside the generator over 3 and 4 days.

The experiment 100% oxygen gas concentration was also performed on "empty" generators which did not contain the chemical core.

The following table shows the results of measuring of oxygen diffusion:

	Measured Oxygen gas concentration			Duration of Test (days)	Estimated Oxygen Exchange Rate (cm^3/sec)
	Initial (average %)	Final (average %)	Change (average %)		
Generator back-filled with 100% O_2	99.2%	91.2%	8.0%	4	9.398×10^{-5}
Generator back-filled with 100% N_2	0.2%	3.1%	2.9%	4	3.442×10^{-5}
"Empty" Generator filled with 100% O_2	99.3%	95.3%	4.0%	3	9.402×10^{-5}

Oxygen gas concentration in the generators filled with 100% oxygen showed a similar pattern of change. Therefore, this probably was not the cause of tin oxidation.

Analysis of the tin used in the manufacturing process:

Depending on the year of manufacturing, two grades of tin powder were used for the chemical core of the oxygen generators. The particle sizes of the tin grades are different: the tin powder containing particles sized 1 to 2 microns is identified by the name Sn-100, while the average particle size in the coarser grade identified as F-10 is 20 microns on average.

B/E Aerospace reviewed the results received during the activation of generators produced with the different grades of tin powder (Figure 6 and 7)

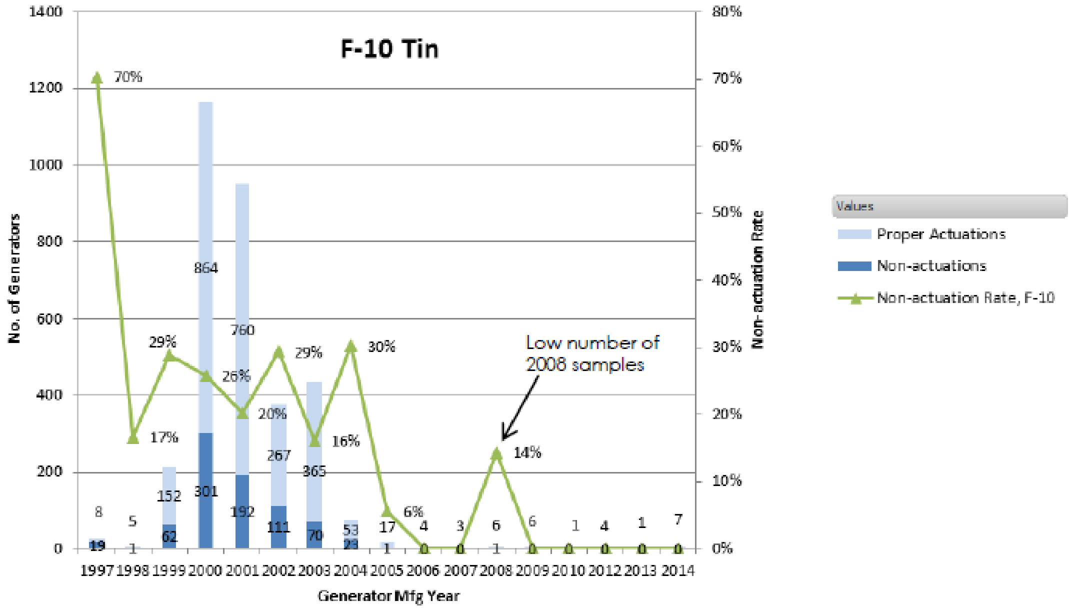


Figure 6: Test result with F-10 tin

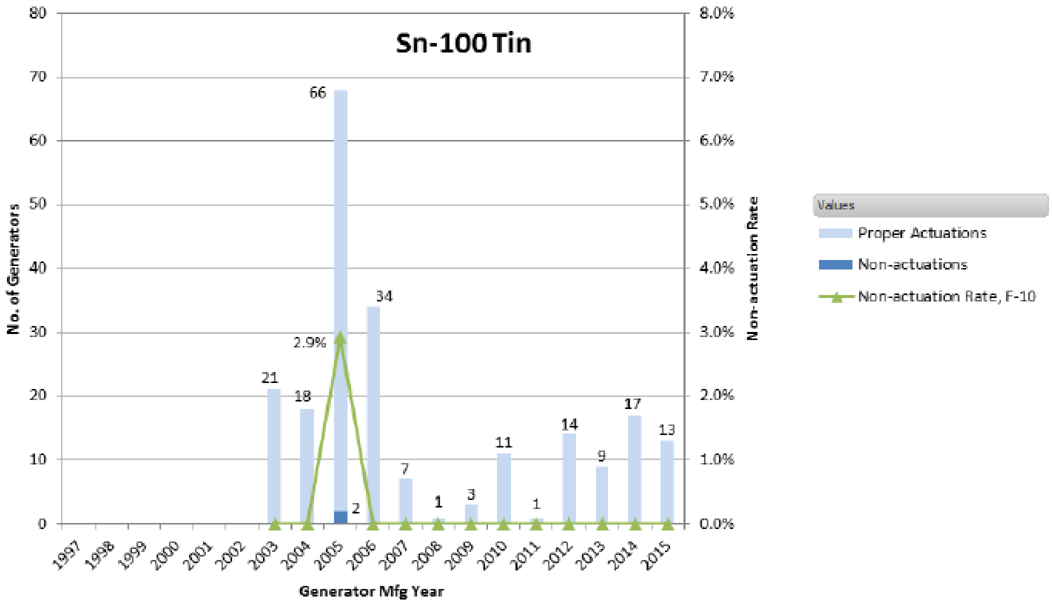


Figure 7: Test result with Sn-100 tin

Figures 6 and 7 indicate the number of generators which failed to activate in dark blue. The figures demonstrate that the two grades of tin powder used in manufacturing show significant differences. Almost all of the malfunctioned generators were made with grade F-10 tin, while almost all of the generators were made with grade Sn-100 tin were serviceable; however, the investigation should also take into account that the generators made with grade F-10 tin were manufacture a few years earlier than those with the grade Sn-100 tin.

The investigation has found that:

1. the generators manufactured earlier are more likely to be unserviceable, regardless of the tin grade used;
2. the generators made with grade F-10 tin are more likely to be unserviceable.

Since the end of 2015, the manufacturer B/E Aerospace uses grade Sn-100 tin instead of grade F-10 tin in the top layer (Layer #1) of the chemical core of the generators with P/N 117042-0X (Figure 8).

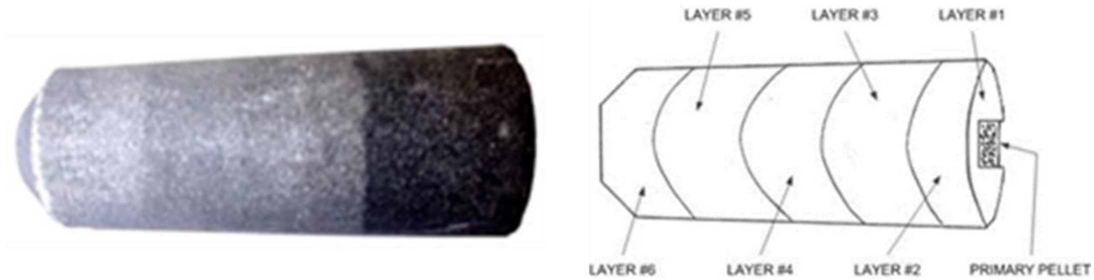


Figure 8: Layers of the chemical core in the generators with P/N 117042-0X

Analysis of tin oxidation:

Tin pest is a phenomenon where spots appear on the surface of an object made of tin, the spots keep growing with time, and finally the whole tin item crumbles. If the powder of the end-product of tin pest contacts intact tin, the typical symptoms of tin pest appear and start to spread out of the point of contact to the intact tin surface. It may also be observed that the progress of tin pest following such “infection” is faster than that of spontaneous tin pest.

The phenomenon of tin pest is caused by a crystalline structure transformation between two allotropic forms of tin. At normal atmospheric pressure, the ductile white tin with tetragonal crystal structure (ß-tin) becomes unstable below 13.2°C temperature and transforms into gray tin (α-tin) which is a more stable, brittle form of tin, with diamond crystal structure. The transformation takes place slowly. Tin pest is faster, however, when an intact white tin surface contacts gray tin somehow. Structural transformation is catalysed by gray tin of relatively large quantity.

The IC’s opinion that, during its useful life, the oxygen generator may be exposed to temperatures below 13.2°C even during storage if stored in unheated warehouse. Following installation in the airplane, the generator may also be exposed to temperatures below 13.2°C on a regular basis in winter operation during night-time storage. Therefore, the conditions leading to tin pest are available.

The IC finds that limitation of the useful life of the oxygen generators with P/N 117042-XX is the only solution to provide their serviceability.

In the course of the investigation, EASA has issued the following ADs relating to the oxygen generators under review:

– EASA AD № 2015-0117 for the airplane types Airbus A318/A319/A320/A321,
– EASA AD № 2015-0118 for the airplane types Airbus A300/A310,
– EASA AD № 2015-0119 for the airplane types Airbus A330/A340.

The above ADs reduce the useful life of chemical oxygen generators from the earlier 15 years to 10 years. The process of replacement of the generators in the airplanes will have been completed by the beginning of 2019. Subsequently, only oxygen generators that are 10 years old or younger may be in place in the airplanes.

The following table shows, in detail, the deadlines for the oxygen generators with P/N 117042-XX required in the EASA AD № 2015-0117 (see attached as Annex 1) relating to the airplane types Airbus A318/A319/A320/A321. The effective date of the AD is 08 July 2015.

Date of manufacturing	Implementation period	Implementation deadline	Time since manufacturing
January 2002	within 12 months	08 July 2016	14 years and 6 months
January 2003	within 16 months	08 November 2016	13 years and 10 months
January 2004	within 20 months	08 March 2017	13 years and 2 months
January 2005	within 24 months	08 July 2017	12 years and 6 months
January 2006	within 28 months	08 November 2017	11 years and 10 months
January 2007	within 32 months	08 March 2018	11 years and 2 months
January 2008	within 36 months	08 July 2018	10 years and 6 months
January 2009	-	January 2019	10 years
January 2010	-	January 2020	10 years

The deadlines in the ADs relating to the other two airplane families are similar.

3. Conclusions

3.1. Factual statements

According to relevant documents, the chemical oxygen generators with P/N 117042-XX, which are involved in the investigation, were installed and maintained in accordance with effective requirements.

When removed from the airplane, the oxygen generators were 5 to 7 months within the useful life specified as 15 years.

None of the oxygen generators removed from the airplane started to produce oxygen gas when activated at the maintenance workshop.

3.2. Causes of the occurrence

During the investigation, the IC came to the conclusion that the causes of the occurrence were as follows:

- a portion of the tin, which constitutes the fuel of the oxygen generator, oxidised in the primary pellet (which triggers the chemical reaction) prior to actuation, therefore insufficient heat energy was only produced by the chemical reaction,
- a portion of the tin, which constitutes the fuel of the oxygen generator, oxidised in the chemical core (which contains the chemical substances) prior to actuation, therefore a higher temperature would have been necessary to trigger the chemical reaction; the chemical core did not react, therefore the self-sustaining chemical reaction failed to start.

Factors contributing to the occurrence:

- prior to installation in the airplane, the oxygen generators might have been exposed to temperatures below 13.2°C if stored in non-heated warehouse, i.e. the conditions leading to the development and spread of tin pest were available,
- following installation in the airplane, the oxygen generators might have been exposed to temperatures below 13.2°C on a regular basis in winter operation during night-time storage; therefore, the conditions leading to the development and spread of tin pest were available;

4. Safety recommendations

4.1. Actions taken by EASA during the investigation

By means of the following ADs issued, EASA limited the period of time for which the oxygen generators may be in service in airworthy airplane:

- AD № 2015-0118 (24 June 2015) for the airplane types Airbus A300-600, A300-600ST, and A310
- AD № 2015-0117 (24 June 2015) for the airplane types Airbus A318, A319, A320, A321 (see Annex 1)
- AD № 2015-0119 (24 June 2015) for the airplane types Airbus A330 and A340.

The relevant ADs continuously reduce the useful life of the oxygen generators from 15 years to 10 years, depending on their respective dates of manufacture. Such transitional period of the AD finishes at the beginning of 2019, i.e. all airworthy airplanes type Airbus A300/A310, Airbus A318/A319/A320/A321 and Airbus A330/A340 may have only such oxygen generators with P/N 117042-XX in place which are less than 10 years old.

4.2. Safety recommendation issued during the investigation

TSB issued no safety recommendation during the investigation.

4.3. Safety recommendation issued after the investigation

The IC did not find any circumstances that would justify issuance of safety recommendations.

Budapest, 13 July 2018

....	....
Ferenc Kamasz	**Gergely Maróti**
Investigator-in-Charge	IC Member

....
Gábor Erdősi
IC Member

ANNEXES

Annex 1: AD № 2015-0117 (24 June 2015) issued by EASA

EASA AD No.: 2015-0117

EASA	AIRWORTHINESS DIRECTIVE
	AD No.: 2015-0117 **[Correction: 07 August 2015]** **Date: 24 June 2015** Note: This Airworthiness Directive (AD) is issued by EASA, acting in accordance with Regulation (EC) No 216/2008 on behalf of the European Community, its Member States and of the European third countries that participate in the activities of EASA under Article 66 of that Regulation.

This AD is issued in accordance with EU 748/2012, Part 21.A.3B. In accordance with EU 1321/2014 Annex I, Part M.A.301, the continuing airworthiness of an aircraft shall be ensured by accomplishing any applicable ADs. Consequently, no person may operate an aircraft to which an AD applies, except in accordance with the requirements of that AD, unless otherwise specified by the Agency [EU 1321/2014 Annex I, Part M.A.303] or agreed with the Authority of the State of Registry [EC 216/2008, Article 14(4) exemption].

Design Approval Holder's Name:	**Type/Model designation(s):**
AIRBUS	A318, A319, A320 and A321 aeroplanes

TCDS Number:	EASA.A.064
Foreign AD:	Not applicable
Supersedure:	This AD supersedes EASA AD 2014-0275R1 dated 19 January 2015.

ATA 35	**Oxygen – Chemical Oxygen Generators – Replacement**
Manufacturer(s):	Airbus (formerly Airbus Industrie)
Applicability:	Airbus A318-111, A318-112, A318-121, A318-122, A319-111, A319-112, A319-113, A319-114, A319-115, A319-131, A319-132, A319-133, A320-211, A320-212, A320-214, A320-215, A320-216, A320-231, A320-232, A320-233, A321-111, A321-112, A321-131, A321-211, A321-212, A321-213, A321-231 and A321-232 aeroplane models, all manufacturer serial numbers, except those that have embodied Airbus modification 33125 (gaseous system for all oxygen containers) in production.
Reason:	Reports have been received indicating premature ageing of certain chemical oxygen generators, Part Number (P/N) 117042-XX (XX representing any numerical value), manufactured by B/E Aerospace. Some operators reported that when they tried to activate generators, some older units failed to activate. Given the number of failed units reported, all generators manufactured in 1999, 2000 and 2001 were considered unreliable. This condition, if not corrected, could lead to failure of the generator to activate and consequently not deliver oxygen during an emergency, possibly resulting in injury to aeroplane occupants. To address this potential unsafe condition, Airbus issued Alert Operators Transmission (AOT) A35N006-14, making reference to B/E Aerospace Service Information Letter (SIL) D1019-01 (currently at Revision 1) and B/E Aerospace Service Bulletin (SB) 117042-35-001. Consequently, EASA issued AD 2014-0275 (later revised) to require identification and replacement of the affected oxygen generators.

	Since EASA AD 2014-0275R1 was issued, and following new investigation results, EASA have decided to introduce a life limitation concerning all P/N 117042-XX chemical oxygen generators, manufactured by B/E Aerospace. For the reason described above, this AD retains the requirements of the EASA AD 2014-0275R1, which is superseded, expands the scope of the AD to include chemical oxygen generators manufactured after 2001, and requires their removal from service before exceeding 10 years since date of manufacture. This AD is re-published to correct a template error, removing the word 'Proposed' and replacing the acronym 'PAD' with 'AD'.
Effective Date:	08 July 2015
Required Action(s) and Compliance Time(s):	Required as indicated, unless accomplished previously: **Partial restatement of the requirements of EASA AD 2014-0275R1:** (1) Within the compliance time specified in Table 1 of this AD, as applicable, identify the date of manufacture (see Appendix 1 of this AD where this is located) of each oxygen generator, having a P/N as listed in Table 1 of this AD, in accordance with the instructions of Airbus AOT A35N006-14. A review of aeroplane maintenance records is acceptable to make this identification, provided those records can be relied upon for the purpose of this requirement. (2) Within the compliance time specified in Table 1 of this AD, as applicable, remove each affected oxygen generator from service and replace it with a serviceable unit in accordance with the instructions of Airbus AOT A35N006-14 (for 15 and 22 min generators), or the instructions of B/E Aerospace SB 117042-35-001 (for 15 min generators). B/E Aerospace SIL D1019-01 Revision 1 provides instructions for the activation and the disposal of a removed oxygen generator. Airbus AOT A35N006-14 (Appendix 1) includes instructions for reporting the results of the activation (including no findings) of removed units.

Table 1 – Replacement of pre-2002 Oxygen Generators

P/N (type)	**Compliance Time**
117042-02 (15 min - 2 masks) 117042-03 (15 min - 3 masks) 117042-04 (15 min - 4 masks) 117042-22 (22 min - 2 masks) 117042-23 (22 min - 3 masks) 117042-24 (22 min - 4 masks)	For units manufactured in or before 1999, before exceeding 15 years since date of manufacture, or within 30 days after 24 December 2014 [the effective date of the original issue of EASA AD 2014-0275], whichever occurs later
	For units manufactured in 2000, within 6 months after 24 December 2014 [the effective date of the original issue of EASA AD 2014-0275]
	For units manufactured in 2001, within 12 months after 24 December 2014 [the effective date of the original issue of EASA AD 2014-0275]

	New requirements of this AD: (3) Within the compliance time as specified in Table 2 of this AD, as applicable, and, for generators with a manufacturing date 2009 or later, before exceeding 10 years since date of manufacture of the oxygen generator, remove from service each oxygen generator manufactured by B/E Aerospace and having a P/N 117042-XX, and replace it with a serviceable unit (see Note) in accordance with the instructions of Airbus AOT A35N006-14 (for 15 and 22 min generators), or the instructions of B/E Aerospace SB 117042-35-001 (for 15 min generators). Note: For the purpose of this AD, a serviceable unit is an oxygen generator having P/N 117042-XX with a manufacturing date not older than 10 years, or any other approved P/N, provided that the generator has not exceeded the limit established for that generator by the manufacturer.

Table 2 - Replacement of 2002-2008 Oxygen Generators

Year of manufacture	Compliance Time (after the effective date of this AD)
2002	Within 12 months
2003	Within 16 months
2004	Within 20 months
2005	Within 24 months
2006	Within 28 months
2007	Within 32 months
2008	Within 36 months

	(4) From the effective date of this AD, it is allowed to install on any aeroplane an oxygen generator, provided it is determined, prior to installation, that the oxygen generator is a serviceable unit (see Note).
Ref. Publications:	Airbus AOT A35N006-14 dated 10 December 2014, or Revision 01 dated 17 June 2015. B/E Aerospace SB 117042-35-001 original issue dated 10 December 2014. The use of later approved revisions of these documents is acceptable for compliance with the requirements of this AD. B/E Aerospace SIL D1019-01 Revision 1, dated 03 January 2000, provides instructions for the activation and the disposal of a removed generator.
Remarks:	1. If requested and appropriately substantiated, EASA can approve Alternative Methods of Compliance for this AD. 2. This AD was posted on 22 May 2015 as PAD 15-062 for consultation until 19 June 2015. The Comment Response Document can be found at http://ad.easa.europa.eu/. 3. Enquiries regarding this AD should be referred to the Safety Information Section, Certification Directorate, EASA. E-mail: ADs@easa.europa.eu. 4. For any question concerning the technical content of the requirements in this AD, please contact: AIRBUS – Airworthiness Office – EIAS; Fax +33 5 61 93 44 51; E-mail: account.airworth-eas@airbus.com.

EASA AD No.: 2015-0117

Appendix 1 – Passenger Oxygen Generator Date of Manufacture

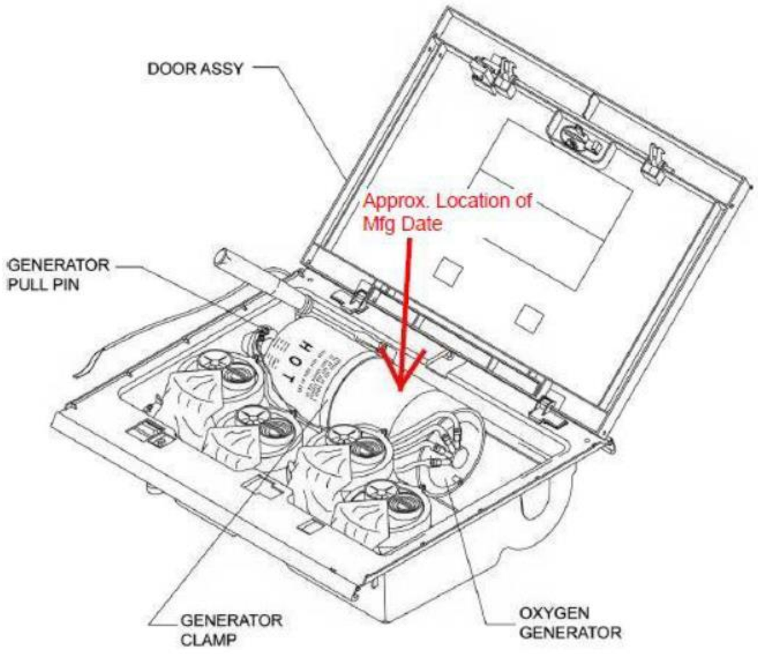


Figure 1 – Location of date (MM-YY)

Figure 2 – MFG.DATE (05-02 = May 2002) example