Federal Aviation Administration

Memorandum

Date: March 23, 2015

To: Manager, Wichita Aircraft Certification Office, ACE-115W

From: Manager, Transport Airplane Directorate, ANM-100

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Subject: INFORMATION: Equivalent Level of Safety (ELOS) Finding for 3S Certification's Crew Determination of Oxygen Quantity and Determination of Minimum Oxygen flow for the Lavatory Oxygen System on Airbus Model A319, A320, and A321 Airplanes, FAA Project # ST05968WI-T

ELOS Memo # ST05968WI-T-SM-1

Regulatory Ref.: 14 CFR 21.21(b)(1), 25.1441(c), and 25.1443(c)

This memorandum informs the certificate management aircraft certification office of an evaluation made by the Transport Airplane Directorate (TAD) on the establishment of an equivalent level of safety (ELOS) finding for Airbus Model A319, A320, and A321 airplanes.

Background

Determination of Oxygen Quantity (§ 25.1441(c))
A means must be provided to allow the crew to readily determine, during flight, the quantity of oxygen available in each source of supply per § 25.1441(c). For typical passenger systems that use gaseous oxygen, the oxygen supply is stored in large, remotely located high pressure bottles interconnected together via high pressure lines and plumbed to the passenger masks via low pressure distribution lines running the length of the airplane. Pressure transducers at the bottles or in the high pressure portion of the system measure pressure are then used to provide oxygen quantity information to the flightcrew.

The § 25.1441(c) requirement to provide a means for the crew to readily determine, during flight, the quantity of oxygen available in each source was originally required by Civil Air Regulations (CAR) Part 4b. The associated guidance at the time, Civil Aeronautics Manual (CAM) 4b, tied the CAR 4b requirement to the measurement of pressure, which corresponds to the design of typical systems at the time and today, as previously described. CAM 4b stated that at least one pressure gauge, which could be observed by a flightcrew member during flight, should be installed to indicate the pressure in each source of oxygen supply.

The ability to obtain oxygen quantity information is important for typical gaseous oxygen system designs. These designs commonly utilize several pressurized cylinders which are connected together with a manifold and act as a single supply source. By knowing the pressure in this supply source and the number of cylinders, the quantity of oxygen can be determined. Depletion of oxygen within this system due to use or leakage is not uncommon. Leakage most often occurs in the high pressure portion of the system, typically at the bottle, pressure regulators or at fittings associated with the high pressure tubing interconnecting the bottles, and can be related to improper maintenance activities or in-service wear or damage. Maintenance activities associated with this kind of system that can expose it to damage include replacing or refilling depleted bottles, removing and replacing bottles for periodic maintenance, and performing periodic leak checks. Because the quantity of oxygen within this system depletes over time, a means to determine the quantity of oxygen (i.e., system pressure) is made available to the flightcrew during flight.

3S Certification is installing a lavatory oxygen system to support compliance with Federal Aviation Administration (FAA) Airworthiness Directive (AD) 2012-11-09. The 3S Certification lavatory oxygen system differs from past lavatory oxygen systems in that the oxygen supply is in small single use gaseous bottles located within the lavatory, similar to systems that use chemical oxygen generators. These are sealed, one-time use bottles that provide oxygen to the lavatory occupants if a decompression occurs. Once expended, they cannot be refilled on the airplane and must be removed and replaced, similar to chemical oxygen generators.

Determination of Minimum Oxygen Flow (§ 25.1443(c))

Section 25.1443(c) specifies minimum mass flow requirements for passenger supplemental oxygen systems in terms of mean tracheal partial pressure, breathing rate, and tidal volume per breath at standard body temperature and pressure (BTPS), as follows:

Cabin Altitude	Mean Tracheal Oxygen Partial Pressure	Breathing Rate (constant time interval between respirations)	Tidal Volume
Above 10k feet up to and including 18.5k feet	100 mm Hg	15 liters/minute	700 cc
Above 18.5k feet up to and including 40k feet	83.8 mm Hg	30 liters/minute	1100 cc

Section 25.1443(c) requirements correspond to constant flow oxygen systems and test methodologies available at the inception of the rule forty years ago, and do not specifically correspond to how human subjects would respond if actually subjected to decompression conditions.

Historically, manufacturers substantiated compliance with § 25.1443(c) by installing passenger oxygen masks that meet Technical Standard Order (TSO)-C64a and ensure the balance of the

system can support delivery of oxygen to the mask per the § 25.1443(c) flow rates. Per the TSO, individual masks are evaluated as follows:

a. Interface the mask with test equipment that measures the partial pressure of oxygen being delivered through the mask while mechanically testing the mask's ability to deliver oxygen per the breathing rates and tidal volumes specified in § 25.1443(c).

b. Evaluate the effectiveness of the mask using human subjects. To do this, minimum allowable blood saturation of oxygen (SaO2) levels for each subject are established by measuring the subject's SaO2 levels at 10k and 14k feet pressure altitudes without supplemental oxygen by exposing the subject to these pressure altitudes in an altitude chamber. The SaO2 levels at 10k and 14k feet establish the "minimum allowable SaO2 levels" between 10k and 18.5k feet, and 18.5k and 40k feet, respectively, for each subject. Next, SaO2 levels are measured as each subject dons supplemental oxygen equipment and is exposed to reduced oxygen levels up to a pressure altitude of 40k feet to ensure that his/her SaO2 levels do not fall below his/her "minimum allowable levels."

The 3S Certification lavatory oxygen system installation delivers a high concentration of oxygen to each passenger at the start of their inhalation cycle where physiologically it is most efficiently absorbed by the alveoli. After the initial high oxygen concentration provided at the start of inhalation, the remainder of the breathing cycle consists of ambient air. The system does not continuously maintain the minimum mass flow performance parameters specified in § 25.1443(c). A high concentration of oxygen at the start of inhalation provides a level of protection from the harmful effects of hypoxia equivalent to that provided by previously certified systems because oxygen at a high concentration is provided during the phase in the respiratory cycle when it is most effectively used by the body.

Applicable regulation(s)

14 CFR 25.1441(c) and 25.1443(c)

Regulation(s) requiring an ELOS finding

14 CFR 25.1441(c) and 25.1443(c)

Description of compensating design features or alternative Methods of Compliance (MoC) which allow the granting of the ELOS (including design changes, limitations or equipment needed for equivalency)

Determination of Oxygen Quantity (§ 25.1441(c))

The 3S lavatory oxygen system differs from past systems in that the lavatory oxygen supply is in small pressurized bottles, similar to systems that use chemical oxygen generators. These are sealed, one-time use bottles that provide oxygen to the occupants of a specific lavatory if a decompression occurs. Once expended, they cannot be refilled and must be removed and replaced, similar to chemical oxygen generators. The following conditions apply to the 3S Certification oxygen bottles:

1) The bottle is designed and tested to ensure that it will retain its required quantity of oxygen throughout its expected life under foreseeable operating conditions.
2) A means is provided for maintenance to readily determine whether a bottle has discharged.
3) The life limit of the bottle is established by test and analysis.
4) Each bottle is labeled such that the expiration date can be easily determined by maintenance.
5) 3S Certification defines maintenance and inspection procedures in the Maintenance Planning Document/Maintenance Manual for FAA acceptance to ensure that:
    i) discharged bottles are removed from the airplane within a reasonably short time under normal maintenance procedures, and
    ii) bottles are not installed on the airplane past their expiration date.

Determination of Minimum Oxygen Flow (§ 25.1443(c))
The new lavatory oxygen system has a gaseous oxygen supply source. In each lavatory, the existing Chemical Oxygen Generator (COG) is removed and a high pressure oxygen bottle is installed in the place that was occupied by the removed COG. Each oxygen bottle is stand-alone (sealed, one time used, similar in concept with the COG) and provides oxygen to the lavatory occupants if a decompression occurs. The new lavatory oxygen system delivers an oxygen flow rate established by measuring the blood saturation level directly on human subjects in lieu of assuming a homogeneous gas mixture and maintaining the tracheal oxygen partial pressure specified in § 25.1443(c). Using blood oxygen saturation levels during human subject testing may result in a less conservative, yet sufficient supply of supplemental oxygen for lavatory occupants in the event of rapid decompression. Establishing the minimum oxygen flow rate based on the level of oxygen blood saturation provides a level of protection from the harmful effects of hypoxia equivalent to or better than the protection provided by the previously certified system.

Explanation of how design features or alternative Methods of Compliance (MoC) provide an equivalent level of safety to the level of safety intended by the regulation

Determination of Oxygen Quantity (§ 25.1441(c))
The lavatory oxygen cylinders may be inspected to determine if the cylinder relieved its contents. If the cylinder is expended, the cylinder must be replaced. Once a new cylinder is installed, oxygen supply for the lavatory occupants is assured because the cylinders are sealed-for-life. Maintenance planning requires periodic inspection and removal of cylinders prior to their manufacturer recommended life limit. The cylinders are designed and tested to assure they will retain their contents through their expected life span.

Determination of Minimum Oxygen Flow (§ 25.1443(c))

The 3S Certification lavatory oxygen system installation replaces the current chemical oxygen generators. The system provides a minimum time of 15 minutes of oxygen for two passengers, which is equivalent to the original rated output of the chemical oxygen generator installed in the lavatory. The system delivers a high concentration of oxygen to each passenger at the start of their inhalation cycle where physiologically it is most efficiently absorbed by the alveoli. After the initial high oxygen concentration provided at the start of inhalation, the remainder of the breathing cycle consists of ambient air. The system does not continuously maintain the minimum tracheal oxygen partial pressures specified in § 25.1443(c). However, providing a high concentration of oxygen at the start of inhalation provides a level of protection from the harmful effects of hypoxia equivalent to that provided during the phase in the respiratory cycle when it is most effectively used by the body.

FAA approval and documentation of the ELOS finding

The FAA has approved the aforementioned ELOS finding in project issue paper SM-1. This memorandum provides standardized documentation of the ELOS finding that is non-proprietary and can be made available to the public. The TAD has assigned a unique ELOS memorandum number (see front page) to facilitate archiving and retrieval of this ELOS. This ELOS memorandum number must be listed in the Limitations and Conditions section of the supplemental type certificate. An example of an appropriate statement is provided below.

Equivalent Level of Safety Findings have been made for the following regulation(s):

14 CFR 25.1441(c) Oxygen Equipment and Supply, and 14 CFR 25.1443(c) Minimum mass flow of supplemental oxygen (documented in TAD ELOS Memo ST05968WI-T-SM-1)

Original signed by
Victor Wicklund — *March 23, 2015*

Transport Airplane Directorate, Aircraft Certification Service — Date

ELOS Originated by Wichita ACO	Project Engineer David Enns	ACE-116W