Federal Aviation Administration

Memorandum

Date: 2/2/2015

To: Manager, Fort Worth Special Certification Office, ASW-190

From: Manager, Transport Airplane Directorate, ANM-100

Prepared by: Robert Hettman, ANM-112

Subject: INFORMATION: Equivalent Level of Safety (ELOS) Finding for Passenger Lavatory Oxygen System Installed on Boeing DC-9-82 & DC-9-83 Aircraft, FAA Project # K3568

ELOS Memo#: K3568-S-1

Regulatory Ref: 14 CFR 25.1441(c), 14 CFR 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 the installation of passenger lavatory oxygen systems on Boeing DC-9-82 & DC-9-83 aircraft.

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 Title 14 Code of Federal Regulations (14 CFR) 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 used to provide oxygen quantity information to the flight crew.

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 flight crew member during flight, should be installed to indicate the pressure in each source of oxygen supply.

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 lavatory oxygen system installation is designed to deliver a high concentration of oxygen to each passenger at the start of his/her 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). American Airlines, Inc. contends that 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 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)

§§ 25.1441(c), 25.1443(c)

Regulation(s) requiring an ELOS finding

§§ 25.1441(c), 25.1443(c)

Description of compensating design features or alternative standards which allow the granting of the ELOS (including design changes, limitations or equipment need for equivalency)

Determination of Oxygen Quantity (§ 25.1441(c))
The lavatory oxygen system differs from typical systems in that the oxygen supply is in small pressurized bottles located within the lavatory, similar to systems that use chemical oxygen generators. They 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.

1) The bottle is designed and tested to ensure that it retains 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) American Airlines, Inc. defines maintenance and inspection procedures in the instructions for continued airworthiness 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 measured 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 can provide 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 standards 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 are inspected to see if the cylinder has relieved its contents. If the cylinder has been 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 that they retain their contents throughout their expected life span.

Determination of Minimum Oxygen Flow (§ 25.1443(c))
The lavatory oxygen system installation is designed to deliver a high concentration of oxygen to each passenger at the start of his/her 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, by 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 S-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 should be listed in the limitations and conditions section of the supplemental type certificate (STC). An example of an appropriate statement is provided below.

Equivalent Level of Safety Findings have been made for the following regulation(s):
§ 25.1441(c) Oxygen equipment and supply
§ 25.1443(c) Minimum mass flow of supplemental oxygen
(Documented in TAD ELOS Memo K3568-S-1)

Victor Wicklund — 2/3/15

Transport Airplane Directorate,
Aircraft Certification Service — Date

ELOS Originated by: Fort Worth Special Certification Office	Project Engineer: Gregory Thiele	Routing Symbol: ASW-190