

**Proposed Special Conditions on Auxiliary Oxygen system as a supplemental oxygen source  
applicable to AgustaWestland AW139**

**Introductory Note**

The hereby presented Special Conditions have been classified as important and as such shall be subject to public consultation, in accordance with EASA Management Board decision 12/2007 dated 11 September 2007, Article 3 (2.) of which states:

"2. Deviations from the applicable airworthiness codes, environmental protection certification specifications and/or acceptable means of compliance with Part 21, as well as important special conditions and equivalent safety findings, shall be submitted to the panel of experts and be subject to a public consultation of at least 3 weeks, except if they have been previously agreed and published in the Official Publication of the Agency. The final decision shall be published in the Official Publication of the Agency."

**Identification of Issue**

The Applicant applied to EASA for approval of an STC for the installation of an auxiliary gaseous oxygen system in the AW139 rotorcraft to be used as a supplemental source, i.e., to prevent "hypoxia".

The AW139 is a large rotorcraft designed by Agusta-Westland and approved by EASA as Category A and Category B, according to a Certification Basis established on JAR 29 Amendment 3 (dated April 1<sup>st</sup>, 2002) (see CRI A-1).

The STC consists in the installation of a gaseous oxygen system for compliance with JAR OPS 3 requirements to allow operations over 10000ft pressure altitude for unpressurized helicopters. The system will supply oxygen to both crew members (pilot and co-pilot) and passengers.

JAR 29, Amdt. 3 as applicable to the rotorcraft AW 139 certification basis, as well as current certification specifications (CS 29), does not contain airworthiness requirements to be directly applicable to the installation of an oxygen system, neither with the aim at mitigating the associated hazards to the rotorcraft derived from the installation and its operation, nor prescribing minimum standards addressing the performance and reliability of the oxygen system operation (minimum mass flow rate, redundancies, duplication,...) as a supplemental oxygen source as envisaged in the application proposed for EASA approval by the Applicant.

According to the IR 21.16B (a)(2) – use of product is unconventional - in order to assess the proposed design, EASA must issues a *special condition* which is appended hereafter.

It contains technical standards applicable to gaseous oxygen system as supplemental oxygen source to let the rotorcraft be operated beyond 10000 ft and up to 18000 ft. Such special conditions will include both requirements addressing the minimum performance standards of the oxygen flow (physiological aspects) and requirements addressing design aspects aiming at minimising the additional explosion/fire risk associated to the installation of oxygen pressurised lines.

Other guidance material related to the installation of gaseous oxygen lines on unpressurised aircraft aimed at minimizing the fire/explosion hazard associated to the oxygen line installation are contained in AC 29-2C MG-6 (EMS Systems – Oxygen installation), AC 43-13-2B, SAE AIR822 and SAE AIR825.

### **Proposed Special Condition**

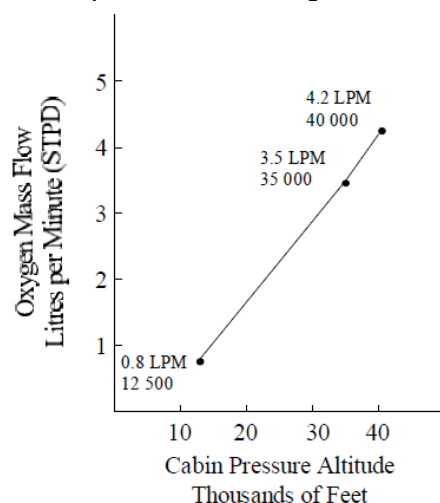
If certification with supplemental oxygen equipment is requested for operation up to and including 5486m (18000ft) (MSL), the following requirements shall be complied with.

#### **1. Oxygen Supply and distribution**

- a. The oxygen system must be free from hazards in itself, in its method of operation, and its effect upon other components
- b. Each flight-crew member on flight deck duty shall be provided with either
  - i. a demand flow oxygen equipment according to section 2.b or
  - ii. a continuous flow oxygen Demand flow oxygen equipment according to section 2.a.ii
- c. For any other occupants the supply terminals and dispensing equipment must be located to allow use of oxygen as required by the operating rules.
- d. There must be an individual dispensing unit for each occupant for whom supplemental oxygen is to be supplied. Each dispensing unit must –
  - i. Provide for effective utilization of the oxygen being delivered to the unit.
  - ii. Provide oxygen for effective utilization only to utilized units.
  - iii. Be capable of being readily placed into position on the face of the user and equipped with a means to retain the unit in position
  - iv. Cover the nose and mouth of the user; or
  - v. Be a nasal cannula, in which case one oxygen dispensing unit covering both the nose and mouth of the user must be available.
  - vi. If radio equipment is installed, the flight crew oxygen dispensing units must be designed to allow the use of that equipment and to allow communication with any other required crew member while at their assigned duty station.
  - vii. Nasal cannulas should be available in a size made specifically for infants and newborn babies.
- e. When oxygen is supplied to both pilots and passengers, the distribution system must be designed as follows:
  - i. A source of supply for the pilots and a separate source for the passengers and other crew members.
  - ii. A backup system for pilots must be provided.
  - iii. Based on maximum operating altitude for which the approval of the oxygen system is required, helicopter performance and hazards associated to the loss of oxygen, applicants could comply with the provisions of sub-paragraph ii above through appropriate system design characteristics that, in case of failure of one system, give priority to the pilots in the oxygen distribution system.
- f. If an automatic dispensing unit system is installed, the crew must be provided with a manual means to make the dispensing units immediately available in the event of failure of the automatic system.
- g. There must be a means to allow the crew to determine whether oxygen is being delivered to the dispensing equipment.
- h. There must be a means to allow the crew to readily determine, during the flight, the quantity of oxygen available in each source of supply.
- i. The flight crew must be provided with a means, readily available in flight, to turn on and shut off the oxygen supply at the high pressure source.

## 2. Minimum physiological requirements for supplemental oxygen

- a. If continuous flow oxygen equipment is installed, the installation must comply with the requirements of either sub-paragraphs (i) and (ii) or sub-paragraph (iii).
  - i. For each passenger, the minimum mass flow of supplemental oxygen required at various cabin pressure altitudes may not be less than the flow required to maintain, during inspiration and while using the oxygen equipment (including masks) provided, the following mean tracheal oxygen partial pressures:
    1. At cabin pressure altitudes above 3048m (10 000 ft) up to and including 5486m (18 000 ft), a mean tracheal oxygen partial pressure of 100 mm Hg when breathing 15 liters per minute, Body Temperature, Pressure, Saturated (BTPS) and with a tidal volume of 700 cc with a constant time interval between respirations.
  - ii. For each flight-crew member, the minimum mass flow may not be less than the flow required to maintain, during inspiration, a mean tracheal oxygen partial pressure of 149 mm Hg when breathing 15 liters per minute, BTPS, and with a maximum tidal volume of 700 cc with a constant time interval between respirations.
  - iii. The minimum mass flow of supplemental oxygen supplied for each user must be at a rate not less than that shown in the following figure for each altitude up to and including the maximum operating altitude of the rotorcraft.



- b. If demand equipment is installed for use by flight-crew members, the minimum mass flow of supplemental oxygen required for each crewmember may not be less than the flow required to maintain, during inspiration, a mean tracheal oxygen partial pressure of 122 mm Hg when breathing 20 liters per minute BTPS. In addition, there must be means to allow the crew to use undiluted oxygen at their discretion.
- c. As used in this paragraph –
  - i. BTPS means Body Temperature, and Pressure, Saturated (which is, 37°C, and the ambient pressure to which the body is exposed, minus 47 mm Hg, which is the tracheal pressure displaced by water vapour pressure when the breathed air becomes saturated with water vapour at 37°C).
  - ii. STPD means Standard, Temperature, and Pressure, Dry (which is 0°C at 760 mm Hg with no water vapour).

## 3. Protection of oxygen equipment from rupture

- a. Oxygen system components subjected to high pressure should be kept to a minimum and should be remotely installed from occupied compartments to the

extent practicable. Where such parts are installed within occupied compartments they should be protected from accidental damage

If the oxygen is stored in high pressure source, such as cylinders, these must be a type with the integral shut-off valve and regulator.

- b. Pressure limiting devices (e.g. relief valves), designed to protect parts of the system from excessive pressure, should prevent the pressures from exceeding the applicable maximum working pressure multiplied by 1.33 in the event of malfunction of the normal pressure controlling means (e.g. pressure reducing valve).
  - i. In addition, the performance of pressure limiting devices should be tested on a complete system under the conditions specified in § 4.c.i but limited to failures which are not shown to be extremely improbable.
  - ii. For testing purposes, oxygen can be replaced by an inert gas (e.g. nitrogen), however relationship between pressure and temperature would not be simulated by the inert gas and should be separately analyzed. Transient Pressure Level (TPL) shall be measured at various locations and each component of the oxygen system exposed to the TPL shall be demonstrated to sustain the pressure level.
  - iii. Each pressure source (e.g. tanks or cylinders) should be provided with a protective device (e.g. rupture disc) against overpressure. Such devices should prevent the pressure from exceeding the maximum working pressure multiplied by 1.5.
  - iv. The discharge from each protective and pressure limiting device should be vented overboard in such a manner as to preclude blockage by ice or contamination, unless it can be shown that no hazard exists by its discharge within the compartment in which it is installed. In assessing whether such hazard exists consideration should be given to the quantity and discharge rate of the oxygen released, the volume of the compartment into which it is discharging, the rate of ventilation within the compartment and the fire risk due to the installation of any potentially flammable fluid systems within the compartment.

c. Operating conditions and failure cases assessment

The hazard related to the rupture of any oxygen component due to abnormal (failure cases) working conditions or to a minor crash landing should be assessed; the following analysis/test sequence should be considered:

- i. Each element of the system should have sufficient strength to withstand the maximum working pressures and temperatures in combination with any externally applied load, arising from consideration of limit structural loads that may be acting on that part of the system in service.
  - 1. The maximum working pressure should include the maximum normal operating pressure, the transient and surge pressures, tolerances of any pressure limiting means and possible pressure variations in the normal operating modes. Transient or surge pressures need not be considered except where these exceed the maximum normal operating pressure multiplied by 1.10.
  - 2. Account should be taken of the effects of temperature up to the maximum anticipated temperature to which the system may be subjected.
  - 3. Strength demonstration using proof and burst pressure coefficients specified in Table 1 below is acceptable, unless higher stresses result when elements are subjected to combined pressure,

temperature and structural loads.

- I. The proof and burst factors in Table 1 should be applied to maximum working pressure obtained from sub-paragraph 3.c.i.1 with consideration given to the temperature of sub-paragraph 3.c.i.2.
- II. Proof pressure should be held for a minimum of 2 minutes and should not cause any leakage or permanent distortion.
- III. Burst pressure should be held for a minimum of 1 minute and should not cause rupture but some distortion is allowed.

TABLE 1

Systems Element	Proof Factor	Burst Factor
Cylinders (i.e. pressure vessels)	1.5	2.0
Flexible hoses	2.0	4.0
Pipes and couplings	1.5	3.0
Other components	1.5	2.0

- ii. Oxygen pressure sources and tubing between the sources and shut-off means should be:
  1. protected from unsafe temperatures and;
  2. located where the probability and hazard of rupture in a crash landing are minimized. At this regard JAR 29.561 provisions should be taken into considerations.

#### 4. Design criteria of oxygen components and lines to minimize fire/explosion risk

##### a. Installation criteria -

- i. Oxygen lines shall be installed so that escaping oxygen cannot cause a fire in normal operation or as a result of failure or malfunction of any surrounding systems.
- ii. Oxygen equipment and lines shall not be located in any designated fire zone and be protected from heat that may be generated in, or escape from, any designated fire zone.
- iii. High pressure shut-off valves should be designed to provide effective slow opening and closing, so as to avoid the possible risk of fire or explosion.
- iv. An analysis shall be performed to identify all possible "external" ignition mechanism. It should be demonstrated that no ignition source exist in the vicinity of the oxygen system installation, in normal operation or as a result of probable failure or malfunction of any systems.
- v. The compartments in which oxygen system components are installed shall provide adequate protection against potential contamination by liquids, lubricant (grease...), dust, etc.
- vi. The compartments in which oxygen system components are installed shall be ventilated in such a way that should a leak occur or should oxygen be discharged directly into the compartment from the protective and pressure limiting device if so designed (see requirement **1Error! Reference source not found.**), a lean mixture would result thereby reducing the likelihood of ignition. The applicant shall substantiate by analysis and/or flight test the rate of airflow changes per minute in the compartment to insure adequate ventilation.
- vii. Except for flexible lines from oxygen outlets to the dispensing units, or where

shown to be otherwise suitable to the installation, non-metallic tubing must not be used for any oxygen line that is normally pressurized during flight. Flexible low pressure non-metallic tubes shall not contain any conductive elements such as internal spring that is a potential source of ignition if electrically energized.

- viii. The installation of the system shall be such that components and lines are:
  - 1. adequately separated from electrical and fluid systems, to avoid electrical arcing - in case of conductive oxygen lines - and exposure to flammable fluids due to probable failure or malfunctions of the related systems;
  - 2. routed so as to minimize joints and sharp bends;
  - 3. clear of moving controls and other mechanisms.
- ix. When the system includes multiple bottles as oxygen sources, each source shall be protected from reverse flow or reverse pressure should a failure occur on one source. Such isolation can be achieved by installing check valves or equivalent means in an appropriate manner.
- x. Recharging systems, if installed, should be provided with means to prevent excessive rates of charging which could result in dangerously high temperatures within the system.
  - 1. The charging system should also provide protection from contamination.
  - 2. Where in-situ charging facilities are provided, the compartments in which they are located should be accessible from outside the aircraft and as remote as possible from other service points and equipment.

b. Failure mode effect Analysis (FMEA) and Safety analysis.

In order to comply with the JAR 29.1309, the applicant should demonstrate that the oxygen systems and its components are designed so that the occurrence of an undetected oxygen fire in remote area is extremely improbable. Detailed FMEA at component level and SSA at system level shall be provided to support the demonstration. To assess the consequences of system/component failures, an Oxygen Hazards Analysis (OHA) should be provided as a part of compliance with the 29.1309, taking into account the guidance defined in following section 4.c

c. Oxygen Hazards Analysis

The applicant shall provide an OHA with a detailed assessment of the potential ignition and combustion mechanism. The OHA shall consider the following:

- i. The most conservative operating conditions shall be taken into consideration including all possible failures.
- ii. The analysis shall contain all component designation and the materials of construction highlighting in particular the non-metallic material. Most materials ignite at lower temperatures in an oxygen-enriched environment than in air, auto-ignition temperature shall be established assuming a 100% enriched oxygen environment. Joints should, where possible, be assembled dry, but where compounds are used for sealing they should be approved for that purpose. The materials used shall be evaluated to determine if they are flammable under the conditions specified in § (c)(i) but limited to failures which are not shown to be extremely improbable.
- iii. The assessment shall address the identification of the possible internal

ignition mechanisms. Amongst other, the following mechanism shall be assessed:

1. adiabatic compression (pneumatic impact),
2. frictional heating,
3. mechanical impact,
4. particle impact,
5. mechanical stress or vibration,
6. static discharge,
7. electric arc,
8. chemical reaction,
9. resonance

Each ignition mechanism should be evaluated to determine if it exists in the component and the system considered under the most conservative operating conditions as specified in § 4.c.i

## **5. Placards**

- a. Where oxygen components are installed, the compartment must be placarded against the storage of oil or hydrocarbons.
- b. All oxygen outlets must be placarded.
- c. In addition, each nasal cannula or its connecting tubing must have permanently affixed –
  - i. A visible warning against smoking while in use;
  - ii. An illustration of the correct method of donning; and
- d. A visible warning against use with nasal obstructions or head colds with resultant nasal congestion.
- e. Placards should be provided, located adjacent to the servicing point, with adequate instructions covering the precautions to be observed when the system is being charged.

## **6. Rotorcraft Flight Manual Supplement**

A Rotorcraft Flight Manual Supplement must be furnished including the limitations, the normal and emergency procedures to be applied for the installed oxygen system. This document has to establish at least the following:

- a. Limits of operations of the installed system. *[Clarification has to be provided that the installed system airworthiness approval does not constitute operational approval. Operations may be conducted with non-pressurized helicopters at pressure altitudes above 10000 ft without the provision of supplemental oxygen equipment capable of storing and dispensing the oxygen supplies required, provided the cabin altitude does not exceed 10000 ft for a period in excess of 30 minutes and never exceeds 12500 ft pressure altitude].*
- b. If the nasal cannula is used to supply oxygen, enough information has to be provided for the cases where the user has a head cold. *[When a user has a cold, the tissue around the nasal end of the Eustachian tube could probably be swollen and experienced ear problems to be aggravated in flight. Flying at low altitude should be the best way in this case. This precaution may prevent a perforated or painful eardrum].*
- c. Instructions to passenger on how and when the masks or the cannula must be used. *A pre-flight briefing to all passengers should be mandated.*

- d. Provide instructions appropriate to the type of system and masks installed for the crew on placards. Include in these instructions a graph or a table with the duration of the oxygen supply for the various cylinder pressures and pressure altitudes.
- e. Functional test of the system before flight in order to assure a correct flow to all crews and passengers.

**7. Instruction for Continued Airworthiness**

- a. Instructions for continued airworthiness must be furnished in accordance with CS 29 requirements.
- b. Particular attention, warnings and details must be provided for oxygen handling.

Note: text in italics contained between brackets is to be considered Advisory Material for the corresponding paragraph.