



AEROSPACE INFORMATION REPORT

AIR5648™**REV. B**

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Superseding AIR5648A

(R) Fuel Versus Oxygen: Evaluations and Considerations

RATIONALE

New technologies such as tablets, personal devices, or electronic flight bags (EFBs) are making it easier to access and manipulate data such that other metrics, aside from quantity (liters or percentage of full) or pressure (psig), can be used to measure aircraft gaseous oxygen systems. This revision explores different metrics to expand the user's ability to manage and convert traditional metrics into other more usable and understandable metrics for the end user. Fuel and oxygen planning are essential requirements for aircraft conducting long overwater flights utilizing Equal Time Point (ETP) analysis and for those approved under ETOPS operations, as outlined in 14 CFR § 121.646 (Critical Fuel Scenario). Global expansion and the implementation of ETOPS regulations necessitate comprehensive fuel and oxygen planning for all long-range aircraft. These requirements not only enhance safety but also provide opportunities for increased operational efficiency and significant fuel cost savings across the industry. Although this document deals with critical fuel scenarios, any aircraft that flies above 10000 feet and carries supplemental oxygen can benefit from the concepts presented.

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1. SCOPE

Current regulations (e.g., Title 14 of the United States Code of Federal Regulations, or 14 CFR) define design requirements for oxygen system provisions for protection of crewmembers and passengers following emergency events such as in-flight decompression. This aerospace information report (AIR) addresses the operational oxygen system requirements for a decompression incident that may occur at any point during a long-range flight, with an emphasis for a decompression at the equal time point (ETP). This AIR identifies fuel and oxygen management contingencies and presents possible solutions for the efficient, safe, and optimum fuel/oxygen flight continuation. Oxygen management is a critical concern for all aircraft, ranging from single-engine types operating above 10000 feet to complex, high-performance aircraft equipped with supplemental oxygen systems. Proper planning ensures compliance with regulations and supports pilot and passenger safety at higher altitudes. This document provides a method which can help guide users in developing an oxygen solution for their aircraft. This document is not intended to change, modify, or alter any existing design or installation procedure and has been mostly developed for flight operations.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

AIR171	Glossary of Technical and Physiological Terms Related to Aerospace Oxygen Systems
AIR825/4	Chemical Oxygen Systems
AIR6829	Oxygen Considerations for High Elevation Airport Operations (HEAO)

2.1.2 Code of Federal Regulations (CFR) Publications

Copies of these documents are available online at <https://www.ecfr.gov>.

14 CFR Part 1	Definitions and Abbreviations
14 CFR Part 25	Airworthiness Standards: Transport Category Airplanes
14 CFR Part 91	General Operating and Flight Rules
14 CFR Part 121	Operating Requirements: Domestic, Flag, and Supplemental Operations
14 CFR Part 135	Operating Requirements: Commuter and on Demand Operations and Rules Governing Persons on Board Such Aircraft

2.1.3 EASA Publications

Available from European Union Aviation Safety Agency, Konrad-Adenauer-Ufer 3, D-50668 Cologne, Germany, Tel: +49 221 8999 000, www.easa.europa.eu.

Air OPS Commission Regulation (EU) No 965/2012, Annex IV, Part-CAT (Commercial Air Transport Operations)

NOTE: Easy Access Rules for Air Operations (EAR for Air OPS) incorporates all the new and amended Implementing Rules (IRs), as well as the Acceptable Means of Compliance and Guidance Material (AMC and GM) to the Air OPS Regulation (Regulation [EU] No 965/2012).

AMC-20 General Acceptable Means of Compliance for Airworthiness of Products, Parts and Appliances

CS-25 European Certification Specifications for Large Aeroplanes

2.1.4 FAA Publications

Available from Federal Aviation Administration, 800 Independence Avenue, SW, Washington, DC 20591, Tel: 866-835-5322, www.faa.gov.

AC 120-42B Extended Operations (ETOPS and Polar Operations)

AC 120-92A Safety Management Systems for Aviation Service Providers

2.1.5 Transport Canada Publications

Available from Transport Canada, Tower C, Place de Ville, 330 Sparks Street Ottawa, Ontario K1A 0N5, Tel: 1-800-305-2059, www.tc.gc.ca.

AWM Chapter 525 Airworthiness Manual Chapter 525, Transport Category Airplanes

CAR 605 Canadian Aviation Regulations Part VI - General Operating and Flight Rules, Subpart 5 - Aircraft Requirements

TP 6327 Safety Criteria for Approval of Extended Range Twin-Engine Operations (ETOPS)

2.2 Related Publications

The following publications are provided for information purposes only and are not a required part of this SAE Technical Report.

2.2.1 FAA Publications

Available from Federal Aviation Administration, 800 Independence Avenue, SW, Washington, DC 20591, Tel: 866-835-5322, www.faa.gov.

InFO 11010 Federal Aviation Administration (FAA) Safety Management Systems (SMS) Developments for General Aviation (GA) Operators

2.3 Abbreviations and Definitions

The following definitions, abbreviations, acronyms, and terminologies, which form a part of this document to the extent specified herein, are provided to ensure clarity and completeness of understanding.

An additional list of accepted definitions can be found in AIR171, which presents a glossary of many technical and physiological terms that are used in this document; terms can also be found in literature covering issues related to aviation oxygen systems and associated topics.

2.3.1 Abbreviations

14 CFR	Title 14 (Aeronautics and Space Section) of the Code of Federal Regulations (formerly referred to as FARs)
AC	Advisory Circular
AFM	Aircraft Flight Manual
AMC	Acceptable Means of Compliance
AWM	Airworthiness Manual (TCCA equivalent to 14 CFR Part 25)
CAR	Canadian Aviation Regulation (TCCA equivalent to 14 CFR other than Part 25)
CAT	Commercial Air Transport Operations
COG	Chemical Oxygen Generator
DCS	Decompression Sickness
EAR	Easy Access Rules
EASA	European Union Aviation Safety Agency
EC	European Community
EDTO	Extended Diversion Time Operations
EFB	Electronic Flight Bag
EU	European Union
FAA	Federal Aviation Administration.
FAR	Federal Aviation Regulations (replaced with 14 CFR)
FF	Fuel Flow
FOB	Fuel on Board
GM	Guidance Material
IRs	Implementing Rules
ICA	Instructions for Continued Airworthiness
ISA	International Standard Atmosphere
LOX	Liquid Oxygen
NTPD	Normal Temperature and Pressure Dry (21.1 °C and 101.3 kPa [760 mm Hg], and p _{H2O} = 0 kPa)
OEM	Original Equipment Manufacturer
OPA	Oxygen Planning Analysis
OPS	Operations
SMS	Safety Management Systems

TC Type Certificate

TCCA Transport Canada Civil Aviation

2.3.2 Definitions

COMPANY FLIGHT MANUAL (CFM): An airplane operating manual based on the manufacturer's AFM but revised specifically to the company's operations.

DECOMPRESSION SICKNESS (DCS): Physiological effects brought on by exposure to reduced atmospheric pressure, dependent upon the actual pressure and the duration of exposure.

EQUAL TIME POINT (ETP): The point reached on an intended route where the time required to continue flight to the destination (or a specified suitable airport ahead) is equal to that required to return to the point of departure (or a suitable airport behind). Fuel and oxygen supplies must be sufficient to cover the distances defined by the ETE.

ESTIMATED TIME EN ROUTE (ETE): Distance divided by the TAS or GS, expressed in time.

EXTENDED DIVERSION TIME OPERATIONS (EDTO): A more generalized extension of the ETOPS concept. Note that the earlier acronym ETOPS also remains in use.

EXTENDED OPERATIONS (ETOPS): Operations intended to be, or actually conducted by, a multi-engine aircraft over a route that contains a point further than 1 hour's flying time (in still air) at the normal one-engine-inoperative cruise speed from an adequate alternative airport. In most recent publications, it is referred to as Extended Diversion Time Operations (EDTO).

FLIGHT CREW OPERATING MANUAL (FCOM): Another reference used to define an Aircraft Flight Manual or a required airplane operating manual which is typically part of an aircraft documentation.

FLIGHT LEVEL (FL): A level of constant atmospheric pressure related to a reference datum of 29.92 in Hg. Each is stated in three digits that represent hundreds of feet. For example, flight level 250 represents a barometric altimeter indication of 25000 feet; flight level 255, an indication of 25500 feet (refer to 14 CFR Part 1). Flight levels are referenced above a certain altitude determined by the appropriate regulatory authority.

FUEL DURATION: Fuel supply available divided by fuel flow rate, expressed in units of time.

FUEL RANGE: Fuel available divided by fuel flow, multiplied by the TAS or GS, expressed in distance.

GROUND SPEED (GS): True airspeed plus a wind factor.

OXYGEN DURATION: The amount of oxygen available, expressed in time.

OXYGEN RANGE: The amount of oxygen available, expressed in time or distance. This can be determined by converting available (remaining) oxygen quantity (pressure, percentage of full, etc.) into liters divided by the total oxygen consumption for a specific oxygen system, which yields to remaining time. Then, multiplying this amount of remaining time by the velocity of the aircraft will provide the remaining distance.

REGULATORY OXYGEN: Refers to the oxygen requirement for a pilot to be breathing supplemental oxygen above a certain altitude, dependent upon which Operational Rule that the aircraft is operating under (e.g., 14 CFR Part 91, 121, 135, etc.).

SaO₂: Arterial Blood Oxygen Saturation typically expressed as a percentage of binding capacity of total hemoglobin of circulating blood, often denoted as SpO₂ if assessed by pulse oximetry

SPECIFIC RANGE (SR): Pounds of fuel per nautical mile.

SUPPLEMENTAL TYPE CERTIFICATE (STC): A Type Certificate issued by an aviation authority for an aircraft that has been modified from its original design.

TRUE AIRSPEED (TAS): It refers to the airspeed of an aircraft relative to undisturbed air. Also referred to as “corrected airspeed,” since it is the indicated airspeed corrected for temperature and altitude. The True Airspeed is equal to equivalent airspeed multiplied by $(p_o/p)^{1/2}$.

USABLE OXYGEN: It refers to the total oxygen amount that can be accessed for any required oxygen use.

UNUSABLE (or RESIDUAL) OXYGEN: It refers to the total amount of oxygen that, on the other hand, is inaccessible due to mechanical, digital, or system constraints. Although physically present in the oxygen cylinder, residual oxygen cannot be included in oxygen duration calculations and must be deducted from the total oxygen supply to determine the usable amount. This relationship is summarized as “Total Oxygen – Unusable Oxygen = Usable Oxygen.”

3. BACKGROUND AND PROBLEM DEFINITION

Differences regarding fuel and oxygen planning have developed over time due to technological advances in modern aircraft designs. In the past, oxygen requirements focused on the design and operation of the oxygen system. The oxygen system is designed by the Original Equipment Manufacturer (OEM). Design basis should include any oxygen flow rate the system can provide to either crew or passenger, and those flow rates should be made available in the aircraft flight manual so the operator has data that can be used for flight planning events where oxygen is used or needed to comply with regulation.

As aviation technology has progressed, procedures for preflight oxygen planning have remained relatively unchanged. The technology available today allows for an improved method of calculating and analyzing oxygen duration. This data will allow a comparison of both fuel and oxygen supplies prior to flight and oxygen quantities can be planned for much in the same way fuel quantities are planned for (refer to Air OPS CAT.OP.MPA.181). Oxygen consumption, including regulatory oxygen required for a single pilot operating above FL410/350 (as per 14 CFR Parts 121 and 135, respectively), or during flights from the ETP to the diversion airport at altitudes above 10000 feet, must be accounted for in oxygen flight planning. This requirement extends to flights over high terrain or into high-elevation airports where supplemental oxygen is necessary. In that case, operational rules such as 14 CFR § 91.211(a)(2) (14000 feet); § 121.327(b)(2), § 121.329(b)(2), and § 135.89(a)(2) (12000 feet); and Air OPS CAT.OP.MPA.285 and CAR 605.31(2) (13000 feet) must also be considered when determining oxygen needs. Comprehensive oxygen planning ensures compliance with regulations and the safety of flight operations.

Note that flying at higher cabin pressure altitudes with lower-than-normal SaO_2 levels presents increased risks to the health and safety of all aircraft occupants. These risks range from anxiety and stress that could impact flight safety and security and/or lead to medical or mental health problems for some airplane occupants to hypoxia, decompression sickness, and other similar physiological conditions. Operators should train crewmembers periodically to recognize and manage such symptoms in order to ensure, to the extent possible, that flight safety and security, as well as the health of occupants, are not compromised by extended diversions at high cabin altitudes.

Because of these increased risks, one of the flight crew's primary responsibilities is to make decisions that affect the safety and well-being of the aircraft's occupants. It should be noted that it is the individual pilot's responsibility to have adequate amounts of fuel and oxygen onboard for each flight prior to departure. Oxygen and fuel quantities must be available to the crew during flight as well as during the preplanning phases. Airworthiness rules such as (AWM) 14 CFR/CS (5)25.1441(c), state, “There must be a means to allow the crew to **readily** determine during flight the quantity of oxygen available in each source of supply.” Similarly, (AWM) 14 CFR/CS (5)25.1337(b) contain similar requirements for fuel system quantity indications.

Traditionally, the quantities for fuel and oxygen have been independently determined and displayed to the flight crew. This AIR intends to highlight the importance of using metrics that can be used by the flight crew to “**readily**” determine the quantity remaining for both systems using one common metric, e.g., time remaining or distance. This provides a flexibility where fuel and oxygen quantities remaining may be exchanged through a change in altitude, providing the pilot with another management tool, thus increasing safety of flight. Pressure is currently the most common means to indicate cylinder oxygen quantity to the flight crew. The flight crew must always have the capability to determine usable oxygen duration to make sound and accurate decisions during emergencies that require extended use of supplemental oxygen. This ensures the safety and effectiveness of flight operations, particularly in critical situations such as depressurization or prolonged high-altitude flight.