



The European Organisation for Civil Aviation Equipment
L'Organisation Européenne pour l'Équipement de l'Aviation Civile

AIRCRAFT FUEL CELL SAFETY GUIDELINES

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FOREWORD

1. This document was prepared jointly by EUROCAE Working Group 80 (WG-80) and SAE Committee AE-7AFC and was approved by the Council of EUROCAE on 8 February 2013.
2. Aircraft will need to reduce their reliance upon external auxiliary power units and have on board fuel cell powered systems. With the onset of new hydrogen fuel cell systems, new mechanical and electrical system safety design parameters will need to be provided for aircraft developers.
3. The purpose of this document is to identify the unique safety criteria for the integration of fuel cell systems into aircraft. This document relates to the overall design, construction, operation and safety of fuel cell installations for aircraft including the integration of the fuel systems (and other fuel cell systems containing potentially hazardous fluids as defined in this document) into the aircraft.
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CHAPTER 1

SCOPE

This document defines the technical guidelines for the safe integration of Proton Exchange Membrane (PEM) Fuel Cell Systems (FCS), fuel (considered to be liquid and compressed hydrogen storage types only), fuel storage, fuel distribution and appropriate electrical systems into the aircraft.

Editorial note: Today PEM systems and fuel storage represent the most mature FCS technology and currently forms the basis for this standard. Other types of fuel cell systems and fuels (including reforming technologies and electrolyzers), may be covered by a further update to this document.

1.1 PURPOSE

The purpose of this document is to provide introductory mechanical and electrical system safety guidelines that should be considered when designing fuel cell power systems for use on FAR/CS, Part 25 aircraft applications.

1.2 FIELD OF APPLICATION

This document covers primarily fuel cell systems in the various intended applications for FAR/CS, Part 25 large aircraft and the installations should comply with all appropriate regulatory requirements.

CHAPTER 2

REFERENCES

The following publications form a part of this information report to the extent specified. Unless otherwise indicated, the latest versions of these publications apply.

2.1 APPLICABLE PUBLICATIONS

The following publications form a part of this report to the extent specified herein.

2.1.1 Regulatory Publications

AC 25.1309	Advisory Circular, System Design and Analysis
AMC 25.1309	Acceptable Means of Compliance, System Design and Analysis
AMC 25.1435	Hydraulic Systems – Design, Test, Analysis and Certification
AMC 25.1453	Protection of Oxygen Equipment from Rupture
FAR/CS 25.1309	System Design and Analysis
FAR/CS 25.1435	Hydraulic Systems
FAR/CS 25.1453	Protection of Oxygen Equipment from Rupture

2.1.2 SAE Publications

Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001

AIR 64	Electrical and Electronic Equipment Cooling in Commercial Transports
AIR 825	Oxygen Systems for Aircraft
AIR 1168	Aircraft Fuel Weight Penalty Due to Air Conditioning
AIR 1277	Cooling of Military Avionic Equipment
AIR 1811	Liquid Cooling Systems
ARP 1870	Aerospace Systems Electrical Bonding and Grounding for Electromagnetic Compatibility and Safety
ARP 4752	Aerospace - Design and Installation of Commercial Transport Aircraft Hydraulic Systems
ARP 4754	Considerations for Highly-Integrated or Complex Aircraft Systems
ARP 4761	Guidelines and Methods for Conducting the Safety Assessment Process on Civil Airborne Systems and Equipment

2.1.3 EUROCAE/RTCA

Available from EUROCAE, 102, rue Etienne Dolet, 92240 MALAKOFF, France.
Website: www.eurocae.net.

ED-14/DO-160 Environmental Conditions for Airborne Equipment

2.1.4 ANSI Standards

The following publication is provided for information purposes only and is not directly applicable to this document. The publication is available from ANSI, 25 West 43rd Street, New York, NY10036-8002.

ANSI/AIAA G-095- Guide to Safety of Hydrogen and Hydrogen Systems
2004

2.1.5 IEC Publications

The following publications are available from International Electrotechnical Commission, 3; rue de Verambe, P.O. Box 131, 1211 Geneva 20 Switzerland.

IEC 60079 Electrical Apparatus for Explosive Gas Atmospheres
IEC 61882 Hazard and Operability Studies – (HAZOP studies) –
Application Guide
IEC 62282-2 Fuel Cell Technologies – Part 2: Fuel Cell Modules

2.1.6 ISO Publications

The following publications are available from ISO Central Secretariat International Organization for Standardization (ISO), 1, ch. de la Voie-Creuse, Case postale 56, CH-1211 Geneva 20, Switzerland www.standardsinfo.net

ISO 3864 Graphical Symbols -- Safety Colours and Safety Signs
ISO 11114-1 Transportable Gas Cylinders -- Compatibility of Cylinder and
Valve Materials with Gas Contents -- Part 1: Metallic Materials
ISO 11114-2 Transportable Gas Cylinders -- Compatibility of Cylinder and
Valve Materials with Gas Contents -- Part 2: Non-Metallic
Materials
ISO 11114-3 Transportable Gas Cylinders -- Compatibility of Cylinder and
Valve Materials with Gas Contents -- Part 3: Autogenous
Ignition Test in Oxygen Atmosphere
ISO 11114-4 Transportable Gas Cylinders -- Compatibility of Cylinder and
Valve Materials with Gas Contents -- Part 4: Test Methods for
Selecting Metallic Materials Resistant to Hydrogen
Embrittlement
ISO 11119 Gas Cylinders of Composite Construction - Specification and
Test Methods
ISO 13984 Liquid Hydrogen -- Land Vehicle Fuelling System Interface
ISO 13985 Liquid Hydrogen -- Land Vehicle Fuel Tanks
ISO/TS 14687 Part 2 Hydrogen Fuel - Product Specification -- Part 2: Proton
Exchange Membrane (PEM) Fuel Cell Applications for Road
Vehicles (Type II (Grade D) Fuel Quality)

ISO 15869	Gaseous Hydrogen and Hydrogen Blends – Land Vehicle Fuel Tanks
ISO/TR 15916	Basic Considerations for the Safety of Hydrogen Systems
ISO 21010	Cryogenic Vessels - Gas/Materials Compatibility
ISO 21011	Cryogenic Vessels. Valves for Cryogenic Service
ISO 21012	Cryogenic Vessels – Hoses
ISO 21013-1	Cryogenic Vessels — Pressure-Relief Accessories for Cryogenic Service — Part 1: Reclosable Pressure-Relief Valves
ISO 21013-2	Cryogenic Vessels — Pressure-Relief Accessories for Cryogenic Service — Part 2: Non-Reclosable Pressure-Relief Devices
ISO 21013-3	Cryogenic Vessels – Pressure-Relief Accessories for Cryogenic Service — Part 3: Sizing and Capacity Determination
ISO 21014	Cryogenic Vessels — Cryogenic Insulation Performance
ISO 21028-1	Cryogenic Vessels - Toughness Requirements for Materials at Cryogenic Temperature - Part 1: Temperatures below -80 °C
ISO 21028-2	Cryogenic Vessels - Toughness Requirements for Materials at Cryogenic Temperature — Part 2: Temperatures between -80 °C and -20 °C
ISO 21029-1	Cryogenic Vessels - Transportable Vacuum Insulated Vessels of not more than 1000 Litres Volume -- Part 1: Design, Fabrication, Inspection and Tests
ISO 21029-2	Cryogenic Vessels -- Transportable Vacuum Insulated Vessels of not more than 1000 Litres Volume - Part 2: Operational Requirements
ISO 23208	Cryogenic Vessels — Cleanliness for Cryogenic Service
ISO 24490	Cryogenic Vessels -- Pumps for Cryogenic Service (if the System is Equipped with one)

2.1.7 Other Publications

ASTM D 1193	Standard Specification for Reagent Water
DOT-CFFC	Basic Requirements for Fully Wrapped Carbon-Fibre Reinforced Aluminium Lined Cylinder (Dedicated to Type 3 Pressure Vessel with Aluminium Liner).
EN 12245	Transportable Gas Cylinders – Fully Wrapped Composite Cylinder
EN 13463	Non-Electrical Equipment for use in Potentially Explosive Atmospheres
NASA/TM—2003–212059	NASA Hydrogen Hazards Analysis on Components and Systems Flammability Limits and Laminar Speed of Hydrogen-Air Mixtures at Sub-Atmospheric Pressures. M. Kuznetsov, S. Kobeltl, J. Grune', T. Jordan'; Pro-Science GmbH, Germany; Institute for Energy and Nuclear Energy, Karlsruhe Institute of Technology
NFPA 2	Hydrogen Technologies Code
NACA Report 1383	Survey of Hydrogen Combustion Properties

2.2 RELATED PUBLICATIONS

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

2.2.1 Regulatory Publications

AC 20-136A	Advisory Circular, Protection of Aircraft Electrical / Electronic Systems Against the Indirect Effects of Lightning
AC 25.981-1C	Advisory Circular, Fuel Tank Ignition Source Prevention Guidelines
AC 25.981-2A	Advisory Circular, Fuel Tank Flammability
FAR/CS 25.561	General
FAR/CS 25.981	Fuel Tank Ignition Prevention

2.2.2 SAE Publications

AIR 825 12A	Oxygen Systems Integration and Performance Precautions
AIR 5744	Composite Fuel Tanks, Fuel systems Design Considerations
AIR 5128	Electrical Bonding of Aircraft Fuel Systems Plumbing systems
ARP 5412	Lightning Wave Forms
ARP 5414	Aircraft Lightning Zoning
ARP 5416	Lightning Test Methods
ARP 5577	Lightning Direct Effects Certification

2.2.3 EUROCAE/RTCA

Available from EUROCAE, 102, rue Etienne Dolet, 92240 MALAKOFF, France.
Website: www.eurocae.net.

ED-12/DO-178B	Software Considerations in Airborne Systems and Equipment Certification
ED-80/DO-254	Design Assurance Guidance for Airborne Electronic Hardware

2.2.4 ANSI Standards

ANSI/IEEE C62.41	Surge Voltages in Low-Voltage AC Power Circuits
ANSI/IEEE C62.45	Equipment Connected to Low-Voltage AC Power Circuits, Guide on Surge Testing for ANSI Z21.83—Standard for Stationary Fuel Cell Power Plants

2.2.5 IEC Publications

IEC 61508-2, 2000	Functional Safety of Electrical/Electronic/Programmable Electronic Safety-Related Systems - Part 2: Requirements for Electrical/Electronic/Programmable Electronic Safety-Related Systems
IEC 61508-4, 1998 & Corrigendum: 04-1999	Functional Safety of Electrical/Electronic/Programmable Electronic Safety-Related Systems - Part 4: Definitions and Abbreviations
IEC 61508-5, 1998 & Corrigendum: 04-1999	Functional Safety of Electrical/Electronic/Programmable Electronic Safety-Related Systems - Part 5: Examples of Methods for the Determination of Safety Integrity Levels
IEC 61508-6, 2000	Functional Safety of Electrical/Electronic/Programmable Electronic Safety-Related Systems - Part 6: Guidelines on the Application of IEC 61508-2 and IEC 61508-3
IEC 61508-7, 2000	Functional Safety of Electrical/Electronic/Programmable Electronic Safety-Related Systems - Part 7: Overview of Techniques and Measures
IEC 62282-1	Fuel Cell Technologies Part 1 Terminology
IEC 62282-2	Fuel Cell Technologies Part 2 Fuel Cell Technologies

2.2.6 ISO Publications

ISO/PAS 15594:2004	Airport Hydrogen Fuelling Facility
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2.2.7 Other Publications

CSA Component Acceptance Service No. 33

FCC Rules and Regulations Parts 15 and 18

2.2.8 Military Standards

Available from the U.S. Government, Department of Defence (DOD), Subscription Service Division, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.

MIL-STD-1472F Human Engineering

2.2.9 EU Directives

The following Directive is available for download from the European Union at <http://www.europa.eu.int/eur-lex/en/index.html>

AGARD The Challenge of the Environment, Volume 2

CHAPTER 3

DEFINITIONS AND ABBREVIATIONS

AC	Alternating Current
AC	Advisory Circular
A/C	Aircraft
AIAA	American Institute of Aeronautics and Astronautics
AIR	Aerospace Information Report
ANSI	American National Standards Institute
AMC	Acceptable Means of Compliance
ASTM	American Society for Testing and Materials
ARP	Aerospace Recommended Practice
ATA	Air Transport Association
BLEVE	Boiling Liquid Expanding Vapour Explosion
BPCU	Bus Power Control Unit
BOV	Boil Off Valve
CFFC	Carbon Fiber Full Composite
CS	Certification Specification
DOD	Department of Defence
DOP	Design Operating Pressure
DOT	Department of Transportation
ECS	Environmental Control System
ENMF	Electrical Network Management Function
EUROCAE	European Organization for Civil Aviation Equipment
FAR	Federal Aviation Regulation
FCA	Fuel Cell Aircraft
FCS	Fuel Cell Stack
FCS	Fuel Cell System
FHA	Functional Hazard Assessment
FMES	Failure Mode Effects Summary
FTA	Fault Tree Analysis
GH ₂	Gaseous Hydrogen
GHe	Gaseous Helium

HAZOP	Hazard and Operability
H ₂ O	Water
HCFC	Hydro-Chlorofluorocarbons
HPZ	High Pressure Zone
He	Helium
IEC	International Electro-technical Commission
IEEE	Institute of Electrical and Electronic Engineers
ISO	International Organization for Standardization
LEL	Lower Explosive Limit
LFL	Lower Flammability Limit
LH ₂	Liquid Hydrogen
LHSS	Liquid Hydrogen Storage System
LN ₂	Liquid Nitrogen
LOX	Liquid Oxygen
LPZ	Low Pressure Zone
LRU	Material Safety Data Sheet
NFPA	National Fire Protection Association
MAWP	Maximum Allowable Working Pressure
MIE	Minimal Ignition Energy
NASA	National Aeronautics and Space Administration
RTCA	Radio Technical Commission for Aeronautics
PEM	Proton Exchange Membrane
PAO	Polyalphaolefin
PRD	Pressure Relief Device
SOV	Shut Off Valve
SAE	Society of Automotive Engineers
SOV	Shut Off Valve
SRV	Safety Relief Valve
SSA	System Safety Assessment
TAO	Thermo Acoustic Oscillators
TMS	Thermal Management System
UFL	Upper Flammability Limit

Standard terminology for the Fuel Cell Aircraft (FCA) is provided below.