



AEROSPACE INFORMATION REPORT

AIR1083™

REV. C

Issued 1969-10
Revised 2012-04
Reaffirmed 2024-04

Superseding AIR1083B

(R) Airborne Hydraulic and Control System Survivability for Military Aircraft

RATIONALE

AIR1083B has been revised for the following reasons:

- Deleted Section 3.9 "Non-Ballistic Threats" and added a reference to MIL-HDBK-2069 Aircraft Survivability.
- Technical changes in terminology have been made to be consistent with the updated references and the deletion of section 3.9
- Other technical changes to reflect the use of technology which, at Revision B, was under development.
- The references called out in the document have been updated.
- Editorial changes have been made to improve the readability of the document.

AIR1083C has been reaffirmed to comply with the SAE Five-Year Review policy.

TABLE OF CONTENTS

1.	SCOPE.....	3
1.1	Purpose.....	3
1.2	Field of Application.....	3
2.	REFERENCES.....	3
2.1	SAE Publications.....	3
2.2	U.S. Government Publications.....	4
2.3	Other Publications.....	4
2.4	Abbreviations	4
3.	TECHNICAL REQUIREMENTS.....	4
3.1	General	4
3.2	Design Considerations.....	5
3.2.1	Design Concepts.....	5
3.2.2	Redundancy	5
3.2.3	Subsystem Arrangement	6
3.2.4	Vulnerable Area Minimization	6
3.2.5	Manual Reversion of Flight Controls.....	6
3.3	Spatial Separation and Isolation	7
3.3.1	Separation of Redundant Circuits.....	7
3.3.2	Structural Shielding	9
3.3.3	Hydraulic System Isolation Valving.....	10

SAE Executive Standards Committee Rules provide that: "This report is published by SAE to advance the state of technical and engineering sciences. The use of this report is entirely voluntary, and its applicability and suitability for any particular use, including any patent infringement arising therefrom, is the sole responsibility of the user."

SAE reviews each technical report at least every five years at which time it may be revised, reaffirmed, stabilized, or cancelled. SAE invites your written comments and suggestions.

Copyright © 2024 SAE International

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, transmitted, in any form or by any means, electronic, mechanical, photocopying, recording, or otherwise, or used for text and data mining, AI training, or similar technologies, without the prior written permission of SAE.

TO PLACE A DOCUMENT ORDER: Tel: 877-606-7323 (inside USA and Canada)
Tel: +1 724-776-4970 (outside USA)
Fax: 724-776-0790
Email: CustomerService@sae.org
http://www.sae.org

SAE WEB ADDRESS:

Full document details: SAE AIR1083C

For more information on this standard, visit
<https://www.sae.org/standards/content/AIR1083C/>

Documents

Standard, visit Sharing Hub

3.4	Leakage Protection	11
3.4.1	Line Check Valves	11
3.4.2	Reservoir Level Sensing	11
3.4.3	Fuses	12
3.4.4	Flow-Differential-Sensing Shutoff Valves	13
3.5	Hydraulic Backup Means	14
3.5.1	Means to Transfer Hydraulic Power	14
3.6	Control Jam Protection	15
3.6.1	Mechanical Jam	15
3.6.2	Hydraulic Lock.....	15
3.7	Fire Protection.....	16
3.7.1	Location of Hydraulic Equipment	16
3.7.2	Hydraulic Distribution Elements	16
3.7.3	Fluid Selection.....	17
3.7.4	Elastomeric Material	17
3.7.5	Electrical Wiring Isolation.....	17
3.8	Detailed Components Consideration	17
3.8.1	Crack-Stop Design for Pressure Vessels	17
3.8.2	The Use of Armor Plating.....	17
3.8.3	Integration and Packaging	18
3.8.4	Jam Resistant Actuator Design.....	18
3.8.5	Gas Pressure Vessels	19
4.	NOTES	20

1. SCOPE

This SAE Aerospace Information Report (AIR) provides the hydraulic and flight-control system designer with the various design options and techniques that are currently available to enhance the survivability of military aircraft.

The AIR addresses the following major topics:

- a. Design concepts and architecture (see 3.2, 3.5, and 3.6)
- b. Design implementation (see 3.3, 3.6, and 3.7)
- c. Means to control external leakage (see 3.4)
- d. Component design (see 3.8)

1.1 Purpose

This document provides the system design engineer with information and design considerations to enhance the airborne hydraulic and control system survivability under combat conditions.

1.2 Field of Application

This AIR will attempt to address the following threats:

- a. Typical small arms fire (5.56, 7.62, 12.7, and 14.5 mm AP)
- b. Cannon (20, 30, and 40 mm API/HEI)

Protection against missiles and non-ballistic threats is beyond the scope of this AIR. This is because except for electronic counter-measures or evasive maneuvers, no practical technology exists which allows an aircraft control and hydraulic system to survive a direct hit by a missile or large caliber anti-aircraft projectile.

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 724-776-4970 (outside USA), www.sae.org.

ARP584	Coiled Tubing - Corrosion Resistant Steel, Hydraulic Applications, Aerospace
ARP993	Fluidic Technology
AS1241	Fire Resistant Phosphate Ester Hydraulic Fluid for Aircraft
AIR1245	Power Sources for Fluidic Controls
ARP1280	Aerospace - Application Guide for Hydraulic Power Transfer Units

AIR1362	Aerospace Hydraulic Fluids Physical Properties
ARP4146	Coiled Tubing - Titanium Alloy, Hydraulic Applications, Aerospace
ARP4378	Aerospace - Accumulator, Hydraulic, Welded Bellows, Factory Precharged
ARP4379	Aerospace - Accumulator, Hydraulic, Cylindrical, Piston Separated
ARP4553	Aerospace - Accumulator, Hydraulic, Self-Displacing

2.1.2 U.S. Government Publications

Available from the Document Automation and Production Service (DAPS), Building 4/D, 700 Robbins Avenue, Philadelphia, PA 19111-5094, Tel: 215-697-6257, <http://assist.daps.dla.mil/quicksearch/>.

MIL PRF-83282	Hydraulic Fluid, Fire Resistant, Synthetic Hydrocarbon Base, Aircraft
MIL- PRF-87257	Hydraulic Fluid, Fire Resistant; Low Temperature, Synthetic Hydrocarbon Based, Aircraft and Missile
MIL-HDBK-2069	Aircraft Survivability
MIL-HDBK-2089	Aircraft Survivability Terms

2.1.3 Other Publications

Aircraft Survivability. Published three times a year by the Joint Aircraft Survivability Program Office (JASPO), 200 12th Street South, Crystal Gateway #4, Suite 1103, Arlington, VA 22202, Tel: (703) 607-3509, <https://jaspo.wpafb.af.mil>.

2.2 Abbreviations

AP	Armor-Piercing
API	Armor-Piercing Incendiary
HEI	High-explosive Incendiary

3. TECHNICAL REQUIREMENTS

3.1 General

A comprehensive knowledge of the hostile environment to which the air vehicle will be exposed will form the basis upon which the overall design philosophy is formulated. The designer should strive to achieve at the absolute minimum a system which provides the actuation and control capability to meet the minimum acceptable flying quality level to complete the operational mission for which the aircraft is designed; i.e., the aircraft can be controlled and the mission terminated safely, including the landing.

The approach and requirements taken by the military aircraft design team may be different for a fighter versus a transport versus a rotary-wing aircraft, but each must consider the primary modes of failure of the aircraft hydraulic and flight control system due to externally caused damage. Although the main thrust of this document is to design an integrated power generation/flight control system to survive under combat conditions, many of the approaches offered herein can also be used to increase the system reliability in general.

MIL-HDBK-2069 provides general concepts and guidelines for aircraft survivability design. Survivability terms and definitions are contained in MIL-HDBK-2089.

3.2 Design Considerations

3.2.1 Design Concepts

The survivability requirements imposed by the aircraft specification have a major impact on the development of the basic system arrangement. The requirements impact the following:

- a. Power source selection
- b. System architecture
- c. Sub-circuit isolation
- d. Supply system
- e. Electrical/fiber optic routing

The military aircraft design team must consider that common-mode failures affecting two or more systems are extremely dangerous and may result in the loss of the aircraft. Devices that potentially bridge two or more systems, such as switching valves or multistage actuators, must be designed and installed with this in mind.

3.2.2 Redundancy

System redundancy has long been used to achieve the required system reliability. A high level of mission reliability usually requires increased levels of redundancy. A failure resulting from a ballistic hit can be treated as a regular failure mode and its effect on the overall system reliability can be evaluated. Adding redundancy thus increases mission reliability and the level of survivability. Usually dual or triple redundancy suffices to meet the survivability requirements. Higher levels of redundancy eventually lead to diminishing returns and are usually not practical from a weight, space, and cost consideration.

Furthermore, the degree of redundancy also depends on:

- a. The number of flight-essential services to be powered
- b. The physical separation of the control elements, availability of any backup control power
- c. The availability of alternate control means that may be used to supply the same control capability

The major consideration in using redundancy for survivability reasons is to ensure that there is sufficient separation of the redundant components and/or subsystems. This is in order to avoid multiple damage to several components from a single hit, resulting in component or total system failure. Furthermore, when using redundant components, means must be provided to assure integrity of all portions of the redundancy including dual load path actuator rods and control valves. If this is not done, redundancy becomes illusory.

The use of independent actuation means, such as integrated actuator packages (IAPs), electrohydrostatic actuators (EHAs), or electromechanical actuators (EMAs), can be a means of enhancing survivability where power and space requirements permit such installations. The remote independent hydraulic power source or actuator, or pure electric actuator, provides for actuation redundancy. This is particularly true for aircraft with large distances between the control surfaces and/or the power sources, where a IAP, EHA, or an EMA can substantially reduce the vulnerable area of a system.

The designer must be aware of the impact of the IAPs, EHAs, and EMAs on the electrical system. The overall survivability must be evaluated considering the impact of the choice of devices used on the total aircraft system.

3.2.3 Subsystem Arrangement

Survivability can be enhanced by the judicious arrangements of subsystems in relation to the supply sources. For example, if both speed brakes and flaps are hydraulically powered, an attempt should be made to power them from separate supply sources to assure availability of at least one drag device in the event of a system loss. The same might be applied to normal and emergency operation of critical subsystems.

Consideration should also be given to the secondary effects of damage such as:

- a. Linkage or mechanism jams or disconnects
- b. Hydraulic fluid loss
- c. Open/shorted wiring

The degradation of aircraft performance may result from a loss of a subsystem. To minimize, or eliminate the effect of a subsystem failure on overall aircraft performance, the designer should address this issue when defining the overall system architecture.

Fly-by-wire (FBW) and fly-by-light systems offer the designer an increased flexibility to vary the control laws following a system failure by allowing the designer to reconfigure the system in such a manner as to negate the effect of the failure on the air vehicle controllability. In addition, the use of EMAs should be considered where pure hydraulic redundancy is insufficient to meet survivability goals.

3.2.4 Vulnerable Area Minimization

A basic method of increasing survivability is to minimize the vulnerable area of the hydraulic system. Since a smaller target is harder to hit, it, therefore, has a better chance at survival. The decision on how to accomplish the required area minimization should be made during the initial stages of the system development.

The primary methods of minimizing the vulnerable areas are:

- a. Simplification, to reduce the number of required components
- b. Increased operating pressure, to minimize line and component size (pressure levels of 5000 psi (35 000 kPa) are now being used in aerospace applications)
- c. Packaging of components to keep the total presented area to a minimum (modular packages offer a good solution to reduce the vulnerable area)
- d. Component miniaturization

3.2.5 Manual Reversion of Flight Controls

A means of increasing flight control redundancy is to revert to manual control in the event of total hydraulic power loss. This approach is usually limited to slower fixed wing or smaller rotary wing aircraft and cannot be employed on aircraft that are naturally unstable and require a control system to make the aircraft flyable.

Generally some type of retained cylinder damping is needed to maintain full stability of the control surface with loss of all hydraulic power. In the case of fly-by-wire (FBW) controls with direct mechanical reversion to provide redundancy against FBW failures, care must be taken to trim gradually to the pedal/stick position during such a reversion to avoid a damaging sudden step input. This would be particularly important if the aircraft were being flown automatically (for example in a high speed, low level terrain-following mode). In this mode the manual control may not be in an active-stand-by mode and the pilot will have little or no time to correct any pitch down.