



AEROSPACE INFORMATION REPORT

AIR560™**REV. D**

Issued 1957-05
Reaffirmed 2007-07
Revised 2025-11

Superseding AIR560C

(R) Missile Hydraulic Pumps and Their Power Sources

RATIONALE

AIR560D incorporates technical and editorial changes which were identified from the Five-Year Review of the document.

FOREWORD

Missile pumps are categorized by a moderate testing life and a relatively short operational service life. Generally, the pumps are operated at higher speeds, temperatures, and pressures than those used in manned aircraft systems, yet reliability should be extremely high since redundant systems are rarely aboard the missile. Due to the short but critical life and performance requirements, development, reliability, and acceptance testing should be focused on eliminating infant mortality failures.

Missile pumps should be compatible with very severe environmental conditions during the service life. In general, the temperature, vibration, shock, and acceleration encountered are more severe than those met in manned aircraft.

This SAE Aerospace Information Report (AIR) will be confined to describing missile environments and pump usage that differ significantly from those normally encountered in manned aircraft. Since missile pumps are usually driven by a secondary power source, and since this AIR is intended for use by systems designers, as well as pump designers, a brief description of some of these sources and some potential problem areas associated with each are included for reference. A more detailed treatment of auxiliary power sources can be found in AIR744.

Detailed test requirements are not included in this AIR since a wide variation exists between those operating conditions and environments that might be encountered on an air-to-air missile, hung beneath the wing of a fighter aircraft, and that of an ICBM (Intercontinental Ballistic Missile), launched from an environmentally controlled silo. Missile pumps frequently have their genesis in standard aircraft pumps; however, what distinguishes them from manned aircraft pumps is that they are usually operated outside of, or at the extreme of their long-life design parameters. Therefore, if a new design pump is being proposed for a missile application, the environmental conditions referenced in this AIR should be considered, as opposed to long-life operation and environmental requirements of a manned aircraft engine-driven pump. Section 5 of this report is intended to indicate typical environments for several different types of missiles. The actual requirements for a given system should be used and specified in the detailed specification.

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 © 2025 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: 1-877-606-7323 (U.S. and Canada only)
Tel: 1-724-776-4970 (outside U.S. and Canada)
Fax: 724-776-0790
Email: CustomerService@sae.org
<http://www.sae.org>

SAE WEB ADDRESS:

Full document details: SAE AIR560D

For more information on this standard, visit
<https://www.sae.org/standards/content/AIR560D/>

Documents

Standard, visit Sharing Hub

TABLE OF CONTENTS

1.	SCOPE.....	4
2.	APPLICABLE DOCUMENTS.....	4
2.1	SAE Publications.....	4
2.2	U.S. Government Publications.....	4
3.	RECOMMENDED REQUIREMENTS.....	4
3.1	Materials.....	4
3.2	Design and Construction.....	5
3.2.1	Damping of Dynamic Spring-Mass Systems.....	5
3.2.2	Temperature Effects.....	5
3.2.3	Cooling Circulation Ports.....	5
3.2.4	Pump Drive Shaft.....	5
3.2.5	Automatic Purging of Gases.....	5
3.2.6	Weight Reduction.....	5
3.2.7	Workmanship.....	5
3.2.8	Markings.....	5
3.2.9	Variation of Inlet Pressure.....	5
3.2.10	Pump Efficiency.....	6
3.2.11	Design Misalignment.....	6
3.2.12	Shaft Seal Leakage.....	6
3.2.13	Rapid Pump Start-Up.....	6
3.2.14	Operating Temperature.....	6
3.2.15	Contamination Control.....	6
3.2.16	Pump Storage.....	6
3.2.17	Control Stability of Variable Displacement Pumps.....	7
3.2.18	Pump Speed.....	7
3.2.19	Rated Pressure.....	7
3.2.20	Duty Cycle.....	7
4.	POWER SOURCES.....	7
4.1	DC Electric Motors.....	7
4.1.1	General.....	7
4.1.2	Battery Storage Limitations.....	7
4.1.3	Weight.....	8
4.1.4	Battery Starting Current.....	8
4.1.5	Electromagnetic Interference.....	8
4.2	AC Electric Motors.....	8
4.2.1	General.....	8
4.2.2	High-Power Electric Drives.....	8
4.3	Ram Air Turbines.....	8
4.3.1	General.....	8
4.3.2	Speed Control.....	9
4.3.3	Extension at High Mach Number Airspeeds.....	9
4.3.4	Start-Up Characteristics.....	9
4.3.5	Hydraulic Units Using Fixed Displacement Pumps.....	9
4.3.6	Flow-Sensitive Pressure Regulator Performance.....	9
4.3.7	Variable Displacement Pumps Controls.....	9
4.4	Turbine Drives.....	10
4.5	Positive Displacement Motors.....	10

5.	ENVIRONMENTAL CONDITIONS	11
5.1	Temperature.....	11
5.2	Vibration	11
5.2.1	Ground-to-Ground Missile Vibration	11
5.2.2	Ground-to-Air Missile Vibration	12
5.2.3	Underwater to Ground Missile Vibration	13
5.2.4	Air-to-Air Missile Vibration.....	13
5.2.5	Air-to-Ground Missile Vibration	13
5.3	Shock	16
5.3.1	Ground-to-Ground Missile Shock.....	16
5.3.2	Ground-to-Air Missile Shock	17
5.3.3	Underwater to Ground Missile Shock	17
5.3.4	Air-to-Air Missile Shock.....	18
5.3.5	Air-to-Ground Missile Shock	18
5.4	Acceleration	18
5.4.1	Ground-to-Ground Missile Acceleration.....	18
5.4.2	Ground-to-Air Missile Acceleration	18
5.4.3	Underwater to Ground Missile Acceleration.....	19
5.4.4	Air-to-Air Missile Acceleration	19
5.4.5	Air-to-Ground Missile Acceleration	19
6.	TEST REQUIREMENTS	19
6.1	General	19
6.1.1	Endurance.....	20
6.1.2	Low-Temperature Testing.....	20
7.	NOTES	20
7.1	Revision Indicator.....	20
7.2	Dimensions	20
Figure 1	Air-to-ground missile vibration test levels - captive flights	14
Figure 2	Air-to-ground missile vibration test envelope - free flight.....	14
Figure 3	Air-to-ground missile random vibration test level - free flight.....	15
Figure 4	Ground-to-ground missile shock spectrum-operating test levels.....	16
Figure 5	Ground-to-ground missile shock spectrum-nonoperating test levels.....	16
Table 1	Ground-to-ground missile vibration levels during the vibration test.....	11
Table 2	Ground-to-ground missile vibration levels after the vibration test.....	11
Table 3	Ground-to-ground missile nonoperating vibration test levels.....	12
Table 4	Ground-to-air missile vibration levels during the vibration test	12
Table 5	Ground-to-air missile vibration levels after the vibration test.....	12
Table 6	Underwater to ground missile random operating vibration test levels	13
Table 7	Underwater to ground missile sinusoidal operating vibration test levels	13
Table 8	Underwater to ground missile nonoperating shock test levels.....	17
Table 9	Underwater to ground missile operating shock test levels.....	17
Table 10	Air-to-ground missile shock test levels.....	18
Table 11	Air-to-air missile acceleration test levels.....	19

1. SCOPE

This AIR provides information about the specific requirements for missile hydraulic pumps and their associated power sources.

2. 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 SAE Publications

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

AIR744	Aerospace Auxiliary Power Sources
AIR974	Long-Term Storage of Missile Hydraulic Systems
AS598	Aerospace Microscopic Sizing and Counting of Particulate Contamination for Fluid Power Systems
AS4059	Contamination Classification for Hydraulic Fluids
AS5440	Hydraulic Systems, Military Aircraft, Design and Installation, Requirements For
AS19692	Aerospace – Military Type Variable Delivery, Pressure Compensated Hydraulic Pump

2.2 U.S. Government Publications

Copies of these documents are available online at <https://quicksearch.dla.mil>.

MIL-STD-461	Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment
MIL-STD-810	Environmental Test Methods and Engineering Guidance

3. RECOMMENDED REQUIREMENTS

3.1 Materials

All materials need to be carefully chosen for chemical and dimensional stability when subjected to extremes of temperature and varieties of hydraulic fluids.

The choice and installation of elastomeric materials are particularly affected by ranges of temperature and pressure and the chemical nature of the hydraulic fluid. Careful attention needs to be given to the requirements of the detailed specification.

Chemically active materials such as cadmium, zinc, and silver whose reactions with other materials are accelerated by high operating temperatures are not recommended to be used in contact with the operating fluid. In elevated fluid temperature and/or elevated ambient temperature applications, consideration should also be given to stress alloying with steel components. In particular, cadmium is not recommended to be used at temperatures conducive to stress alloying of steel parts.

3.2 Design and Construction

3.2.1 Damping of Dynamic Spring-Mass Systems

All dynamic spring-mass systems in the pump should be damped to an extent that assures no adverse operation under the specified vibrational requirements. Ensure that acceleration forces will not adversely affect the compensator control in variable displacement pumps.

3.2.2 Temperature Effects

All compliant members need to be chosen, designed, or installed such that any changes in strength and/or modulus of elasticity caused by changes in the temperature environment will not affect the operating characteristics of the pump.

Insofar as possible, the pump design should minimize the effect on performance resulting from changes in fluid viscosity, density, and compressibility caused by changes in temperature.

3.2.3 Cooling Circulation Ports

If cooling circulation ports are used, the flow passages in the pump should be designed so that they will not add additional pressure drop (heat) in the circulation process. In applications where the pump is contained in a reservoir, the reservoir should be capable of heat dissipation. In cases where the reservoir heat rejection is insufficient, the downstream leakage and/or system bleeds can be considered for heat dissipation.

3.2.4 Pump Drive Shaft

The pump drive shaft is recommended to not incorporate a shear section and to have at least the capability of withstanding the torque of the internal pump drive mechanism. This precludes premature failure in rapid start-ups or high-pressure surge conditions.

3.2.5 Automatic Purging of Gases

It is desired that provisions for the automatic purging of gases entrained within the fluid be included in the pump design. This frequently may not be possible, and therefore, care should be exercised in the filling and bleeding procedures used. Where possible, vacuum filling should be considered.

3.2.6 Weight Reduction

The reduction of weight is of extreme importance. This includes consideration of enclosed fluid as well as the weight of the pump structure. The use of "plug-in" pumps, manifold porting, and nonstandard mounting flanges should be considered.

3.2.7 Workmanship

Because of the stringent reliability requirements, a very high quality of workmanship is required in fabricating the pumps. In particular, great care needs to be exercised to avoid free particles, hanging burrs, or other contaminants that may dislodge during operation and initiate a malfunction within the pump or within the system in which the pump will be used.

3.2.8 Markings

Where pumps are to be operated at high temperatures, nameplates, identification tags, inspectors' marks, etc., should be of thermally inert materials and attached in a manner that will not be affected by high temperatures. For pumps submerged in oil, minimum external marking should be permitted. All marking should be either of a permanent nature or by nameplates securely attached to the pump body.

3.2.9 Variation of Inlet Pressure

Pumps should be designed so that the effects of variation in inlet pressure are minimized. System designers should be aware of the effects of variation in inlet pressure on discharge pressure and design accordingly.

3.2.10 Pump Efficiency

The overall efficiency of the pump needs to be as high as possible, consistent with the requirements of the missile and cost-effectiveness. The low flow losses may be more important than the full flow losses. Sometimes, trade-offs in these areas are possible, for example, with DC motor-driven pumps, it may be possible to improve the partial flow efficiencies at the expense of full flow efficiency by modifying the electric motor characteristics, to minimize the total power loss.

3.2.11 Design Misalignment

The pump does not need to be subjected to testing in which a design misalignment between the base of the pump mounting flange and the test mounting fixture exists unless such a possibility also exists in the actual application.

3.2.12 Shaft Seal Leakage

Shaft seal leakage, especially during storage, is frequently a problem. Storing pumps in systems with 1 to 5 psig (7 to 35 kPa) inlet pressure requires careful design in the shaft seal area. Typically, the allowable leakage is 13 drops (0.05 in³) (818 mm³) per year, static; 1 drop per 5 minutes, operational. However, some systems specify zero leakage.

Provision should be made for visually determining if leakage has occurred and for suitable ways of measuring any leakage without disassembly of the unit.

3.2.13 Rapid Pump Start-Up

Rapid start-up of the pump with only low reservoir storage inlet pressure (especially at cold temperatures) can cause pump damage and/or inability to meet initial flow and pressure requirements in some systems. Influencing factors are acceleration time, choice of fluid, reservoir type and initial pressure, pump design, and operating speed. Prefiring warm-up time and/or heater blankets are additional considerations in very low-temperature start environments.

3.2.14 Operating Temperature

Many hydraulic pumps can operate for one duty cycle well above the rated temperature. For example, AS5440 Type II pumps that have a maximum rated temperature of 275 °F (135 °C) can reliably perform one terminal cycle up to 350 to 400 °F (177 to 204 °C). Temperatures from -65 °F (-24 °C) to over +700 to 800 °F (371 to 427 °C) have been considered for missile pumps. Operation at extremely elevated (overdesign) temperatures needs to consider the limited volume of fluid in the system and relate this to limited fluid leakage requirements resulting in degraded pump performance when fluid temperatures are well above rated.

3.2.15 Contamination Control

Contamination control is a major problem in aircraft hydraulic systems. It is even more critical in missile systems. Pumps should be examined for contamination-generating characteristics and also for the ability to survive in a contaminated environment. In systems where contamination is critical, a patch test, as reflected in AS19692, should be established; the wear-out characteristics and performance degradation of the pump with oil contaminated to the level expected in the missile should be explored.

Almost all systems incorporate a filter in the outlet of the pump. Filters are usually between 3 and 10 µm, depending on the dirt sensitivity of the system and the contamination level expected. It is good practice to use either new fluid or purified fluid which is clean and has a low total water content along with a "clean up" filter during initial system operation. The filter element should be replaced with a new clean filter element before delivery.

3.2.16 Pump Storage

Indications are that pumps can operate satisfactorily after up to 5 to 15 years or longer in storage, depending on the environment, frequency of exercise, etc. Refer to AIR974 for additional information.