



AEROSPACE INFORMATION REPORT

AIR5829™

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Air in Aircraft Hydraulic Systems

RATIONALE

This Aerospace Information Report is prepared to aid engineers and technicians in the understanding of the forms and sources of air in hydraulic systems and discusses design and maintenance alternatives for reduction or elimination of the effects of air on hydraulic system performance.

AIR5829 has been reaffirmed to comply with the SAE Five-Year Review policy.

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1. SCOPE

This SAE Aerospace Information Report (AIR) discusses the forms that air may take in aircraft hydraulic systems. Further, the effects of the various air forms on system operation are addressed. Recommended system design to prevent air effects and maintenance procedures to prevent and remove air are provided. Nitrogen leakage from accumulators is also a source of gas in hydraulic systems and may compose a portion of the “air” in the hydraulic system. The term “air” in this report does not differentiate between a gas composed strictly of normal atmospheric air or one that includes a mixture of additional nitrogen as well. The discussions of the report apply equally with any proportions of atmospheric air and nitrogen in the system.

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.

AS1241	Fire Resistant Phosphate Ester Hydraulic Fluid for Aircraft
AIR1362	Aerospace Hydraulic Fluids Physical Properties
AIR1922	System Integration Factors That Affect Hydraulic Pump Life
ARP4752	Aerospace - Design and Installation of Commercial Transport Aircraft Hydraulic Systems
AS5440	Hydraulic Systems, Aircraft, Design and Installation Requirements for
AIR5451	A Guide to Landing Gear System Integration

2.1.2 U.S. Government Publications

Available from the Standardization Document Order Desk, 700 Robbins Avenue, Building 4D, Philadelphia, PA 19111-5094. Tel: 215-697-2179. <http://assist.daps.dla.mil/quicksearch/>.

MIL-PRF-5606	Military Specification Hydraulic Fluid, Petroleum Base; Aircraft, Missile and Ordnance, NATO Code Number H-515 (Inactive for New Design)
MIL-PRF-83282	Performance Specification Hydraulic Fluid, Fire Resistant Synthetic Hydrocarbon, Metric, NATO Code Number H-537
MIL-PRF-87257	Military Specification Hydraulic Fluid, Fire Resistant; Low Temperature, Synthetic Hydrocarbon Base, Aircraft and Missile, NATO Code Number H-538

2.2 Definitions

AIR: Normal earth atmosphere composed of 79% nitrogen and 21% oxygen with other gasses in minor (<1%) amounts.

HENRY'S LAW: The weight of gas absorbed is directly proportional at equilibrium to the gas pressure above the fluid.

OPEN-LOOP: This term refers to the use of a hydraulic ground cart attached to the aircraft hydraulic system with the control valve on the cart set to operate the aircraft system using the ground cart reservoir as a fluid source.

CLOSED-LOOP: This term refers to the use of a hydraulic ground cart attached to the aircraft hydraulic system with ground cart valves set to use the aircraft reservoir as a fluid source.

3. TECHNICAL DISCUSSION

3.1 Forms of Air in Closed Hydraulic Systems

3.1.1 Dissolved Air

Air is dissolved in hydraulic fluids proportional to the pressure. Henry's Law applies to the solution of air in hydraulic fluids in relation to pressure. Dissolved gas content as a function of temperature is less predictable, increasing at lower temperatures and decreasing at higher temperatures. At one atmosphere and 68 °F (20 °C), a phosphate ester hydraulic fluid, AS1241, can have 9.0 percent of air dissolved by volume at 100 percent saturation. Hydrocarbon hydraulic fluids, MIL-PRF-5606, MIL-PRF-83282 and MIL-PRF-87257, can have 11.8 percent of air under the same conditions. As an example, a regional commercial jet hydraulic system may contain 24 gallons of phosphate ester fluid. If this fluid were saturated at one atmosphere, there would be approximately 2.2 gallons by volume of air dissolved in the fluid. At one atmosphere and above, the air in the fluid remains dissolved and does not affect system operation. If the local pressure at any point drops below one atmosphere, the air within that local area will proportionately come out of solution. Figure 1 shows the air solubility of several hydraulic fluids at low pressure. Air in solution is not considered to affect performance of hydraulic components.

3.1.2 Entrained Air

Entrained air appears in fluid as froth, foam or bubbles. This is the first state of air when it comes out of solution. For example, in a sealed container containing hydraulic fluid at one atmosphere, reducing the pressure will cause air to come out of solution. This air will appear as microscopic bubbles. If the container is maintained at the lower pressure condition for a sufficient time, the bubbles will join into larger bubbles and eventually rise to the top of the container. If the pressure is increased sufficiently, the air will begin to dissolve back into the fluid at any air to fluid interface. Entrained air in sufficient quantity will affect hydraulic system performance.

3.1.3 Free Air

Free air is the accumulation of air bubbles at the local highest point in a component or tube. Free air will only be present if the container is left undisturbed, without fluid motion, for a sufficient time to allow entrained air to coalesce into a visible volume of air. Free air in sufficient quantity will affect hydraulic system performance. Free air can exist in the form of foam, consisting of thousands of minute bubbles adhering together.

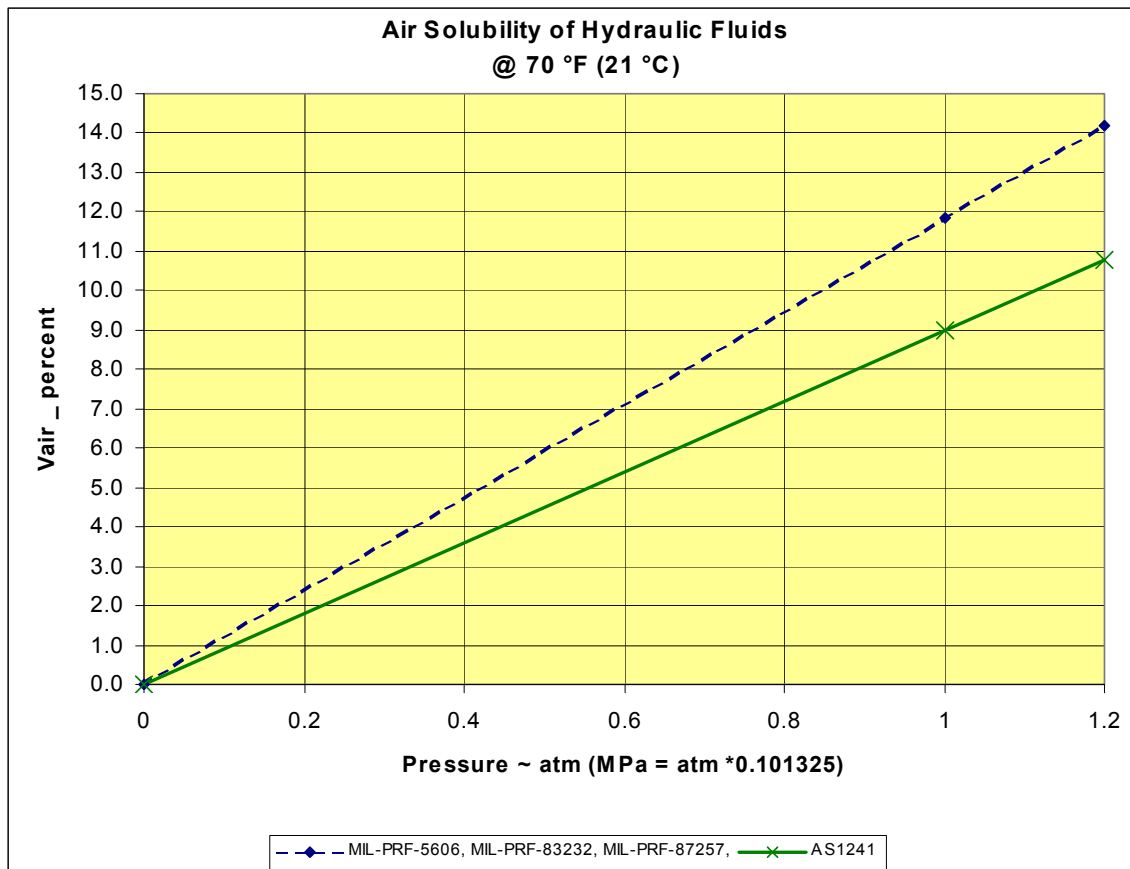


FIGURE 1 - AIR SOLUBILITY OF HYDRAULIC FLUIDS

3.2 Sources of Air in Hydraulic Systems

3.2.1 Maintenance

When the hydraulic system is disassembled at any point, the fluid in the component or tube drains by gravity unless means are taken to prevent fluid loss. The volume created by the loss of fluid is replaced by air. When the system is reassembled the air will remain in the closed system unless steps are taken to displace the air with hydraulic fluid, e.g. bleed the system.

3.2.2 Operation

Throughout the hydraulic system, air is constantly going into solution and coming out of solution as the local pressure increases and decreases and the local temperature decreases and increases. In portions of the system at maximum system operating pressure, all the air may be dissolved in the fluid. As pressure decreases when flowing through a component, the dissolved air will come out of solution and occur as entrained air until the local pressure increases again. When the aircraft is shut down and the hydraulic system is depressurized, all of the air in the system comes out of solution until the local pressure stabilizes. As a rule air will come out of solution much more quickly than it will return into solution. In the presence of a vacuum, release of dissolved air is rapid. In a controlled test, about 75 percent of dissolved air was released within two minutes; the remaining 25 percent required one-half up to one hour. A significant source of entrained air in a system may be traced to restrictors that reduce the fluid pressure below the critical point. Results have been reported of tests showing release of dissolved air with fluid flow through improperly designed restrictors.