



AEROSPACE INFORMATION REPORT

AIR6942™

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Nitrogen Absorption/Desorption (Gas Dissolution) in Aircraft Shock Absorbers

RATIONALE

Despite the fact that air (nitrogen) and mineral oil (hydraulic fluid) have been the two fluids used in aircraft shock absorbers for more than 50 years, the detailed behavior of gas in solution in shock absorbers is not well understood. As modern designs push aircraft and landing gears to finer margins, an improved understanding of this behavior is required.

TABLE OF CONTENTS

1.	SCOPE.....	2
2.	REFERENCES.....	2
2.1	Applicable Documents	2
2.1.1	SAE Publications.....	2
2.1.2	U.S. Government Publications.....	2
2.1.3	Other Publications.....	2
2.2	Acronyms	3
3.	GAS SOLUBILITY IN LIQUIDS.....	4
4.	ABSORPTION AND DESORPTION IN OLEO-PNEUMATIC SHOCK ABSORBERS	4
5.	FLUID/GAS MIXING DYNAMICS AND KINEMATICS	9
6.	TEMPERATURE DEPENDENCE.....	10
7.	BULK MODULUS.....	10
8.	DISCUSSION ON HISTORICAL GUIDELINES AND RECOMMENDATIONS FOR FUTURE WORK.....	11
9.	NOTES.....	12
9.1	Revision Indicator.....	12
Figure 1	Model of gas going into solution	5
Figure 2	Model of gas coming out of solution	6
Figure 3	Impact of gas solubility on shock absorber behavior	7
Figure 4	Pressure versus time for static shock absorber.....	8
Figure 5	Solubility versus pressure curve for MIL-PRF-5606	9
Figure 6	Compressibility curves for nitrogen assisted liquid springs	11

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Documents

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1. SCOPE

This document outlines the current state of the art in the understanding of gas in solution in shock absorber oils (hydraulic fluid, referred to hereafter as oil or fluid [refer to AIR5358B]) in unseparated shock absorbers. A literature review, overview of Henry's law, Henry's law coefficients for known gas and oil couples, in-service operational problems, lessons learned, and potential future work are discussed in the document.

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.

AIR81E	Importance of Physical and Chemical Properties of Aircraft Hydraulic Fluids
AIR1362D	Aerospace Hydraulic Fluids Physical Properties
AIR5358B	Landing Gear Shock Strut Hydraulic Fluid With Extreme Pressure and Anti-Wear Activities
AIR5829	Air in Aircraft Hydraulic Systems
ARP5908A	Landing Gear Servicing

Magorien, V., "Dissolved Gas - The Hidden Saboteur," SAE Technical Paper 931404, 1993, <https://doi.org/10.4271/931404>.

2.1.2 U.S. Government Publications

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

MIL-PRF-5606	Hydraulic Fluid, Petroleum Base, Aircraft, Missile, and Ordinance
MIL-PRF-83282	Hydraulic Fluid, Fire Resistant, Synthetic Hydrocarbon Base, Metric, Nato Code Number H-537
MIL-PRF-87257	Hydraulic Fluid, Fire Resistant, Low Temperature, Synthetic Hydrocarbon Base, Aircraft and Missile

2.1.3 Other Publications

Material related to this subject was presented during SAE A-5 panel meetings from October 2003 through October 2006. Most of the data in this report is from the presentations from the panel meetings.

- [1] Schmidt, R.K. (2021). *The design of aircraft landing gear*. SAE International.
- [2] Frolich, P.K., Tauch, E.J., Hogan, J.J., and Peer, A.A. (1931). Solubilities of gases in liquids at high pressure. *Industrial & Engineering Chemistry*, 23(5), 548-550.
- [3] McClain, J.G. and Crenshaw, B.M. (1990, October 8-12). *Landing gear improvements for transport aircraft* [Conference paper]. In *AGARD Conference Proceedings 484: Landing gear design loads*. 71st Meeting of the AGARD Structures and Materials Panel, Povoá de Varzim, Portugal.

- [4] Sheikh Al-Shabab, A.A., Grenko, B., Silva, P.A.S.F., Antoniadis, A.F., Tsoutsanis, P., and Skote, M. (2024). Unsteady multiphase simulation of oleo-pneumatic shock absorber flow. *Fluids*, 9(3), 68. <https://doi.org/10.3390/fluids9030068>.
- [5] Willich, F., Holzapfel, F., and Vrabec, J. (2025). Modeling dynamic pressure loss by absorption in oleo-pneumatic shock absorbers without separator. *Nonlinear Dynamics*. <https://doi.org/10.1007/s11071-025-10947-1>.
- [6] Wahi, M.K. (1976). Oil compressibility and polytropic air compression analysis for oleopneumatic shock struts. *Journal of Aircraft*, 13(7), 527-530. <https://doi.org/10.2514/3.44540>.
- [7] Yin, Y., Rakheja, S., Yang, J., and Boileau, P., "Effects of Entrapped Gas within the Fluid on the Stiffness and Damping Characteristics of a Hydro-Pneumatic Suspension Strut," *Commercial Vehicles* 10(1):204-209, 2017, <https://doi.org/10.4271/2017-01-0411>.
- [8] U.S. Army Materiel Command. (1971). *Engineering design handbook: Hydraulic fluids* (AMC Pamphlet No. 706-123).
- [9] Leslie, R.L. (1964). The relation of fluid properties and high temperature hydraulic performance. *A S L E Transactions*, 7(2), 180-185. <https://doi.org/10.1080/05698196408972047>.
- [10] Aksenov, A.F. (1970). *Aviation fuels, lubricants and special liquids* (Report No. FTD-MT-24-07-71). Machine translation of *Aviatsionnyye Topliva, Smazochnyye Materialy i Spetsial'nyye Zhidkosti*, 1970, Moscow, Izd-vo "Transport," pp. 1-255. Foreign Technology Division, Air Force Systems Command, U.S. Air Force.
- [11] Fick, A. Ueber diffusion [On diffusion]. (1855). *Annalen der Physik und Chemie* von J.C. Poggendorff, 94, 59-86.
- [12] Savery, R. (1973). *Fluid spring shock absorbers* (U.S. Patent No. 3747913). U.S. Patent and Trademark Office.

2.2 Acronyms

AIR	aerospace information report
ARP	aerospace recommended practice
AS	aerospace standard

3. GAS SOLUBILITY IN LIQUIDS

Significant portions of this document are adapted from reference [1]. Most gases are soluble in liquids to a certain degree. A common example is the carbon dioxide dissolved in water to make carbonated beverages.¹ Scuba divers are taught to avoid “the bends”: the formation of nitrogen bubbles in the blood if the diver ascends too quickly. In both cases, it is apparent that the liquid can contain more dissolved gas when the pressure is increased. Upon opening a carbonated beverage, the pressure within the vessel is rapidly reduced to atmospheric pressure, and bubbles of carbon dioxide are formed in the drink. Similarly, when diving, the diver and the breathing gas are under greater pressure than that at the surface. If the diver comes to the surface too quickly, the amount of nitrogen which can be held in the bloodstream is less than the amount which has dissolved during the dive, and bubbles of nitrogen can form. The relationship between pressure and the solubility of a gas in a particular liquid is governed by Henry’s law (refer to SAE Technical Paper 931404), which states that the concentration of a gas in a liquid at any given temperature is directly proportional to the partial pressure of the gas above the solution:

$$C = kP \quad (\text{Eq. 1})$$

where:

C = concentration of the gas

k = proportionality constant (often referred to as the Henry’s law constant)

P = partial pressure of the gas above the solution

Henry’s law describes the amount of gas in solution when the gas/liquid system has reached equilibrium. It is possible for less gas to be dissolved in the liquid than described by Henry’s law; it is also possible to have (at least briefly) a supersaturated condition. Sometimes, the Henry’s law constant k is expressed as the Henry’s volatility coefficient, which is $1/k$.

It is generally considered that gas which has been dissolved (or absorbed) in the liquid is filling the interstitial spaces between the liquid molecules, and as a result, this dissolved gas does not change the volume of the liquid, and it seems that it does not appreciably alter the bulk modulus (refer to AIR81E and AIR1362D) of the liquid (at least not for normal oleo-pneumatic shock absorber pressure ranges). Note that this is distinct from “entrained” gas, which refers to gas bubbles in the oil, which is associated as well with the formation of foams; refer to AIR5829 for further details on the differences between dissolved gas and entrained gas. Further discussion on this point is addressed in [Section 7](#).

4. ABSORPTION AND DESORPTION IN OLEO-PNEUMATIC SHOCK ABSORBERS

The process of a gas going into solution in a liquid is shown in [Figure 1](#) for a closed system. In the absence of mixing or agitation, the gas molecules diffuse into the liquid, generating a distribution from high concentration near the interface with the gas to a low concentration away from the gas (following Fick’s law of diffusion [11]). In this condition, the diffusion rate is dominated by the gas pressure and the oil/gas surface area. A larger surface area provides a greater possibility for diffusion to occur. Given sufficient time, the liquid will reach a point where it is fully saturated and the liquid and gas are in equilibrium. If any of the conditions (pressure, temperature, etc.) change, then the equilibrium will be upset and the process will progress toward a new equilibrium. In a closed system, such as a pressure vessel filled with gas and oil, as gas molecules migrate into the liquid, they no longer contribute their energy to generating the gas pressure above the liquid, and the pressure in the system will reduce. The equilibrium pressure will be below the initial condition pressure (if all other conditions remain constant). In a shock absorber on the ground, the pressure will remain constant (provided the aircraft weight is constant) and the shock absorber will compress (depending on the amount of stiction present in the strut), reducing the available gas volume.

¹ Some of the carbon dioxide also reacts with water to form carbonic acid; however, the ubiquitous nature of this example makes it useful to illustrate the principle.