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AEROSPACE INFORMATION REPORT

AIR 974A

Issued 10-15-68
Revised 7-1-81

LONG-TERM STORAGE OF MISSILE HYDRAULIC SYSTEMS

1. PURPOSE: Queries are not easily answered as to how long a missile hydraulic system may be inoperatively stored without affecting its final performance. This Aerospace Information Report summarizes the pertinent results of hydraulic system practices leading to greater storability.

2. SCOPE: Much of the available long-term storage test data has been reviewed and topically separated to enable the independent discussion of storage effects on fluids, seals, hydraulic components, and hydraulic systems. Comments are made in Section 4 concerning the applicability of the test results and regarding design practices for storability. Conclusions are drawn in Section 5 regarding inactive storage of hydraulic systems for at least a 7 year period.

3. TEST RESULTS AND EVALUATIONS: An interest in the length of time a missile hydraulic system can be stored was officially initiated by the USAF on the Minuteman Program in about 1957. One result of this interest was increased activity by various companies to evaluate the storage capabilities of other hydraulic systems and components.

3.1 Storage of Hydraulic Fluids: Hydraulic fluid long-term storage data are confined to information resulting from storage of MIL-H-5606A fluid samples and samples of fluid having the same petroleum base as MIL-H-5606A. This fluid is used in many aircraft and missile hydraulic systems and has been termed the standard "red oil" for a number of years. Storage tests were performed to evaluate conditions under which contaminants are precipitated in the fluid and to determine the source of the contaminants and how they might be controlled.

An analysis of the test results shows that though contaminants may agglomerate in fluids being stored, redistribution usually occurs by agitation of system operation. In addition the needle-like particles formed in MIL-H-5606A, due to conditions associated with the viscosity improver additive, will disappear by heating or system operation. Because fluid samples stored for as long as 17 years have shown no significant deviation from the original fluid specification, contamination control appears to be the only improvement needed when considering the ability to store fluids for long periods. The contamination control needed involves making sure the fluid is as clean as possible at the initiation of storage. Sampling during the storage period to evaluate contamination level is not advisable since agglomerated particles, or false readings from the needle-like particles, may indicate a contamination problem that really does not exist. System operation during the storage period does not appear to be an advisable practice, as such operation will generate contaminant particles which, when present, may result in a condition more severe than agglomeration.

Extensive tests were conducted on samples of MIL-H-5606A fluid that were removed after ten years of operational storage in Minuteman Missiles. The testing showed that no deterioration in the functional capability of the fluid occurred during the ten-year period.

The summary results of some of the more important documented fluid storage tests follow. Other references to storage effects related to fluids will be found in the discussion on seals, components and systems.

3.1.1 Summary of Reference 1 Fluid Data: Storage data from seven sources, including two fluid manufacturers, indicated no changes in properties of MIL-H-5606A (some MIL-O-5606 also) over long time periods, provided that the surfaces in contact with the fluid are not in contact with air. There is no reason why fluid, suitably formulated and kept in a clean, closed system, cannot remain usable for three years or possibly longer.

3.1.2 Summary of Data from Reference 13: Five-gallon (19 liter) samples were periodically removed from a stored 55-gallon (208 liter) drum of MIL-H-5606A over a period of more than six years. Ambient air filled the space voided by the sampling. Analysis of the samples showed no significant change in fluid properties.

3.1.3 Summary of Data from References 9 and 13: During a three-year fluid-seal-component test program samples of fluids placed in tin plate cans, glass bottles, and polyethylene bags were evaluated at four-month intervals. The bags were leached, dissolved, or both by MIL-H-5606A; other containers showed no interaction.

3.1.4 Summary of Reference 12 Fluid Data: There was no conclusive evidence that the viscosity improver additive produces deposits in normal system operation. Particle agglomeration occurred after three months storage of a 100 ml fluid sample to which was added 0.3 mg AC dust. The sample was pressurized with nitrogen during the storage period.

3.1.5 Summary of Reference 14 Fluid Data: The agglomeration of particles evidenced after fluid storage for long periods may be dispersed by agitation, but will recur by renewed storage. Particle growth can be synthetically induced in MIL-H-5606A fluid by addition of contaminants. This cannot, however, be accomplished in fluids containing polar rust preventive agents or in fluids that do not contain methacrylate viscosity-temperature improvers. The precipitate may be controlled by minimizing the original contaminant.

3.1.6 Summary of Reference 8 Fluid Data: The contamination associated with stored hydraulic fluid appears to be conclusively related to viscosity improvers in the fluid. This conclusion resulted from tests showing that heating MIL-H-5606A to 350°F (177°C) for 2 minutes after a 180°F (82°C) soak reduced the silting index considerably and in addition dissolved the needle-like crystals that form in the fluid under certain circumstances.

3.1.7 Summary of Data from References 5 and 13: The disassembly of hydraulic parts showed no evidence of corrosion following storage for 18 months of a F4U-4 aircraft with MIL-O-5606 retained in the system. It was concluded that MIL-O-5606 did not need to be replaced by preservative fluid prior to storage.

3.1.8 Summary of Data from References 2, 6 and 13: Fluid samples were removed from the B-24 "Lady Be Good" aircraft after 17 years in the Libyan Desert. The AN-VV-O-366 fluid met the original specification.

3.2 Storage Effects On Seals And Seal Materials: The greater majority of the data available from the evaluation of seals for long-term storage has been provided from shelf aging tests of elastomers. Data have been reported from tests where seals were: individually packaged, loose in closed cardboard containers, or in polyethelene bags. Uninstalled elastomers suffer no serious degradation, at least for periods of 6 to 8 years, regardless of whether they were stored in open containers or sealed. Oven aging at increased temperatures proved to be a reasonable procedure to obtain accelerated aging though the estimate of the equivalent natural age varied between 10/1 and 30/1 for 160 F (71°C) aging to 70/1 for 186 F (86°C) aging.

Swell tests with Buna N and Viton A after three years showed both materials were acceptable but that beyond three years the Buna N was somewhat more satisfactory than Viton A.

Excessive seal stiction associated with long-term storage of flight control actuators having polyurethane seals has been reported. The reason for the stiction has not been determined.

The data from the aging and swell tests do not provide conclusive evidence that seals are adequate in component installations. However, an indication of the adequacy of seals in the installed condition has been shown by some storage tests on linear actuators. Actuators incorporating O-rings of various materials were stored to evaluate seal deterioration that would lead to leakage and material cold flow that would lead to stiction. It was concluded that seal deterioration was not a serious problem since leakage was observed in only a few random cases.

The comparison of the breakaway friction before and after 14 years storage indicated some variation. One set of data showed the range of breakaway friction as 5 to 35 lb (22 to 156 N) for the actuators prior to storage and 7 to 28 lb (31 to 125 N) after storage. From these data it must be concluded that no definite pattern was established that showed evidence of seal material cold flow (compression set) resulting in increased breakaway friction following long-term storage. Another set of data showed the worst condition of change in breakaway force as 13 to 72 lb (58 to 320 N). This change on a percentage basis is great, but from a force magnitude basis is usually insignificant in a 3000 psi (21 MPa) hydraulic system for a typical missile application. However there have been recent applications where single-stage (low pressure gain) servovalves and small area actuators are employed. A large friction increase in these applications may be intolerable. The other major point is that the increased breakaway friction would only be encountered on the initial stroke of the actuator following long-term storage. Normal operating breakaway friction values would be encountered in subsequent strokes.

Based on the percentage increase in average force, from the above data, a testing agency's recommendation was that breakaway friction needed to be reduced and that an interim solution would be to exercise hydraulic systems during storage. Since this conclusion was not formulated using all of the facts, i.e., breakaway force versus total available force, it should be considered invalid. Furthermore the permanent solution to decreasing stiction is by redesign of the seal gland, which design should be thoroughly evaluated prior to recommending the expensive program of requiring system exercising during storage.

There appears to be no justified cause to doubt the ability to store elastomeric seals, either installed or loose, for periods in excess of 10 years. The summary of results of some of the more important documented seal storage tests follows.

Other references to storage effects on seals will be found in the discussion on components and systems. Section 6.3 contains a reference list of material on seal shelf aging that became available too late to be incorporated in this report.

3.2.1 Summary of Reference 13 Seal Data: Several independent evaluations have led to the conclusion that elastomers stored outside of components apparently suffer no serious degradation, regardless of whether they are stored in open containers or sealed, at least for periods of 6 to 8 years. The worst variation in seal properties of Buna N O-rings after a four year shelf aging test was as follows:

a. The change in tensile strength was + 14% from 1510 psi (10.4 MPa)
b. The change in elongation was -22% from 226%