



AEROSPACE RECOMMENDED PRACTICE

ARP5891™

REV. A

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Superseding ARP5891

Achieving Cleanliness Standards for Aircraft Hydraulic Systems During Manufacture

RATIONALE

ARP5891 has been updated to Revision A to incorporate technical and editorial changes.

FOREWORD

There are many steps in the fabrication and assembly of an aircraft hydraulic system that can create contamination, including:

- Tube extrusion requires lubricants for the dies. Tube bending requires lubricant for the bend mandrels. If they are not removed, these lubricants may pollute the hydraulic fluid.
- Cutting processes trim the tube stock to finished length. During many of the steps, solid contamination is created to some extent, affecting the contamination classification of the tubing or components in the system.

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1. SCOPE

This SAE Aerospace Recommended Practice (ARP) provides processes for achieving the required cleanliness standards during the fabrication, assembly, and functional test of aircraft hydraulic systems. It covers exclusion and removal of solid and liquid contaminants from tubing during manufacture and final assembly, flushing of the installed system, and final checks to ensure cleanliness requirements are met.

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 a 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: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

AIR1362	Aerospace Hydraulic Fluids Physical Properties
ARP994	Design of Tubing Installations for Aerospace Hydraulic Systems
ARP5376	Methods, Locations, and Criteria for System Sampling and Measuring the Solid Particle Contamination of Hydraulic Fluids
AS1241	Fire Resistant Phosphate Ester Hydraulic Fluid for Aircraft
AS4059	Aerospace Fluid Power - Contamination Classification for Hydraulic Fluids

2.2 NAS Publications

Available from Aerospace Industries Association, 1000 Wilson Boulevard, Suite 1700, Arlington, VA 22209-3928, Tel: 703-358-1000, www.aia-aerospace.org.

NAS847	Caps and Plugs, Protective, Dust and Moisture Seal
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2.3 U.S. Government Publications

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

MIL-PRF-83282	Hydraulic Fluid, Fire Resistant, Synthetic Hydrocarbon Base, Aircraft, Metric, NATO Code Number H-537
MIL-PRF-87257	Hydraulic Fluid, Fire Resistant; Low Temperature, Synthetic Hydrocarbon Base, Aircraft and Missile, NATO Code Number H-538
MIL-STD-419	Cleaning, Protecting, and Testing Piping, Tubing, and Fittings for Hydraulic Power Transmission Equipment

3. OUTLINE OF BUILD PROCESS

The following subchapters describe the fabrication, assembly, and functional test stages for the aircraft hydraulic tubing system, and the recommended steps for achieving a clean system.

3.1 Tube Fabrication

The stock tubing lengths are formed according to the defined bend data on applicable tube detail or assembly drawing for each tube elements. Following forming, the tubes should be subjected to a cleaning process that removes solid contaminants and forming lubricants from the interior and exterior of the tube detail. The cleaning method varies, but usually involves a degreasing operation of the tube followed by a rinse operation to give a clean, non-tacky interior and exterior surface on the tube. Following the degreasing process, the tubes should be capped or bagged to maintain cleanliness for the next operation. MIL-STD-419 has detailed recommendations on the cleaning of tubes. Degreaser and rinse agents should be selected to avoid chemical pollution of the tubes and therefore fluid.

3.2 Tube Assembly

Following forming, cleaning, and degreasing, fittings are attached to those tubes as called up on the tubing assembly drawing. If required, tubes that have one or more permanent fittings will be trimmed to a length with allowance for final trim in preparation for final installation. The completed assembly is subjected to a proof pressure test and identification and function tapes are applied. There are several points of quality inspection that may be applied during and following the prescribed steps:

- a. The contamination classification of the fluid used for proof pressure testing should be controlled in the test bench to one or two classes cleaner than the final system to help meet final contamination classification requirements. Test bench environment should be kept clean.
- b. The use of gas or hydraulic fluid for the proof pressure test prevents the tube interior from becoming tacky and prone to picking up contamination. Either media should be cleaner than the final system as noted above to promote meeting the delivered contamination classification requirement. The use of air for proof pressure should be limited to 150 psi (1034 kPa) for safety reasons (or a lower value on low pressure or return lines according to the system design specification).
- c. Tube assemblies should be drained, dried, capped, bagged, or plugged upon completion of this operation using fluid compatible materials for the caps and plugs. Metallic caps and plugs are recommended, but plastic plugs can be used for permanent end fittings or free end pipes (authorized in MIL-STD-419, which requires caps according to NAS847). Caps should be cleaned before their use.

3.3 Tube Installation

As the airframe subsections progress through their build process, the formed tubing is installed and clamped in accordance with released installation drawings. Usually, the system components are in place to the maximum extent possible in order to use the components to establish the final, installed position of the tubing. During this stage, tubing which requires in-place permanent joints will be trimmed, deburred, and joined. This operation can be one source of solid contaminant within the tube assemblies.

Contamination generated by this operation should be removed by flushing (see 4.1) before the operation of components, to avoid lodging contaminants within close tolerance parts in valves, actuators, and other components. It will help to reduce contamination generation at the system level if the design of permanent joints between major airframe sections is such that no trimming is necessary.

3.4 Installation Leak Check and Pressure Test

Leak testing at this point allows easier access in event of a leaking joint. The assembled tubing, with pressure-tight plugs at the endpoints, will be subjected to a low-pressure leak check, for example with hydraulic fluid or nitrogen. Leaks detected at this point are corrected. For safety reasons, high-pressure tests should be conducted using hydraulic fluid.

At this point, sections of tubing joined at this stage will receive a pressure test with the components removed. The tubing in major airframe sections may be pressure tested at low pressure and system design operating pressure (DOP) with applicable hydraulic fluid as an assembly before joining with other sections in final assembly.

4. SYSTEM CLEANUP

4.1 Tube Flushing

4.1.1 Need for Flushing

Flushing is used to remove the solid contaminants generated during the tube fabrication, installation, and assembly process with a high degree of confidence in the result. Unless verifiable quality control standards are used to guarantee that no contamination of a tube assembly has occurred during the previous processes, steps to eliminate any contaminant previously generated are needed. Once all tubing is installed and all tube joints completed, components must be removed and flushing of each tube path should be conducted to reduce any solid contamination to an established standard.

NOTE: For aircraft hydraulic systems, the flushing procedures of this document are more relevant than MIL-STD-419 flushing procedures and should be used instead of MIL-STD-419 procedures whenever possible.

4.1.2 Flushing Definition

Flushing is defined as the sequential application of sufficient flow through each tube circuit to produce turbulent flow in the circuit. For this document, a conservative Reynolds number (Nr) value of 4000 is used.

The flushing fluid should be the applicable hydraulic fluid to limit the risk of chemical pollution.

4.1.3 Fluid Cleanliness

A fluid cleanliness of at least one level cleaner than the final delivered contamination classification is recommended.

A tiered approach will simplify the clean-up of the system in the final stages when the assembly of the system is complete, as shown in the example.

If the hydraulic fluid contamination classification of AS4059 Class 7 is required for delivery, then Class 6 should be a goal during the buildup of the hydraulic system. Every component should be sufficiently cleaned such that when a fluid sample is taken from a filled component, it should meet AS4059 Class 5 contamination classification requirements.

4.1.4 Sampling Problems

Interim contamination testing on fluid samples at this stage for completed major sub-sections is conducted to verify cleanliness. The conditions for fluid samples as per ARP5376 are often not ideal at this stage of build-up. If care is not exercised in the processing of bottled samples, the results may be one or possibly two classes dirtier than obtained with online sampling.

Taking of return fluid samples directly into sample bottles may be done, but does not always give a representative sample, as the initial discharge of fluid may contain higher levels of contamination. The practice of establishing a stream of fluid into a waste container, then switching to a clean sampling bottle without disturbing anything, will improve sampling into a clean bottle.

The sampling process can be improved by the use of a valve designed for sampling assembled to a clean hose that is connected to the return side of the section being flushed. A proper sampling valve installed in the return line from the aircraft system at the ground cart will aid in getting representative samples. The continuous online sampling of the return fluid going back to the ground cart is a time-saving process, eliminating the time loop required for taking samples, submission to the lab for analysis, and getting a report on results.

4.1.5 Flushing Tool Kit

Flushing of the aircraft hydraulic system should be supported by a defined “tool kit” consisting of a selection of hose sizes and lengths, and adapter fittings in the various tube sizes to accommodate each installation. The kit should include a set of industrial ball or needle valves, and any special assemblies of hose, tubing, and valve(s) needed to flush dense, low access areas.

All fittings, hoses, and valves in the kit should be rated for the highest pressure to be applied while installed. This would usually be proof pressure.

The jumper hose, shut-off valves, and other tooling used in the flushing process should be drained and capped when not in use to help maintain cleanliness.

4.1.6 Flushing Power Source

Flushing of tubing is accomplished by using a ground cart or central hydraulic system with a high-capacity industrial filter in the return circuit. The ground cart return filter should be rated to at least the level of the finest filter in the aircraft. The hydraulic fluid used should be the same fluid specification as approved for the aircraft hydraulic system.

It is essential that the fluid used for flushing is being periodically checked for contamination classification and acceptable values for water content, chlorine content, and acidity. The fluid should be maintained at one to two levels cleaner than the requirement for the aircraft system. The use of a commercial fluid purifier on the hydraulic power source used for flushing will reduce fluid waste and maintain high-quality fluid for repeated usage.

4.2 Factors Which Affect Flushing

4.2.1 Generation of Turbulent Flow

For flushing, the ground cart pressure is raised just enough to force fluid through each circuit in the system at a flow rate that guarantees turbulent flow. Conservatively, a Reynolds number of at least 4000 should be generated. Turbulent flow is essential to generate the flow forces at the tube wall to dislodge and carry off solid contaminants in the fluid stream. The flow rates shown in this ARP are applicable for any stage of manufacture and build-up.

4.2.2 Time Required

The length of time to flush each circuit can be established with experience. The initial process can start with flushing each circuit for 10 minutes, then adjusting the time upward or downward as indicated by fluid sample results. This will establish a production process that gives the desired result with minimum time expended. The amount of time for effective flushing will be proportional to the volume of fluid to be cleaned, the efficiency of the ground cart return filter, and the amount of contamination to be removed.

When an online measurement device is installed on the return line it is efficient to record the pollution class of fluid in real-time and stop flushing as soon as the contamination classification becomes stable.

4.2.3 Fluid Temperature

Another factor, which aids in the rapid flushing of the hydraulic system, is to conduct flushing at a fluid temperature above 100 °F (38 °C). A fluid temperature of 120 to 140 °F (49 to 60 °C) temperature range is recommended. While the required Reynolds number can be generated at lower temperatures, it has been found by experience that the higher temperature gives a shorter flushing time.

With ground carts, warming the fluid to the required temperature is done by operating the cart in by-pass mode. The pump discharge is simply routed through the by-pass circuit via a restriction back to the reservoir until the desired temperature range is achieved. With the thermal mass of fluid in the cart reservoir warmed to the required range, the temperature will remain within the required range during flushing operations, which generates heat as well. A central hydraulic system may require the use of a temperature control circuit, adjustment of cooling water rate, or limited by-passing of flow through the heat exchanger to achieve the minimum fluid flushing temperature.