

	SURFACE VEHICLE RECOMMENDED PRACTICE	
	SAE	J2333 MAY2013
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Ship Systems and Equipment - Hydraulic Systems - Filter Selection Parameters		

RATIONALE

J2333 has been reaffirmed to comply with the SAE five-year review policy.

Foreword—This SAE Recommended Practice is based to a large extent on a paper prepared by Wayne K. Wilcox of the Naval Sea Systems Command titled "Selection Parameters for Hydraulic System Filters with a Comparison of Aircraft and Marine Applications" which was published in the September 1987 issue of the Naval Engineers Journal. Much of the material in this document has been extracted directly from the paper with the permission of the author.

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- 1. Scope**—This SAE Recommended Practice identifies and examines the various parameters which must be considered in selecting hydraulic system filters, their locations within the system and the dirt capacity of the filter elements.

- 1.1 Field of Application**—This document is generally applicable to all ship hydraulic systems but does not apply to personal or recreational watercraft.

2. References

- 2.1 Applicable Publications**—The following publications form a part of the specification to the extent specified herein. Unless otherwise indicated, the latest revision of SAE publications shall apply.

- 2.1.1 SAE PUBLICATIONS**—Available from Society of Automotive Engineers, Inc., 400 Commonwealth Drive, Warrendale, Pa 15096.

SAE AIR 887—Liquid Filter Ratings, Parameters and Tests

SAE J1778—Hydraulic Fluids For Marine Vehicles

SAE J1779—Hydraulic System Design Criteria for High-Performance Marine Surface Vehicles and Small Submersible Vehicles

SAE J2321—Ship Systems and Equipment—Filter Elements—Hydraulic and Lube Oil Service (Document under development)

- 2.1.2 NFPA PUBLICATIONS**—Available from National Fluid Power Association, 3333 North Mayfair Road, Milwaukee, WI 53222.

T3.10.8.8—Multi-Pass Method for Evaluating the Filter Performance (Note: Expected to be replaced with ISO 16889.)

- 2.1.3 ISO DOCUMENTS**—Available from International Organization for Standardization, 1 rue de Varembe, 1211 Geneva 20, Switzerland or from the National Fluid Power Association (NFPA).

ISO 4406—Hydraulic fluid power—Fluids—Codes for defining the level of contamination of solid particles

ISO 4572—Hydraulic fluid power—Filters—Multipass method for evaluating filtration performance of a fine filter element (Note: Expected to be replaced with ISO 16889.)

ISO 12103-1—Road vehicles—Test dust for filter evaluation—Part 1: Arizona test dust

ISO 111711—Hydraulic fluid power—Calibration of liquid automatic particle counters

- 2.1.4 DEPARTMENT OF DEFENSE PUBLICATIONS**—Available from DODSSP, Subscription Services Desk, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.

MIL-F-5504—Filter and Filter Elements, Fluid Pressure, Hydraulic Micronic Type

MIL-H-5606—Hydraulic Fluid, Petroleum Base, Aircraft and Ordnance

MIL-F-8815—Filter and Filter Elements, Fluid Pressure, Hydraulic Line, 15 Micron Absolute and 5 Micron Absolute, Type II Systems, General Specification for

MIL-F-17111—Fluid, Power Transmission

MIL-L-17331—Lubricating Oil, Steam Turbine and Gear, Moderate Service

MIL-PRF-17672—Hydraulic Fluid, Petroleum, Inhibited

MIL-H-19457—Hydraulic Fluid, Fire-Resistant, Non-Neurotoxic

MIL-H-22072—Hydraulic Fluid, Catapult, NATO Code Number H-579

MIL-F-24402—Filter (Hydraulic), Filter Elements (High Efficiency) and Filter Differential Pressure Indicators
MIL-F-24402/4—Filter Elements, Hydraulic, Disposable (Expected to be replaced by SAE J2321)
MIL-F-24702—Filter Elements, Hydraulic, Disposable, General Specification for (Expected to be replaced by SAE J2321 when issued)
MIL-PRF-83282—Hydraulic Fluid, Fire Resistant, Synthetic Hydrocarbon Base, Aircraft, Metric, NATO Code Number H-537

2.2 Other Publications

Downs, David C., "Clean hydraulics cuts downtime," Machine Design, Dec. 14, 1995, pg. 113-119
Needleman, W. M., "Filtration," STLE Handbook of Lubrication and Tribology, E. R. Booser, Ed., CRC Press, 1994
Pall Industrial Hydraulics Corporation, "Contamination Control and Filtration Fundamentals," 1993, 2200 Northern Blvd., East Hills, NY 11548-1289
Parker Hannifin Corporation, "The Handbook of Hydraulic Filtration," Hydraulic Filter Division, 16810 Fulton County Road #2, Metamora, OH 43540
Vickers, Incorporated "Vickers Guide to Systemic Contamination Control, 12/1992. P.O. Box 302, Troy, MI 48007-302
Wilcox, Wayne K., "Selection Parameters for Hydraulic System Filters with a Comparison of Aircraft and Marine Applications," Naval Engineers Journal, Sept. 1987, Vol. 99, No. 5, pp. 62-70
Zingaro, A. "Walking the fluid cleanliness tightrope, Part 5: Fluid cleanliness standards, the Multipass Test, Beta Ratios, Contaminant loading, particle capture efficiency, and filter selection and location," Hydraulic & Pneumatics, March 1996. (Reprint of entire series available from Parker Hannifin Corporation, Filtration Group, Cleveland, Ohio 44112.)

3. Definitions

- 3.1 Filtration Efficiency**—Efficiency ratings measure the ability of a filter element to remove contaminants. Various efficiency ratings are described as follows:
- 3.2 Absolute Rating**—The diameter of the largest hard spherical particle (usually a glass bead) which will pass through the filter medium under specified conditions. (Since contaminants are rarely spherical, the absolute rating cannot be correlated with efficiency rating and is usually less significant in defining filter performance than is the efficiency rating. When using a multi-pass test to determine efficiency, the particle size at which the filtration ratio is 75 or 100 is sometimes referred to as the "absolute" rating).
- 3.3 Filtration Ratio (Beta Ratio)**—A numerical rating which is the ratio of particles greater than a given size entering a filter divided by the number of particles larger than the same size simultaneously leaving the filter. A Beta rating means that AC fine test dust was the contaminant used for the test. (AC fine test dust is no longer available and is being replaced by ISO 12103-1 A3 Medium Test Dust). A rating, $\beta = 50$ at $10\ \mu$, means that for particles $10\ \mu$ m and larger, the upstream count is 50 times the downstream count. The Beta rating, or Filtration Ratio, can be converted to an efficiency rating by Equation 1:

$$\text{Efficiency (\%)} = (1 - 1/\text{Beta Ratio}) \times 100 \quad (\text{Eq. 1})$$

Therefore, a filter with a rating, $\beta = 50$ at $10\ \mu$, will remove 98% of fine test dust particles larger than $10\ \mu$ m. The same filter might have a rating, $\beta = 10$ at $5\ \mu$, meaning that the element will remove 90% of the fine test dust particles larger than $5\ \mu$ m. The filtration ratio is often determined for a number of particle sizes and at differential pressures up to at least the terminal pressure drop of the element.

3.4 Nominal (Size) Rating—This is an obsolete rating term used in the past to indicate removal of certain percentage of particles greater than a certain size. To be meaningful, the percentage removal (90, 95, or 98%) needs to be identified along with the test contaminant and the test procedure.

3.5 Percentage by Weight—Some older military specifications have required that a filter element remove a certain percentage by weight of a contaminant (glass beads or test dust of a specific size distribution). This test basically provides a measure of the efficiency of a new element but provides little information as to how the efficiency changes as differential pressure increases across the element.

4. Filter Selection Guidelines

4.1 Background—Many times the filtration installed for ship hydraulic systems has been inadequate. Common deficiencies have been:

- a. Short element life
- b. Bypass relief valves lift even with new elements installed
- c. Excessive pressure drop across the filter
- d. Element collapse
- e. Low-filtration efficiency
- f. Element media incompatible with water in the fluid

4.2 Causes of Past Deficiencies—Some of the past deficiencies in ship hydraulic filtration have resulted from the utilization of aircraft filters and design practices without careful evaluation of the differences in the applications.

4.3 Selection Parameters—In order to provide effective filtration for ship hydraulic systems, a number of parameters must be considered. The parameters identified and discussed in this document include the following:

- a. Fluid viscosity and flow rate
- b. Location of filter assemblies
- c. Essentiality of system operation
- d. Duration of system operation
- e. Required filtration level (efficiency)
- f. Maintenance philosophy
- g. Logistic support requirements
- h. Initial and operating costs
- i. Filter size and weight

Most of these parameters are interdependent and while each will be discussed separately, one must not neglect their interdependence.

4.4 Fluid Viscosity and Flow Rate

4.4.1 ELEMENT SIZING—One of the most important considerations in filter selection is assuring that the filter elements are sized to handle the flow and viscosity of the fluid to be filtered at the desired dirt capacity of the element. The differential pressure across a filter element is a function of the flow rate and the fluid viscosity. Almost all losses across the element are viscous losses directly proportional to fluid viscosity. Therefore, the safest practice is to assume that pressure losses are proportional to absolute fluid viscosity and flow rate. Flow rates are usually relatively easy to determine. (Absolute viscosity equals kinematic viscosity times the mass density. For commonly used hydraulic fluids, the absolute viscosity in centipoises is usually within 15% of the kinematic viscosity in centistokes.) However, fluid viscosity varies with the type of fluid, fluid temperature, and pressure.

- 4.4.2 **VISCOSITY OF HYDRAULIC FLUIDS**—Because of cold ambient temperatures for start-up and operation, aircraft hydraulic fluids have a relatively low viscosity. One low viscosity hydraulic fluid, MIL-H-5606, is often used for testing of filter elements for ship hydraulic applications as well as aerospace and industrial applications. However, the fluids used in most ship hydraulic systems tend to be considerably more viscous than MIL-H-5606. See SAE J1778 for characteristics of ship hydraulic fluids and their selection parameters. Table 1 summarizes the viscosity of MIL-H-5606 and other fluids commonly used in ship hydraulic systems. Note that the viscosity of some hydraulic fluids at 40 °C are five to seven times that of the MIL-H-5606 fluid commonly used to test filter elements. At 0 °C, the viscosity of these fluids may be 30 or more times the viscosity of MIL-H-5606 at 40 °C which is the temperature most often used for filter element testing.

TABLE 1—VISCOSITY OF COMMONLY USED SHIP HYDRAULIC FLUIDS

Fluid Symbol of Designation	Military Specification	Kinematic Viscosity in Centistokes 40 °C	Kinematic Viscosity in Centistokes 0 °C
Petroleum Base			
	MIL-H-5606	14	45
NATO H-575	MIL-F-17111	27–30	
ISO VG 32	MIL-PRF-17672, 2075-TH	32% ± 10%	150–200
ISO VG 46	MIL-PRF-17672, 2110-TH	46% ± 10%	275–300
ISO VG 68	MIL-PRF-17672, 2135-TH	68% ± 10%	475–525
	MIL-L-17331, 2190TEP	74–97	1000–2000
Synthetic Hydrocarbon			
NATO H-537	MIL-PRF-83282	14 (Min.)	90
Triaryl Phosphate Ester			
NATO H-580	MIL-H-19457	43–50	
Water-glycol			
NATO H-579	MIL-H-22072	36–43	

- 4.4.3 **OPERATING TEMPERATURE RANGE**—Filters must be designed and sized to perform over the operating temperature range of the system. If the systems must start at cold ambient temperatures, this must be considered. Generally, fluids in aircraft systems must operate over a wider temperature range than fluids in ship hydraulic systems. This is the primary reason that a low viscosity fluid is selected. While ship hydraulic systems operate in a narrower temperature range, the higher viscosity fluids with lower viscosity indexes may result in even greater viscosity variations than found in aircraft systems. Only the lower temperature of the operating range is important in sizing filter elements. If the filter elements are not designed for the viscosity at the coldest temperature, excessive pressure losses across the filter will be experienced, bypass relief valves may lift or the element may collapse due to excessive differential pressure.
- 4.4.4 **CHANGE OF VISCOSITY WITH PRESSURE**—Designers often are unaware of and ignore the change of viscosity with pressure although this can be a significant factor with most fluids. Fluids whose viscosity varies significantly with temperature are subject to viscosity change with pressure. The viscosities of water-base fluids change relatively little with pressure, but these fluids are seldom used in ship systems since they are not suitable for cold temperatures. For MIL-H-5606 aircraft hydraulic fluid at 40 °C, the increase in viscosity at 20 MPa (2900 psi) is approximately 30% compared to the viscosity at atmospheric pressure and 40 °C, increasing by nearly 75% at –40 °C a typical temperature requirement for cold start of aircraft systems in cold climates. For the more viscous fluids normally used in ship hydraulic systems, the increase is even greater. For example, the viscosity of 2135TH fluid (ISO viscosity grade 68) increases by factors of 1.65 and 3.0 at pressures of 20 MPa (2900 psig) and 60 MPa (8700 psig) respectively. For phosphate-ester base fluids, the increase in viscosity with pressure is even greater than with petroleum fluids. (See SAE J1778 for additional data on viscosity change with pressure.)