SAE INTERNATIONAL

# SURFACE VEHICLE RECOMMENDED PRACTICE

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## (R) Marine Vehicles - Hydraulic System Pumps and Motors - Design and Specification Guide

RATIONALE

This revision expands the scope to include motors as well as pumps for all marine vehicles, not just advanced surface craft and deep submersibles. It can be used to identify important parameters in hydraulic pump and motor selection even when a detailed pump or motor specification is not being prepared. Several reference documents have been deleted and a number of new reference documents, including many ISO standards have been added. Additional guidance on selection of fluids for preservation prior to installation of components has been provided.

## 1. SCOPE

This SAE Recommended Practice provides guidance for defining the requirements for evaluating hydraulic pumps and motors and for preparing detailed specifications for these components. The user can follow this document to set forth the pump and motor environmental and performance considerations, establish service life and reliability goals, and define specific evaluation tests for marine vehicle applications.

### 1.1 Purpose

The application of aerospace technology to marine vehicle systems has generated the need for more rigorous system designs and detailed specifications of components for advanced surface craft and submersible vehicles. This Recommended Practice is intended to aid in the system design process for the selection of hydraulic pumps and motors and in the preparation of specifications for these components to be used in marine applications. While this Recommended Practices identifies many parameters that must be considered in hydraulic pump and motor selection and procurement, the user must select those that are applicable to a particular system. For example, unique requirements applicable to deep submersibles do not apply for pumps intended for use of surface ships.

## 2. REFERENCES

### 2.1 Applicable Documents

The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest issue of SAE publications shall apply.





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**http://www.sae.org/technical/standards/J1776_201402**

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.

SAE J745 Hydraulic Power Pump Test Procedure

SAE J1777 General Environmental Considerations for Marine Vehicles

SAE J1778 Ship Systems and Equipment - Recommended Practice for Hydraulic Fluid Selection.

SAE J1779 Ship Systems and Equipment - Hydraulic System Design Criteria For Marine Vehicles

SAE J1781 Ship Systems and Equipment - Materials for Fluid Systems

SAE J1782 Ship Systems and Equipment – Hydraulic Systems - Noise Control

SAE J2333 Ship Systems and Equipment - Hydraulic Systems - Filter Selection Parameters

SAE AS19692 Pumps, Hydraulic Power Driven, Variable Displacement

2.1.2 ASME Publications

Available from ASME, P.O. Box 2900, 22 Law Drive, Fairfield, NJ 07007-2900, Tel: 800-843-2763 (U.S./Canada), 001-800-843-2763 (Mexico), 973-882-1170 (outside North America), www.asme.org.

ASME Y14.100 Engineering Drawing Practices

2.1.3 NFPA Publications

Available from National Fluid Power Association, 3333 N. Mayfair Road, Milwaukee, WI 53222-3219; website www.nfpa.com Tel. (414) 778-3353

NFPA T2.13.13 Recommended Practice - Hydraulic Fluid Power - Fluids - Viscosity Selection Criteria For Hydraulic Motors And Pumps

2.1.4 ISO Publications

Available from American National Standards Institute, 25 West 43rd Street, New York, NY 10036-8002, Tel: 212-642-4900, www.ansi.org.

ISO 3019-1 Hydraulic Fluid Power - Dimensions And Identification Code For Mounting Flanges And Shaft Ends Of Displacement Pumps And Motors - Part 1: Inch Series Shown In Metric Units

ISO 3019-2 Hydraulic Fluid Power - Dimensions And Identification Code For Mounting Flanges And Shaft Ends Of Displacement Pumps And Motors - Part 2: Metric Series

ISO 4391 Hydraulic Fluid Power-Pumps, Motors And Integral Transmissions - Parameter Definitions And Letter Symbols

ISO 4409 Hydraulic Fluid Power - Positive - Displacement Pumps, Motors And Integral Transmissions - Methods Of Testing And Presenting Basic Steady State Performance

ISO 8426 Hydraulic Fluid Power - Positive Displacement Pumps And Motors - Determination Of Derived Capacity

ISO 10767-1 Hydraulic Fluid Power - Determination Of Pressure Ripple Levels Generated In Systems And Components - Part 1: Precision Method For Pumps

ISO 10767-2 Hydraulic Fluid Power - Determination Of Pressure Ripple Levels Generated In Systems And Components - Part 2. Simplified Method For Pumps

ISO 17559 Hydraulic Fluid Power - Electrically Controlled Hydraulic Pumps - Test Methods To Determine Performance Characteristics

2.1.5 U.S. Government Publications

Available from DLA Document Services, Building 4/D, 700 Robbins Avenue, Philadelphia, PA 19111-5094, Tel: 215-697-6396, http://quicksearch.dla.mil/.

2.1.5.1 Military Specifications

MIL-PRF-6083 Hydraulic Fluid, Petroleum Base, for Preservation and Operation

MIL-P-17869 Pumps and Motors, Power, Oil Hydraulic (Naval Shipboard Use) MIL-S-901Shock Test HI (High-Impact), Shipboard Machinery, Equipment and Systems, Requirements for

MIL-B-17931 Bearings. Ball. Annular, for Quiet Operation

MIL-PRF-46170 Hydraulic Fluid, Rust Inhibited, Fire Resistant, Synthetic Hydrocarbon Base, NATO Code No. H-544

2.1.5.2 Military Standards

MIL-STD-129 Military Marking for Shipment and Storage

MIL-STD-167-1 Mechanical Vibration of Shipboard Equipment (Type I - Environmental and Type II - Internally Excited)

MIL-STD-740-2 Structureborne Vibratory Acceleration Measurements and Acceptance Criteria of Structureborne Equipment

MIL-STD-810 Environmental Engineering Considerations and Laboratory Tests

MIL-STD-1474 Noise Limits

MIL-STD-2193 Ship Hydraulic System Components

MIL-STD-31000 Technical Data Packages

2.1.5.3 Military Handbooks

MIL-HDBK-470 Designing and Developing Maintainable Products and Systems, Volume I

3. REQUIREMENTS OF PUMP AND MOTOR SPECIFICATIONS

The specification should contain a section that defines and describes the purpose and intended use of the components. This is especially important for submerged operation where the hydraulic system is referenced to ambient ocean pressure. Another section should define the scope of work desired; i.e., design, development, qualification, etc. Within the scope, restrictions can be imposed; i.e., type of pump or motor configuration (piston, gear, vane, screw, etc.). Also, the scope can be used to transmit information on future applications, growth potential, selection criteria, performance optimization and any other information the user considers significant. If there are any design criteria that must be emphasized in the proposal, it can be stated in the Scope section.

The specification must contain a Requirements section in which all of the technical data necessary to design or select the pump or motor is presented. An introductory paragraph expanding the application described in the Scope is sometimes helpful. This paragraph should indicate the intended drive mechanism, mounting orientation, and nature of the load. A schematic of the pump and the system would be a worthwhile guide.

Technical data requirements must be specified. For military applications, MIL- STD-31000 identifies the requirements for preparing a technical data package. ASME Y14.100 is the preferred requirements document for engineering drawing practices.

The following paragraphs identify the type of information needed in a typical Requirements section. Even if a specification is not being prepared the information in this section is useful in evaluating pumps being considered for procurement.

### 3.1 Fluids

All information about the working fluid and operating environment the component is likely to come in contact with (both internally and externally) during normal usage should be presented here. (SAE J1778 provides information on fluids often used in marine vehicle systems. NFPA T2.13.13 provides guidance on selecting the proper fluid viscosity)

#### 3.1.1 Types and Grades of Fluids

List specifications of fluids that are to be used in the component.

#### 3.1.2 Contamination Control

Describe expected fluid contamination type and levels with which the pump or motor must operate or the type, location, and efficiency of filters to be used. See SAE J2333 for additional guidance.

#### 3.1.3 Maintaining Quality

Describe system provisions for maintaining fluid quality. Acceptable limits for entrained or liberated gas must be defined in terms of volume, pressure and temperature.

#### 3.1.4 Viscosity

The range of fluid viscosity under which the component must operate shall be defined. Operation at the extremes may be very important. For systems designed to operate underwater, temperature extremes will affect surface operation while pressure extremes will affect submerged operation.

### 3.2 Operating Conditions

The description of environmental conditions should always consider both normal and extremes of operation. SAE J1777 identifies operating/environmental considerations for marine vehicles while SAE J1779 provide specific hydraulic design guides for different types of vehicles.

3.2.1 Table 1 identifies operating parameters that need to be identified in the specification and the units used in describing these parameters. ISO 4391 describes and systematically defines the principal technical characteristics, and allots letter symbols to these characteristics and indicates how they can be more clearly defined by suffixes. Examples for the use of symbols and definition of terms without symbols are provided.

TABLE 1 - OPERATING PARAMETER INFORMATION

| Parameter/Input | Normal Conditions | Extreme Conditions/Duration |
|---|---|---|
| Pressure - Inlet (kPa/psi) | | |
| Discharge (MPa/psi) | | |
| Case drain (max.) (kPa/psi) | | |
| Temperature – Inlet (°C/°F) | | |
| Ambient - Medium (air, water, oil) | | |
| - Pressure (kPa/psi) | | |
| - Temperature (°C/°F) | | |
| - Thermal Shock (°C/°F) | | |
| Speed Range (rpm) | | |
| Torque Range (J/ft-lbs) | | |
| Drive Acceleration - rpm/s | | |
| Direction of Rotation (CW or CCW) | | |

3.2.2 Detailed Environment

Most marine hydraulic systems operate at atmospheric conditions. A deep submergence hydraulic system will be referenced (compensated) to the ambient ocean pressure. As such, no component, including the pumps and motors, should contain any uncompensated volume in any part during its operating cycle.

3.2.2.1 Inlet Pressure

Inlet conditions involving line loss, lift, and other depressed inlet effects must be described as functions of operating conditions. Minimum and maximum inlet pressure must be specified. Pump inlet pressure on pressure-compensated (deep-submergence) systems is most severe during on-deck and surface operations.

3.2.2.2 Discharge Pressure

Those conditions for which the discharge pressure is higher than the combined inlet and normal pressure rise, such as during shutdown, should be defined.

3.2.2.3 Inlet Temperature

Extreme inlet temperatures affecting line loss (low temperature viscosity) and vapor pressure (high temperature) must be defined.

3.2.2.4 Submergence

Requirements for submergence in specific operating fluids or in seawater shall be identified. For deep-submergence applications, specifications should prohibit uncompensated volumes in any part of the pump during its entire operating cycle.

3.2.2.5 Attitude

Pump installation attitude (position) combined with extreme ship motions, permanent or temporary, shall be specified.

3.2.2.6 Vibration

Both external and self-induced vibration parameters must be considered. MIL-STD-167-1 may be used as a reference; however, specific vibration conditions should be defined over their full amplitude and frequency range. See SAE J1777 for vibration levels that may apply.

3.2.2.7 Acceleration

The vehicle acceleration envelope, including extreme conditions the unit must withstand without damage, shall be specified.

3.2.2.8 Shock

Specify whether the equipment must be able to withstand underwater explosions and/or transportation handling drop tests. (MIL-S-901 is applicable for military applications.)

3.3 Performance Requirements

This section describes what performance is expected of the pump. The detailed requirements for flow, pressure, fluid temperature rise, power limitations, efficiency, etc., must be specified. Degradation of the system must be considered when preparing these specifications. In some cases, performance curves or limit curves are very helpful, especially when trying to describe a range of operation. SAE J745 provides guidance on test methods and presentation of performance data. (See 4.1.4.1 for additional test methods.)

3.3.1 Flow Capacity

The required flow rate should be specified in volumetric terms. The speed/flow relationship should be identified. If the system requires mass flow rate, such as pounds per hour, then enough fluid definition must be available for the supplier to determine volume.

3.3.2 Variable Delivery

If the pump is a variable-delivery type, performance conditions must be specified. Special emphasis must be given to the response characteristics of those applications requiring fast response time, i.e., part load efficiency (temperature rise), and control system design. Reference: SAE AS19692.

3.3.3 Pressure Rise

If a specific pressure versus flow schedule is required, then a graph is recommended. Maximum steady state and transient pressures shall be defined if required.

3.3.4 Temperature Rise

The maximum permissible temperature rise of the pump must be specified if it is critical to the system or personnel safety. Specific conditions of speed, flow, and pressure affecting the temperature must also be considered.

3.3.5 Heat Load

Any heat load rejected by the pump or through system heat exchangers should be defined with relation to the minimum system flow to absorb such. It may be necessary to specify case drain flow for pumps operating in the blocked (zero flow) condition. For systems operating directly in the ocean, heating problems may occur only during on-deck operation. A properly designed submerged system should require no special heat-rejection hardware.

3.3.6 Efficiency

Efficiency at the design point and part load conditions may be a desired specification requirement.

3.3.7 Power Consumption

Maximum power and/or torque during extreme pressure and maximum flow conditions should be considered.

3.3.8 Pump Ripple

The specification should specify the maximum pressure pulsation (pump ripple) permitted.

3.3.9 Noise

Noise can be segregated as airborne, structureborne, or fluidborne. If noise requirements exist, they must be expressed in measurable terms. Fluidborne noise measurements are frequently used for systems operating submerged. SAE J1782 provides techniques for reducing noise while MIL-STD-740-2 and the “Shipboard Equipment Noise” requirement section of MIL-STD-1474 identify test procedures and acceptance criteria for military applications.

3.4 Mechanical Configuration

3.4.1 Pump Drive

The mounting and direction of rotation of the drive as seen from a defined position must be specified. If the drive is to be included as part of the pump, it should be so specified.

3.4.2 Drive Connection

Shafting, coupling, and shear section requirements should be specified. If the drive is included with the pump, its power source connection (pressure and flow or frequency, voltage, current, and phases) must be specified. If drive shaft concentricity is critical, it shall be specified. Details for an indirect drive (e.g., spur-gear, V-belt) must be supplied.

3.4.3 Mounting and Port Configuration

Specify the mounting configuration and indicate mounting misalignment regarding the drive connections. If center of gravity and rotor inertia are required, these must be identified. Specify port requirements (type, size, location). If the pump or motor is to be mounted in an area significantly warmer than the fluid temperature, so state. ISO 3019-1 and ISO 3019-2 provide guidance on mounting flanges and shaft ends for pumps and motors.

3.4.4 Size and Weight

Specify the maximum allowable dimensional envelope and the maximum allowable dry and/or wet weight.

3.4.5 Operating Speed

The range of pump speeds should be specified. Duty cycle, speed modulation, start-up rate, and acceleration schedules may also be required. When high-speed pumps are required, care should be taken to make sure the speed is compatible with the inlet pressure available.

3.4.6 Housings

Any special identification and markings should be specified. Specify proof pressure without permanent deformation and burst pressure. If a mock-up is required for installation checking, it should be specified.

3.4.7 Seals and Drains

The allowed shaft seal leakage and provisions for drainage must be defined. Both static and dynamic leakage rates should be identified. Uncompensated volume between seals must be avoided in deep ocean applications.

3.4.8 Fasteners and Locking Devices

SAE J1780 provides guidance on fastener selection. Any constraints on nuts, bolts, screws, adhesives, welds, locknuts, safety wire, snap rings, and pins, should be specified. (See MIL- STD-2193 for requirements for military applications.)

3.4.9 Nameplate

The location (consider visibility in intended application), means of attachment, data and configuration of the nameplate should be defined. A unique serial number should be assigned to each component.

3.4.10 Bearings and Lubrication

Special bearing loads and/or lubrication requirements should be identified. Requirements for bearings for quiet operation are identified in MIL-B-17931.

3.5 Auxiliary Equipment

3.5.1 Dynamic Response

Applicable control items should have some criteria of dynamic response ranging from a slew time to maximum change in parameter, to a time constant or even a plot of error versus frequency.

3.5.2 Relief Valves and Regulators

The differential pressure versus flow, including hysteresis of these components, and their operation in the system should be described.

3.5.3 Clutches

Part load performance considerations may justify the use of a clutched operation of pump elements. If so, heat generation, dynamic response, and drive shaft torque spikes should be described.

3.5.4 Auxiliary Pumps

The need for, or option of, auxiliary pumps should be explained along with restrictions on failure mode.

3.5.5 Filters and Strainers Integral with Pump

Filters should be defined for efficiency, differential pressure, life with specified conditions, cleaning mechanism, health indicators, and installation and removal considerations. See J2333 for filter requirement guidance.

3.6 Materials

General statements regarding galvanic action, fungus and/or marine life protection should be made. Avoidance of any special material should be specified. Preference for material or indication of special properties must be stated; i.e., for seawater-immersed pumps, corrosion-resistant structural materials must be used. SAE J1781 identifies materials for which there is considerable fabrication and operating experience in the seawater environment. Special requirements on nonmetallic components should be defined. SAE J1781 identifies materials suitable for use in fluid systems of marine vehicles and provides information on corrosion resistance and the galvanic potential of these materials in sea water. MIL-STD-2193 identifies materials and design requirements for hydraulic components on military ships.

3.6.1 Treatment

Special requirements for hardness, ductility, machinability, fatigue life, ultimate strength, etc., should be specified.

3.6.2 Finishes

Special requirements for plating, painting, surface finish, including lay of machining, should all be specified.

3.7 Service Life Requirements

Shelf life and operational (i.e., the duty cycle for calculating operational life) life between repair, overhaul and/or replacement must be specified. The specified life can be related to experience; i.e., “the time between overhaul will be 1000 h after 100 000 h of experience on products conforming to this specification.” This assumes operating experience will result in design improvements that permit the pump or motor to reach its service or overhaul life goals.

3.7.1 Reliability

The required reliability of this product should be stated and the mechanism of analysis or test to demonstrate compliance with this should be defined,

3.7.2 Maintainability

The specification should identify maintainability requirements including any limitations on repair time and tools. The specification may be written to require the pump manufacturer to identify expected repairs, replacement parts and tools needed for repair. Technical manual requirements, provisioning documentation and maintainability requirements (MIL-HDBK-470 provides guidance for requirements to be included in the specification.) For heavy equipment (greater than 23 kg or 50 pounds), attachments or provisions for lifting and handling should be included.

3.8 Emergency Operation

Conditions that represent abnormal operation should be identified in this section.

3.8.1 Overspeed

Overspeed conditions, if required, should be defined. For example, most pumps can run 5% over-speed for 25% of their operating life and higher for shorter periods.

3.8.2 Surge Pressure

“Water-Hammer” effects in the discharge line may cause peak surge pressures. The limits for surge pressures should be defined if they could affect the system.

3.8.3 Dry Lift

Most pumps require the capability to prime themselves under specific inlet conditions. This should be specified, if desired, along with the anticipated temperatures under these conditions. If the suction will always be flooded, so state.

3.8.4 Emergency Fluids

If the pump must operate on alternate fluids for limited periods, this usage must not alter normal pump performance. Alternate fluids, operating conditions and time must be specified.

4. QUALITY ASSURANCE

Either the specification or the contractual document should define the means of recording and filing inspection and test procedures and results for parts and assemblies. It should also indicate what agency or department is responsible and who has surveillance authority on quality assurance matters. Mechanisms to facilitate reworking discrepant or worn parts to agree with drawings should be provided to allow for overhaul and delivery. Unless the correction affects form, fit, or function, this decision can be left to the pump manufacturer.