

# SURFACE VEHICLE INFORMATION REPORT

SAE J1776/HIR1514A

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AUG89

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## (R) DESIGN AND SPECIFICATION GUIDE FOR HYDRAULIC PUMPS USED ON ADVANCED SURFACE CRAFT AND SUBMERSIBLE VEHICLES

**Foreword**—This Document has also changed to comply with the new SAE Technical Standards Board format.

1. **Scope**—This HIR provides guidance defining the hydraulic system requirements and for preparing a detailed specification for a pumping component. The user can follow this document to set forth the pump environmental and performance considerations, establish service life and reliability goals, and define specific evaluation tests in order to qualify it for advanced 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. This Hydrospace Information Report (HIR) is intended to aid in the system design process and in the preparation of a specification for a hydraulic pump to be used on advanced surface craft and submersible vehicles.

### 2. References

2.1 **Applicable Publications**—Specifications, standards, and publications can form part of the pump specification. It is necessary to reference all such documents by number in the detailed section of the specification.

All specifications should contain a statement about preference of conflicting documents. Typically, the detailed specification prevails over referenced specifications.

The following list can be utilized as a source for selecting applicable specifications. This HIR only references a specification from the list if it directly applies. Since standard specifications are periodically deleted or amended, they should be reviewed before using.

2.1.1 SAE PUBLICATIONS—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

HIR1063—General Environmental Considerations for Marine Vehicles  
HIR1149—Hydraulic Fluids for Marine Vehicles  
HIR1415—Design Guide for Hydraulic Systems for Submersible Vehicles  
HIR1496—Hydraulic System Design Criteria for Advanced Marine Surface Vehicles  
HIR1622—Noise Control in Fluid Power Systems of Marine Vehicles  
HIR1694—Materials for Fluid Systems of Marine Vehicles

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AIR887—Liquid Filter Ratings, Parameters and Tests  
AIR1362—Physical Properties of Hydraulic Fluids

2.1.2 U.S. GOVERNMENT PUBLICATIONS—Available from Commanding Officer, Naval Publications and Forms Center, 5801 Tabor Avenue, Philadelphia, PA 19120.

2.1.3 FEDERAL SPECIFICATIONS

TT-S-735—Standard Test Fluids, Hydrocarbon

2.1.4 MILITARY SPECIFICATIONS

DOD-D-1000—Drawings, Engineering and Associated Lists

MIL-H-6083—Hydraulic Fluid, Petroleum Base, Preservative Type Aircraft, Missile Ordnance

MIL-P-16789—Preservation, Packaging, Packing and Marking of Pumps General, and Associated Repair Parts

MIL-P-17869—Pumps and Motors, Power, Oil Hydraulic (SHIPS)

MIL-P-19692—Pumps, Hydraulic Power Driven, Variable Displacement

MIL-S-867—Steel Castings, Corrosion Resisting Austenitic

MIL-S-901—Shock Test HI (High-Impact), Shipboard Machinery, Equipment and Systems

MIL-S-22473—Sealing, Locking, and Retaining Compounds; Single-Component

2.1.5 MILITARY STANDARDS

MIL-STD-22—Welded-Joint Designs

DOD-STD-100—Engineering Drawing, Practices

MIL-STD-129—Marking for Shipment and Storage

MIL-STD-167—Mechanical Vibration of Shipboard Equipment

MIL-STD-278—Fabrication, Welding and Inspection of Machinery, Piping and Pressure Vessels for Ships of the United States Navy

MIL-STD-470—Maintainability Program Requirements

MIL-STD-740-1—Airborne Sound Measurements and Acceptance Criteria of Shipboard Equipment

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

MIL-STD-756—Reliability Prediction

MIL-STD-785—Reliability Program for Systems and Equipment Development and Production

MIL-STD-810—Environmental Test Methods

MIL-STD-889—Dissimilar Metals

MIL-STD-1246—Product Cleanliness Levels and Contamination Control Program

MIL-STD-2193—Hydraulic System Components, Ship

MIL-STD-2175—Casting, Classification and Inspection of

3. **Requirements of a Pump Specification**—The pump specification should contain a section which defines and describes the Purpose and intended use of the pump. 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 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.

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The specification must contain a Requirements section in which all of the technical data necessary to design or select the pump 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. Drafting standards should be specified. For military applications, the level of drawings as defined in DOD-D-1000 must be identified and DOD-STD-100 invoked. The following paragraphs expand the details of a typical Requirements section.

- 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. (HIR1149 provides information on fluids most often used in marine vehicle systems.)
- 3.1.1 **TYPES AND GRADES OF FLUIDS**—List specifications. (AIR1362 provides information on aircraft hydraulic fluids which are sometimes used in marine applications.)
- 3.1.2 **CONTAMINATION CONTROL**—Describe expected fluid contamination levels or the means to be used to control contamination: type and level of contamination with which the pump must operate or the type, location, and efficiency of filters to be used.
- 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 pump 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. HIR1063 identifies operating/environmental considerations for marine vehicles while HIR1415 and HIR1496 provide specific design guides for different types of vehicles.

3.2.1

Parameter/Input	Normal Conditions	Extreme Conditions/Duration
Pressure - Inlet Discharge Case drain (max.)		
Temperature - Inlet		
Ambient - Medium (air, water, oil)		
- Pressure		
- Temperature		
- Thermal Shock		
Speed Range (rpm)		
Torque Range		
Drive Acceleration rpm/s		

This table clearly defines the units used in describing individual parameters.

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 pump, should contain any uncompensated volume in any part during its operating cycle.

3.2.2.1 *Inlet Pressure*—Suction 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 suction 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 may be used as a reference; however, specific vibration conditions should be defined over their full amplitude and frequency range. See HIR1063.

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, 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.

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 pump 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 MIL-P-19692.

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. 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 (dead head) condition. For systems operating directly in the ocean, heating problems should 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. Waterborne noise measurements replace the airborne measurements for systems operating submerged. HIR1622 provides techniques for reducing noise while MIL-STD-740-1 and MIL-STD-740-2 identify test procedures and acceptance criteria.

### **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.

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- 3.4.2 DRIVE CONNECTION—Shafting, coupling, and shear section 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).
- 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 suction head available.
- 3.4.6 HOUSINGS—Any special identification and markings should be specified. Specify proof pressure without 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 LOCKING DEVICES—Constraints on nuts, bolts, screws, adhesives, welds, locknuts, safety wire, snap rings, and pins, should be specified. (See MIL-STD-2193 for requirements on U.S. Navy ships.)
- 3.4.9 NAMEPLATE—The location (consider visibility in intended application), data and configuration of the nameplate should be defined. A unique serial number should be assigned to each pump.
- 3.4.10 BEARINGS AND LUBRICATION—Special bearing loads and/or lubrication requirements should be identified.

### 3.5 Auxiliary Equipment

- 3.5.1 DYNAMIC RESPONSE—All 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 AIR887 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. HIR1694 identifies materials for which there is considerable fabrication and operating experience in the seawater environment. Special requirements on nonmetallic components should be defined. Federal Specification TT-S-735 defines standard low-swelling, medium-swelling, and high-swelling petroleum-base oils that are often used to test elastomeric seals. MIL-STD-22, MIL-STD-278, MIL-STD-889, and MIL-S-867 identify materials and fabrication practices. MIL-STD-2193 provides general guidance on materials and design requirements for hydraulic components on Navy 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 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 (reference MIL-STD-756 and MIL-STD-785).

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-STD-470) should be included in this specification. For heavy equipment, 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 should be defined. For example, most pumps can run 5% overspeed 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.

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.

- 4.1 Acceptance Test (Production Units)**—The specification should identify the specific acceptance tests that are required for each pump or samples from a lot of pumps which are required. An alternative is to require the pump manufacturer to prepare a test procedure for approval by the customer. Provisions for disposition of data and deviation decisions should be clearly identified.
- 4.2 Design Assurance Test**—The following functional, destructive, and nondestructive tests should be considered for specified tests on one or more pumps. When applicable, compliance may be demonstrated by similarity, analysis, inspection, or testing. A formal test plan should be approved before beginning the test. MIL-STD-810 describes environmental test methods which may be applicable. For critical applications analysis of break-in contamination, i.e., pump filter patch test, may be desirable.
- 4.2.1 **PROOF AND BURST PRESSURE TEST**—The housings with appropriately isolated chambers may be subjected to hydrostatic pressure up to the proof pressure level and checked for deformation, depressurized, and checked for permanent deformation and cracks. Burst pressure tests, if required, involve recording the pressure of housings at failure.
- 4.2.2 **SHAFT SHEAR TORQUE**—Selected part(s) of the shaft may be tested on a torsional stress machine to assure load capability and/or overload protection.
- 4.2.3 **INSTALLATION INSPECTION**—An assembled unit may be inspected for conformance with the installation drawing. This inspection should check alignment, size, weight, identification (nameplate), and finish requirements.
- 4.2.4 **PERFORMANCE**—Steady-state tests should be defined to assure compliance with 4.1, 4.2, 4.3, and 4.4. The tests may be under nominal conditions or special conditions such as extreme misalignment. Design specifications should allow for operational wear and degradation.
- 4.2.5 **CYCLE**—Simulated operational tests may be defined to assure dynamic response and other nonsteady-state requirements such as start-up, acceleration, and shutdown.
- 4.2.6 **ACCELERATED ENDURANCE**—Nonoperational thermal tests may be specified to test elastomers and cement. Operational contamination, entrained gas, and extreme thermal tests may also be specified.
- 4.2.7 **SHOCK AND VIBRATION**—These tests are primarily applicable to military applications where specific design requirements are invoked. To facilitate testing, pumps are usually pressurized but often are not required to be operational during testing.
- 4.2.8 **MAINTENANCE**—Demonstration of a repair cycle may be specified.
- 4.2.9 **ACCEPTANCE LEVEL**—For any and all of these tests, a post-test performance acceptance level should be specified which allows for deterioration from the new product performance. Appropriate spot-check performance tests can be performed between selected portions of these tests.
- 4.3 Qualification Test (Typical Production Unit)**—The product will generally undergo a formal qualification test either on the bench with simulated environment or in the actual installation. The qualification test may repeat portions of the design assurance test. The specification should define test points, environment factors, methods of surveillance, and request a detailed test procedure and final report for approval.
- 5. Preparation for Delivery**—Definitions must be given for different areas of shipment such as the customer, government, foreign or domestic with different treatment given immediate use of stored assemblies.