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DEPARTMENT OF DEFENSE
STANDARD PRACTICE

CLEANING, PROTECTING, AND TESTING PIPING, TUBING, AND FITTINGS FOR HYDRAULIC POWER TRANSMISSION EQUIPMENT

AMSC N/A FSC 4730

FOREWORD

1. This standard is approved for use by all Departments and Agencies of the Department of Defense.

2. Comments, suggestions, or questions on this document should be addressed to: Commander, Naval Sea Systems Command, ATTN: SEA 05S 1333 Isaac Hull Avenue, SE, Stop 5160, Washington Navy Yard DC 20376-5160 or emailed to CommandStandards@navy.mil, with the subject line "Document Comment". Since contact information can change, you may want to verify the currency of this address information using the ASSIST Online database at https://assist.daps.dla.mil.

CONTENTS

1. SCOPE

1.1 Scope. This standard covers the requirements governing the basic methods of cleaning and protecting nonferrous and ferrous metal and alloyed pipe, tubing, and fittings prior to installation and after hydraulic tests in hydraulic power transmission applications. This standard is applicable to hydraulic components used in systems filled with either petroleum oil, synthetic poly-alpha-olephin (PAO) fluid, phosphate ester type fluid, or water based fluid.

1.2 Applicability. The procedures described in this standard are intended for the use of shipyard or contractor personnel only in accordance with the safety precautions of section 5.

2. APPLICABLE DOCUMENTS

2.1 General. The documents listed in this section are specified in sections 3, 4, or 5 of this standard. This section does not include documents cited in other sections of this standard or recommended for additional information or as examples. While every effort has been made to ensure the completeness of this list, document users are cautioned that they must meet all specified requirements of documents cited in sections 3, 4, or 5 of this standard, whether or not they are listed.

2.2 Government documents.

2.2.1 Specifications, standards, and handbooks. The following specifications, standards, and handbooks form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those cited in the solicitation or contract.

FEDERAL SPECIFICATIONS

O-H-795	-	Hydrofluoric Acid, Technical
O-S-642	-	Sodium Phosphate, Tribasic, Anhydrous; Dodecayhdrate; and Monohydrate; Technical

COMMERICAL ITEM DESCRIPTIONS

A-A-55828	-	Sulfuric Acid, Technical
A-A-59105	-	Nitric Acid, Technical
A-A-59123	-	Sodium Dichromate, Dihydrate, Technical
A-A-59563	-	Sodium Carbonate, Anhydrous, Technical

DEPARTMENT OF DEFENSE SPECIFICATIONS

MIL-PRF-680	-	Degreasing Solvent
MIL-PRF-6083	-	Hydraulic Fluid, Petroleum Base, for Preservation and Operation
MIL-PRF-16173	-	Corrosion Preventive Compound, Solvent Cutback, Cold-Application
MIL-DTL-16232	-	Phosphate Coating, Heavy, Manganese or Zinc Base
MIL-D-16791	-	Detergents, General Purpose (Liquid, Nonionic)
MIL-PRF-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-I-22110	-	Inhibitors, Corrosion, Volatile, Crystalline Powder

MIL-F-24402	-	Filters (Hydraulic), Filter Elements (High Efficiency), and Filter Differential Pressure Indicators, General Specification for

DEPARTMENT OF DEFENSE STANDARDS

MIL-STD-2073-1	-	Standard Practice for Military Packaging

DEPARTMENT OF DEFENSE HANDBOOKS

MIL-HDBK-407	-	Contamination Control Technology Precision Cleaning Methods and Procedures

(Copies of these documents are available online at https://assist.daps.dla.mil/quicksearch/ or from the Standardization Document Order Desk, 700 Robbins Avenue, Building 4D, Philadelphia, PA 19111-5094.)

2.3 Non-Government publications. The following documents form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those cited in the solicitation or contract.

ASTM INTERNATIONAL

ASTM D6304	-	Standard Test Method for Determination of Water in Petroleum Products, Lubricating Oils, and Additives by Coulometric Karl Fischer Titration
ASTM E1146	-	Standard Specification for Muriatic Acid (Technical Grade Hydrochloric Acid)

(Copies of these documents are available from ASTM International, 100 Barr Harbor Dr., P.O. Box C700, West Conshohocken, PA 19428-2959 or online at www.astm.org)

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION (ISO)

ISO 4406	-	Hydraulic Fluid Power – Fluids – Method for Coding the Level of Contamination by Solid Particles
ISO 11171	-	Hydraulic Fluid Power - Calibration of Automatic Particle Counters for Liquids
ISO 23309	-	Hydraulic Fluid Power Systems – Assembled Systems – Methods of Cleaning Lines by Flushing

(Copies of these documents are available from ISO, 1, ch. de la Voie-Creuse, Case postale 56 CH-1211 Geneva 20, Switzerland or online at www.iso.org)

NATIONAL AEROSPACE STANDARD (NAS)

NAS 847	-	Caps and Plugs, Protective, Dust and Moisture Seal

(Copies of this document are available from Aerospace Industries Association, 1000 Wilson Boulevard, Suite 1700, Arlington, VA 22209-3901 or online at www.aia-aerospace.org.)

SAE INTERNATIONAL

SAE-AS4059	-	Aerospace Fluid Power – Cleanliness Classification for Hydraulic Fluids
SAE-ARP-598	-	Aerospace Microscopic Sizing and Counting of Particulate Contamination for Fluid Power Systems

SAE J2321 - Ship Systems and Equipment – General Specification for Filter Elements-Hydraulic and Lube Oil Service

(Copies of these documents are available from SAE World Headquarters, 400 Commonwealth Drive, Warrendale, PA 15096-0001 or online at www.sae.org.)

2.4 Order of precedence. Unless otherwise noted herein or in the contract, in the event of a conflict between the text of this document and the 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.

3. DEFINITIONS

3.1 Flushing. The process of cleaning a hydraulic piping system that involves the circulation of turbulent flushing fluid within piping system loops to remove, transport and filter out particles and other contaminants that may have been introduced into the system during manufacture, construction and/or maintenance.

3.2 Outflushing. Unrestricted discharge of sufficient fluid volume to an open container or bucket to remove contamination from a dead end in the piping.

3.3 Pickling. A treatment of metallic surfaces in order to remove impurities, stains, rust, or scale with a solution called pickle liquor, containing strong mineral acids, before subsequent processing, such as extrusion, rolling, painting, galvanizing or plating.

4. GENERAL REQUIREMENTS

4.1 Recycled, recovered, or environmentally preferable materials. Recycled, recovered, or environmentally preferable materials should be used to the maximum extent possible, provided that the material meets or exceeds the operational and maintenance requirements, and promotes economically advantageous life cycle costs.

4.2 Cleanliness. Pipe tubing and fittings related to the hydraulic power transmission equipment shall be thoroughly cleaned and pickled as necessary prior to installation (see 5.2 and 5.3). They shall be free from scale and foreign matter which could be detrimental to operation of hydraulic equipment such as pumps, motors, valves, rams, and accumulators.

4.3 Pipe construction and cleaning. Pipe required to complete a hydraulic installation shall be constructed in a shop where adequate facilities exist. However, shipboard or vehicle construction is allowed, provided adequate provisions exist to allow cleanliness controls and preclude damage to equipment. Subassemblies shall be used to the maximum extent practicable. After construction and bending operations are completed, the constructed and bent pipe, tubing, and fittings shall be cleaned and pickled in accordance with the procedures specified herein (see 5.2). Hydraulic components which may be constructed of materials not compatible with the pickling solution shall not be immersed in the cleaning or pickling baths. Complex components, such as pumps, valves, and rams, which may be compatible with the pickling solution but will require disassembly to remove residual fluids, shall not be immersed in the cleaning or pickling baths. No hydraulic component that is mechanically connected (union, flange) to rigid piping shall be subject to the pickling solution.

4.4 Abrasive blasting. Sand, shot, or other abrasive blasting shall not be permitted on any part of the hydraulic system. Unless a separate isolated room is provided in the shop for construction of hydraulic piping, abrasive blasting shall be prohibited in the same building in which an open hydraulic component is housed. Abrasive blasting, chipping, or grinding shall not be permitted in the vicinity of an installation site for an open hydraulic system.

4.5 Sand packing. Hydraulic pipe or tubing shall not be packed with sand during the bending process.

4.6 Wire brushing. The pipe and tubing shall not be wire brushed after pickling.

4.7 Cloth and paper. Cloth or paper material shall not be used in drying operations, nor for capping open ends (see 5.7).

4.8 Corrosion protection. The interior and exterior of the ferrous pipe, tubing, and fittings (except corrosion-resistant steel) shall be treated as specified in 5.5 to prevent corrosion.

4.9 Capping. Openings shall be capped and sealed air tight immediately after the cleaning process with a cap or plug in accordance with NAS 847 (see 5.7). The openings shall remain capped until immediately before connecting to the equipment for which the pipe is intended.

4.10 Heat treated piping and tubing. Pipe or tubing that has had heat applied at the site of installation to assist in forming shall be returned to the shop or other areas where facilities exist for recleaning, repickling (if necessary), and retesting.

5. DETAILED REQUIREMENTS

5.1 Safety precautions. The contractor or shipyard representative shall ensure that this cleaning is coordinated through the safety superintendent to provide adequate personnel protection from acid and chemical hazards. In general, all chemicals involved are harmful to the eyes and skin. Personal contact with chemicals should be avoided. Obtain medical attention immediately if acid or caustic gets in the eyes. Face shields or goggles shall be worn by personnel involved in chemical cleaning. Avoid breathing mists or vapors over mixing tanks. Protective equipment, including personal protective equipment (PPE) for eyes, face, head, and extremities, protective clothing, respiratory devices, and protective shields and barriers, shall be required for personnel who are mixing caustic or acidic cleaning solutions.

5.2 Cleaning. The cleaning and treatment compounds described herein are environmental pollutants if discharged to the water and may be toxic to fresh water and marine organisms. Disposal procedures specified in 5.9 shall be followed. Pickling is not required to clean existing installations during repair or modification unless the pipe or tube has internal oxide scale that cannot be removed by wire brush, water jet, or flushing. If new piping sections have been installed, only the new pipe or tube installed requires pickling. New piping sections do not require pickling if already pickled as specified herein prior to delivery and a clean condition has been maintained during construction. Heat discoloration of piping interior due to welding is not cause for pickling. The following procedure shall be followed in preparation for pickling:

a. If surfaces are coated with oil or preservatives, the component shall be immersed in the degreasing solution both before and after brushing and air blasting.

b. Wire-brush entire surface, including interior. Boiler tube brushes or commercial pipe-cleaning apparatus may be used.

c. Blast thoroughly with air below 30 pounds per square inch (lb/in^2) to remove loose particles. Effective chip guarding and personal protective equipment shall be used during air blasting operations.

d. Remove grease, oil, and shop dirt by immersing the work in sufficient quantity of the following solution at 160±10 °F for 15 minutes or longer, depending upon the degree of contamination:

(1) Trisodium phosphate monohydrate (in accordance with O-S-642) – 7 to 10 ounces.

(2) Detergent, nonionic (polyethylene-glycol monoalkylaryl ether) (in accordance with MIL-D-16791, Type I) – 1 fluid ounce.

(3) Water – 1 gallon.

e. Rinse thoroughly in warm water (at least 120 °F).

f. If cleaned pipe, tubing, and fittings are not pickled immediately, dry with warm, dry, oil-free air which has been filtered through at least 15-micrometer absolute rated filters (hereafter referred to only as clean air), and protect from dust, dirt, oil and moisture.

5.2.1 Compressed air cleaning plugs. The use of commercially available pipe cleaning plugs or “pigs” that are close fitting to the inside diameter of the pipe and driven by compressed air for mechanical removal of contaminants in corrosion resistant pipe assembly is acceptable, provided that the pipe assembly contains no dead legs, branches, or reductions in area. Accountability shall be provided for any plugs that were used to ensure that they are not left behind in the pipe assembly.

5.3 Pickling and hydrostatic tests (prior to installation). Pickling and hydrostatic tests shall be in accordance with the procedures specified herein. Caution shall be exercised by the operator during the pickling process insofar as time of immersion in the acid bath is concerned. The assembly shall remain in the bath only long enough to permit adequate pickling (removal of scale), as determined visually. Due to the nature of the pickling process, this caution is necessary to ensure and protect the mechanical properties of the pipe, tubing, or fitting. The position of the tubing in the pickling bath shall be changed occasionally to make sure that if gas pockets form they shall not always be at the same location. When hydraulic fluid is used for hydrostatic testing, the assembly shall be degreased just prior to further brazing or welding.

5.3.1 Nonferrous pipe, tubing, and fittings (bronze, copper, copper-nickel, and nickel-copper, not aluminum or aluminum alloys). Aluminum and aluminum alloys shall not be pickled.

5.3.1.1 Nonferrous metals other than nickel-copper. The pickling procedure shall be as follows:

a. Pickle free from scale in a solution of the following composition at 60 to 100 °F:

(1) Sulfuric acid, 66 degrees Baume, specific gravity (sp. gr.), 1.83, conforming to Type I, Class 1 of A-A-55828 – 7 to 14 fluid ounces.

(2) Water – 1 gallon.

(Caution: The acid shall always be added carefully with stirring to cooled water. This mixing procedure shall always be followed when adding concentrated sulfuric acid to water.)

Note: If red stains appear, immerse the work briefly in a solution formulated as above but which contains, in addition, 2 to 4 ounces of sodium dichromate (per gallon of water) conforming to A-A-59123. This solution shall be maintained at a temperature range of 70 to 120 °F.

5.3.1.2 Nickel-copper. The pickling procedure shall be as follows:

a. Pickle for 20 to 40 minutes in a hot solution (180±10 °F) of the following composition:

(1) Hydrochloric acid, 20 degrees Baume, sp. gr 1.16 (in accordance with ASTM E1146) – ½ gallon.

(2) Cupric chloride – 4 ounces.

(3) Water – 1 gallon.

b. Rinse in warm water (over 120 °F).

c. Immerse for 5 to 10 minutes in a bath composed as follows (temperature 70 to 100 °F).

(1) Sulfuric acid, 66 degrees Baume, sp. gr. 1.83 conforming to Type I, Class 1 of A-A-55828 – 13 fluid ounces.

(2) Sodium dichromate (in accordance with A-A-59123) – 17½ ounces

(3) Water – 1 gallon.

5.3.1.3 Treatment following pickling. The treatment following pickling shall be as follows:

a. Immediately after pickling, rinse in a clean, warm water bath.

b. Neutralize traces of acid from the pickling operation by rinsing the work in an alkaline bath containing 4 ounces (per gallon of water) of sodium carbonate in accordance with A-A-59563.

c. Rinse thoroughly in fresh, warm water (over 120 °F).

d. If hydrostatic test will not be performed with water (see 5.3.1.4), dry with clean air.

5.3.1.4 Hydrostatic test prior to installation. The piping assembly shall be subjected to the specified test pressure (usually specified in system diagrams) with tap water or with hydraulic fluid equal to, or compatible with, which is normally used in the system. If leaks occur, they shall be repaired and the assembly retested. Following a satisfactory test, the solution shall be drained and all openings capped. If water is used, the assembly shall be blown dry by clean dry air before openings are capped. The piping assembly shall then be installed up to the components (see 4.2).

5.3.2 Ferrous pipe, tubing, and fittings (other than corrosion-resistant steel). The pickling procedure shall be as follows (see 5.3):

a. Pickle free from rust and scale in a hot solution (150±10 °F) of the following composition:

(1) Sulfuric acid, 66 degrees Baume, sp. gr. 1.83 conforming to Type I, Class 1 of A-A-55828 – 7 to 14 fluid ounces.

(2) Sulfuric acid pickling inhibitor – Quantity recommended by manufacturer.

(3) Water – 1 gallon.

5.3.2.1 Treatment following pickling. The treatment following pickling shall be as follows:

a. Rinse immediately after pickling in a clean, warm water (over 120 °F) bath.

b. Immerse for several minutes in an alkaline bath containing 4 ounces (per gallon of water) of sodium carbonate conforming to A-A-59563.

c. Rinse by immersing in a clean, warm water (over 120 °F) bath.

d. Immerse in a corrosion inhibitor bath according to manufacturer's recommendations.

e. If the hydrostatic test is to be performed with hydraulic fluid (see 5.3.2.2), rinse the work with clean water, then dry with clean air.

5.3.2.2 Hydrostatic test prior to installation. The piping assembly shall be subjected to the specified test pressure using a hydraulic fluid equal to, or compatible with, that normally used in the system. If leaks occur, they shall be repaired and the assembly treated and retested as specified herein. Following a satisfactory test, the fluid shall be drained and all openings capped. If a water solution has been used, the assembly shall be blown dry with clean dry air before openings are capped. The piping assembly shall then be installed up to the components (see 4.3).

5.3.3 Corrosion-resistant steel pipe, tubing, and fittings. The pickling operation shall be as follows (see 5.3):

a. Immerse work for 10 to 15 minutes in a hot solution (130±10 °F) of the following composition:

(1) Nitric acid (in accordance with A-A-59105) – 13 to 20 fluid ounces.

(2) Hydrofluoric acid (60 percent) (in accordance with O-H-795) – 1 to 2 fluid ounces.

(3) Water – 1 gallon.

b. Rinse in a clean, warm water (over 120 °F) bath.

c. If hydrostatic test will not be performed with water (see 5.3.1.4), dry the piping assembly with clean air.

5.3.3.1 Hydrostatic test prior to installation. The piping assembly shall be subjected to the test specified in 5.3.1.4.

5.4 Flush of installed system for removal of brazing fluxes. The entire piping system, after installation up to, but not including, the components shall be flushed to remove brazing fluxes. Flushing blocks and other jumpers shall be used to connect piping around components not being flushed. Before filling the system with water, a low pressure air test (up to 100 lb/in^2) shall be applied to the piping to check for leaks. Any one of the three following procedures shall be conducted. (The hot flush and hot circulation methods are preferred.)

a. Hot flush soak with nonrecirculating fresh water for 1 hour while ensuring that the temperature at any part of the system does not go below 110 °F.

b. As an alternative to the hot flush procedure, a hot recirculating procedure with fresh water may be conducted for a period of 1 hour for systems where such an arrangement is feasible. The system temperature shall be monitored so that no part of the system falls below 110 °F. Following the recirculating procedure, the system shall be flushed with fresh water for 15 minutes at a minimum temperature of 60 °F.

c. Cold soak the system for 12 hours using fresh water at a minimum temperature of 60 °F. At the completion of the 12-hour soak, systems shall be flushed with nonrecirculating fresh water at a minimum temperature of 60 °F for 4 hours.

Under all of the above flux removal procedures, the system shall be full of water so that joints are completely submerged at all times. The minimum flow rate in gallons per minute (gal/min) required for removal of residual brazing flux in piping systems shall be 1.5 times the internal pipe diameter (id) in inches. Upon completion of the flux removal procedure, completely drain the system and dry with air.

5.4.1 Requirements for final fit-up joints using minimum flux brazing procedure. Final fit-up joints that are used to install piping assemblies that were brazed and flushed prior to installation do not require a system flush following installation provided that a qualified minimum flux brazing procedure is used for joint fit-up.

5.5 Hydrostatic test after installation. The entire piping system, after installation up to the components, shall be subjected to the specified test pressure with tap water or with a hydraulic fluid equal to, or compatible with, the fluid normally used in the system. If water has been used, the system shall be drained completely after the test and blown dry with clean air. Components and piping assemblies which passed a hydrostatic test prior to installation need not be retested.

5.5.1 Hydraulic system/component preservation. Hydraulic systems and components which are subject to corrosion shall be preserved in accordance with MIL-STD-2073. Prior to all assembly, all oil films and preservatives shall be removed from those sections which shall be subjected to welding or brazing operations. Assembled systems which have been protected by a preservative fluid (see 5.5.1.1) shall be thoroughly drained and blown down before adding the system fluid. (See 5.9 for disposal instructions for these fluids.) If the assembled system has not been thoroughly cleaned prior to adding protective fluids, a complete flush (see 5.6) shall be required before putting the system into operation.

5.5.1.1 Assembled systems. Hydraulic systems which are to be left inactive for 6 months or less shall be protected by filling with the system fluid. Those systems, fabricated from non-corrosion resistant piping, which are to be left inactive for an extended period (6 months or more) shall be filled with a suitable preservative fluid. For systems containing petroleum base or PAO base fluids, the preservative fluid shall be in accordance with MIL-PRF-6083. For systems containing phosphate ester base hydraulic fluids such as MIL-H-19457 fluids, the preservative fluid shall be in accordance with MIL-H-19457 with addition of a vapor phase inhibitor in accordance with MIL-I-22110 in accordance with manufacturer's instructions. For water based systems, the preservative fluids shall be the system fluid in accordance with MIL-H-22072. Adequate vents and tanks shall be provided to compensate for the expanding and contracting fluid and minor system leaks. When the system is preserved with other than the normal system fluid, tags with the following information shall be conspicuously attached: "This system has been filled with preservative fluid to (specification) on (date). This fluid shall be completely drained and blown down before adding system fluid."

5.5.1.2 Components. If system components are not to be installed immediately, preservation shall be in accordance with the requirements specified in 5.5.1.2.1 through 5.5.1.2.3.

5.5.1.2.1 Short term (internal surfaces). For petroleum or PAO oil system components, short term preservation of internal surfaces shall be accomplished with fluids in accordance with MIL-PRF-6083. For phosphate-ester system components, internal surfaces shall be preserved with fluids in accordance with MIL-H-19457 with addition of vapor space inhibitor in accordance with MIL-I-22110, in accordance with the inhibitor manufacturer's instructions. Water based fluid system components in long term storage shall require annual treatments with the system fluid, as specified in MIL-H-22072. Preservation with coatings in accordance with MIL-PRF-6083 or MIL-H-19457 fluids is satisfactory for 1 year, after which recoating is required. Since these fluids, in small quantities, are compatible with the system operating fluids, draining of residual fluid prior to installation will provide adequate removal of the preservatives. (See 5.9 for disposal instructions for these fluids.) (See 5.6.1 for definition of acceptable liquid contamination.) Complete removal and degreasing is required when brazing or welding is necessary to reassemble the system. A tag with the following information shall be attached to the assembly: "The interior of this item has been (filled, coated) with corrosion preventive fluid to (specification) on (date). Coatings require replacement 1 year from date. Prior to assembly, complete removal and degreasing is required if brazing or welding is necessary to assemble components."

5.5.1.2.2 Long term (internal surfaces). For petroleum or PAO oil system components, which are expected to be in storage for considerably longer than 1 year, and are easily disassembled and cleaned, the internal surfaces shall be treated with preservative in accordance with MIL-STD-2073, Type P-2 (MIL-PRF-16173, Grade 2). A tag with the following information shall be attached to the assembly: "The interior of this item is coated with corrosion preventive compound, Grade 2 of MIL-PRF-16173. This compound shall be removed just prior to installation." Phosphate ester system components in long term storage will require annual treatments with fluid in accordance with MIL-H-19457 with addition of vapor space inhibitor in accordance with MIL-I-22110. The assembly shall be tagged as specified in 5.5.1.2.1.

5.5.1.2.3 External surfaces. For external surfaces of petroleum or PAO oil and phosphate ester fluid system components requiring preservation, coatings in accordance with MIL-STD-2073, Type P-1 (MIL-PRF-16173, Grade 1) or Type P-19 (MIL-PRF-16173, Grade 4) shall be applied where the preservative will not have to be removed for system operation, or where preservative removal by scraping or solvent action would not damage the part or equipment. Where removal of the preservative will be required, such as when the preservative would otherwise be in contact with the system fluid, a coating in accordance with MIL-STD-2073, Type P-2 or Type P-19 shall be applied. A tag with the following information shall be attached to the assembly: "The exterior of this item has been coated with corrosion preventive compound to (specification), (coating type or grade). Removal of this compound (is, is not) necessary prior to installation."

5.5.1.3 Preservative removal. The coatings in accordance with MIL-STD-2073, Type P-2 and P-19 and fluid films in accordance with MIL-PRF-6083 may be removed with dry cleaning solvent in accordance with MIL-PRF-680, Type II. Surfaces cleaned with solvent will be left unprotected and shall be immediately wetted with the system fluid unless welding or brazing will be required to reassemble the system. For preserved petroleum or PAO fluid system components which will not require degreasing, the system oil may be used to remove the preservative. When solvent in accordance with MIL-PRF-680 is used to remove protective coatings, complete removal of the solvent is required to avoid subsequent contamination of the system operating fluid. (See 5.9 for disposal instructions for these fluids.)

5.6 System flushing. Installed piping shall be flushed before being put into operation. It is important for designers of hydraulic systems to plan for system flushing in the design phase. Dead ends without circulation shall be avoided. If there is a risk of particulate contamination moving from the dead end to the rest of the system, then the dead end shall be capable of being outflushed or a flush path loop using temporary jumpers shall be established. Flushing fluid shall be the system operating fluid or a fluid compatible with system fluid as approved by the acquiring activity. The primary difference between flushing oils and the system fluid is viscosity; lower viscosity oils (such as MIL-PRF-5606 and MIL-PRF-17672, Sym 2075TH) require much lower flow rates to maintain the Reynolds number specified in 5.6.1 while having much lower pressure drops than the higher viscosity oils (such as 2135TH and 2190TEP). This means that by using low viscosity oils as the flushing fluid, longer pipe lengths for any given pipe size can be flushed with a given flushing plant or the same length of pipe can be flushed at higher flow rates than with high viscosity oils. Flushing shall be performed on the entire system, but may be accomplished piecemeal on those circuits which can be independently cleaned and isolated. Complex systems may be divided into parts in order to assure the required flow rate in every part of the system during flushing. Hydraulic pumps, motors, complex valves, and devices that restrict flow or could be damaged by contaminants dislodged during flushing shall be removed from the circuit; and temporary pipe, flushing blocks, tube or hose substituted in their place. See figure 1 for an example of a typical flushing loop on a complex system, such as that on a submarine. System flushing shall be in accordance with the following:

a. A temporary filter, in accordance with SAE J2321, or equal, shall be installed in the circuit being flushed and clean filter elements installed as necessary to keep the pressure drop across the filter within specified limits. Care shall be taken to select a filter with the optimum filtration ratio, so as to achieve the desired cleanliness level within an acceptable period of time. Filter bypass valves shall not be used. The flushing fluid shall be filtered through a filter in accordance with SAE J2321, or equal, as the system is filled.

b. Flushing shall be performed in the same direction as the normal fluid flow during system operation. When the normal system flow may be in either direction, such as in control port actuator lines, flushing these lines in both directions shall be required only when specified by the acquiring activity. Circuits having a rise in elevation in the direction of flow shall require reversing the direction of the flush to ensure that the system is clean in both directions only when specified by the acquiring activity. When flushing is done in both directions, flushing in the direction of normal flow shall be done last.

c. Large components that are assembled or disassembled in place to support new construction or overhaul of hydraulic systems can be cleaned in place. Best shop practice and judgment shall be used in determining the extent of assembly or disassembly of these large components in obtaining a visually clean condition of the component's internal parts as an alternate to flushing the component.

d. Components such as reservoirs, accumulators, and cylinders shall be flush rinsed with a high velocity jet stream or wiped clean with a lint-free cloth as conditions permit to attain a visually clean condition. Pistons shall be removed from cylinders and accumulators for shop cleaning when practical. When wiping is necessary, lint-free toweling shall be used. Components cleaned in the shop prior to installation and properly preserved, sealed, and stored may be connected to the piping after the piping is flushed, without further cleaning (see 5.5.1.2).

e. Reasonable technical competence shall be exercised in planning the flushing of a system. (MIL-HDBK-407 is recommended for background information). Unless otherwise specified by the contracting officer or the ship supervisor (see 6.1), flushing shall continue until the fluid indicates that the class 9 cleanliness requirement of SAE-AS4059 (or ISO 4406) has been achieved to suit the turbulent flow requirements of paragraph 5.6.1 and the minimum flushing time specified in 5.6.1.1. Prior to termination of flushing the system piping, the water content of the flushing fluid shall be determined when the flushing fluid is not water based. Unless otherwise specified by the ordering document (see 6.1), the water content shall not exceed 0.05 percent by volume for any single sample. Unless otherwise specified by the ordering document (see 6.1), the average of the samples taken prior to terminating the flush shall not exceed 0.03 percent by volume for any system or circuit thereof. After flushing and reassembly, the system shall be filled with fluid which meets the applicable system fluid specification, satisfies the required system fluid cleanliness requirements, and has been final filtered through a filter in accordance with SAE J2321, or equal, during the system fill process.

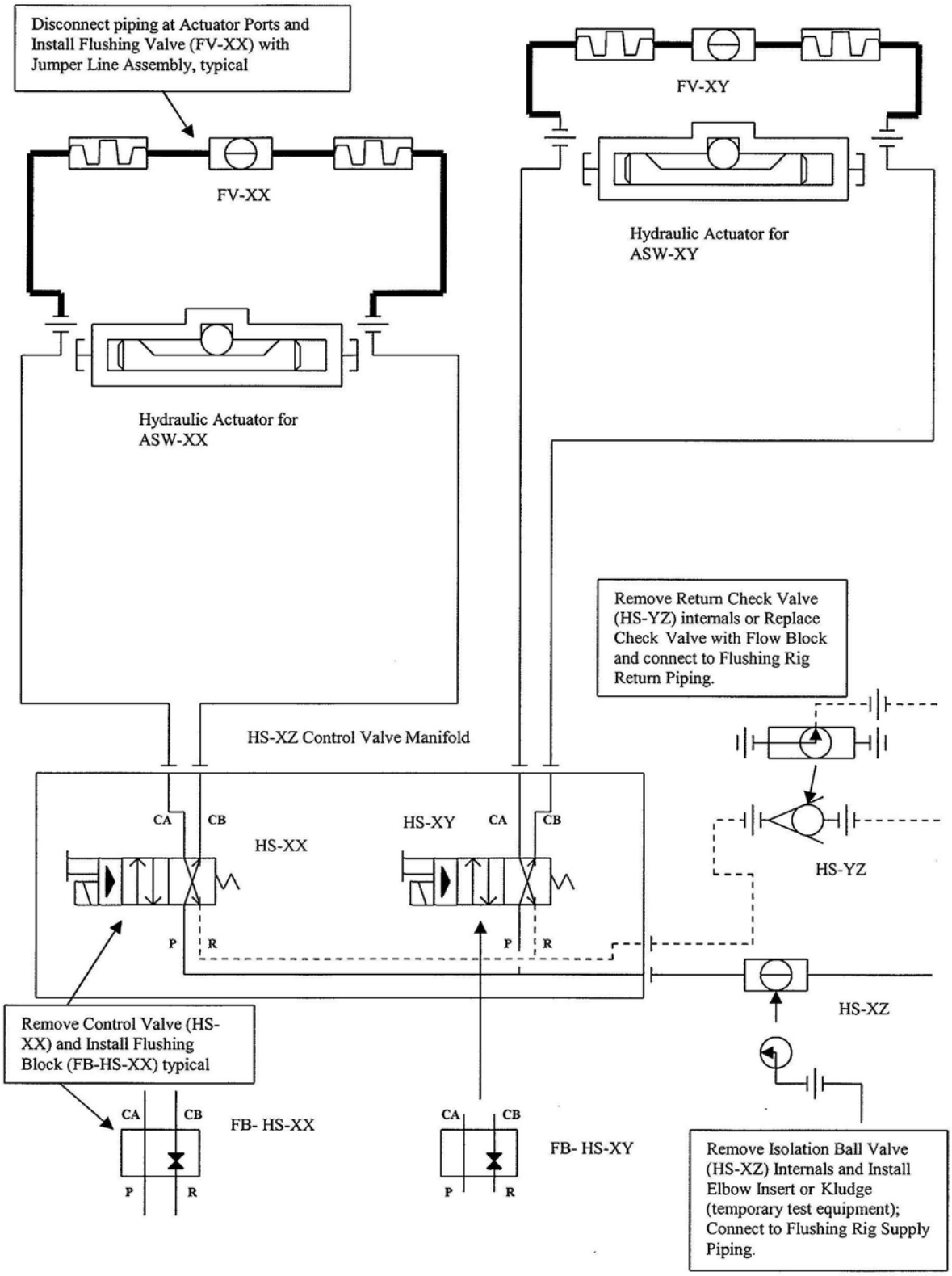

FIGURE 1. Typical flushing loop.

5.6.1 Procedure for system operating fluid flush. Flushing with system operating fluid or a fluid compatible with system fluid as approved by the acquiring activity shall be performed. For systems utilizing MIL-PRF-17331, MIL-PRF-17672, or PAO base fluids, flushing may be conducted with lower viscosity MIL-PRF-17672 or MIL-PRF-6083 fluids. In order to effectively remove particulate contamination from hydraulic piping, the flushing fluid should achieve turbulent flow. Reynolds number (Re) is calculated by the following equation:

Re = 3160*Q/(d*v)

Where:

Q = flow rate (gpm)

d = waterway cross-section, pipe ID (inches)

v = fluid viscosity (centistokes c.s.)

Note: The value 3160 is a constant corresponding to units of gpm, inches, and c.s.

For pipe sizes greater than ½ inch, the fluid, flow rate, and fluid temperature shall be defined to achieve a Reynolds number of at least 4000. For ½ inch pipe, if a Reynolds number of 4000 cannot be achieved, then the pipe shall be agitated, the original established flushing time doubled, and a minimum Reynolds number of 2000 achieved. For pipe sizes less than ½ inch, when piping cannot be reasonably flushed in short enough sections to stay within the pressure limits of the piping (and system), the Reynolds number shall not drop below 2000. Upon completion of flushing with fluids other than the system operating fluid, the system shall be completely drained and blown free of flushing fluid, and the system refilled with operating fluid. Depending upon the complexity of the system and the amount of flushing oil left behind, a second or third drain-and-fill sequence may be required to provide minimal acceptable liquid (not solid) contamination.

5.6.1.1 Minimum flushing time. Flushing at turbulent flow shall continue until the volume of piping being cleaned, or the individual flushing loop as shown in figure 1, has been displaced a minimum of 20 times, as calculated in accordance with ISO 23309 below, or 20 minutes, whichever is greater.

T = 20V/qv

where:

t = minutes

V = volume of piping being cleaned (gal)

qv = flow rate through the loop (gpm)

5.6.2 Flushing fluid samples. Unless otherwise specified by the contracting officer or ship supervisor (see 6.1), samples shall be taken from the bottom side of the pipe within 5 feet of the inlet of the flushing filter during full flow. The size of each sample drawn shall not exceed 1 liter and shall include the fluid and contaminants trapped by the valve and adapter during the preceding 5-minute flushing period. (Open the valve to draw an amount greater than the volume of branch pipe and valve, close the valve and wait 5 minutes and draw the sample.) The entrance to the sampling port shall be flush with the inner circumference of the pipe, and the valve connector (adapter) shall not extend into the pipe beyond the inner surface of the pipe. For taking samples from the system during flushing, diaphragm (packless) valves are recommended. Where the hydraulic system is equipped with sampling valves, samples may be taken from those valves, in lieu of the location specified above. The use of in-line fluid cleanliness monitoring, such as automatic particle counters, may be used to indicate the real time cleanliness level of the flushing fluid. When using in-line or continuous fluid cleanliness monitoring equipment, a periodic verification of equipment performance by an independent fluid sample analysis shall be performed. If this analysis indicates unsatisfactory equipment performance, then the flushing activity shall take the following corrective actions: (a) restore adequate equipment performance and (b) provide assurance of adequate system cleanliness, to include repeat flushing of any suspect flow loops.

5.6.2.1 Sample analyses. The test method for determination of particulate contamination shall be in accordance with SAE-ARP-598 or an automatic particle counter calibrated in accordance with ISO 11171. Directions in the manual for the respective instrument shall be followed. Water content shall be determined in accordance with ASTM D6304, or with commercially available automatic water-analyzing equipment that shall accurately determine water content down to 0.01 percent.

5.7 Capping and sealing open ends. Open ends shall be capped or sealed to preserve cleanliness of assemblies for stowage, transit, or installation operations. Caps shall have the same grade of cleanliness as the pipe or assembly to be sealed. The use of electrical plastic tape or other compatible tape is allowed to hold caps in place. However, the use of any tape as a cap is prohibited. Caps shall be made in accordance with NAS 847.

5.7.1 Petroleum or PAO based hydraulic fluid caps. In systems using petroleum or PAO base hydraulic fluid, plastic or rubber material may be used for caps, with the exception of butyl or ethylene propylene rubber. All other incompatible rubbers shall be prohibited. The pipe end shall be completely covered with sheet plastic or rubber (except butyl) and secured to the pipe outside diameter (od) with electrical plastic tape or some other compatible tape. Nitrile rubber is recommended for caps. These materials may be used for threaded and unthreaded closures.

5.7.2 Phosphate ester based hydraulic fluid caps. In systems using phosphate ester type fire-resistant hydraulic fluid, butyl or other compatible rubber and compatible plastics may be used for caps. The pipe end shall be completely covered with compatible sheet plastic or butyl rubber, and secured to the pipe od with a compatible tape.

5.8 Ferrous systems (except corrosion-resistant steel). When specified by the command or agency concerned, ferrous piping, tubing, and fittings shall be phosphate coated, prior to installation, in accordance with the specified type and class of MIL-DTL-16232.

5.9 Disposal of waste materials used in cleaning. The following materials and solutions containing these materials shall not be discharged overboard. They shall be retained in containers and held for shore disposal:

a. Sodium chromate.

b. Sodium dichromate.

c. Lubricating oil.

d. Cleaning oil.

e. Corrosion preventive, solvent cutback, cold application.

f. Dry cleaning solvent.

g. Hydraulic fluids.

Other materials shall be disposed of in accordance with local, state, and Federal laws or retained in containers for shore disposal.

6. NOTES

(This section contains information of a general or explanatory nature that may be helpful, but is not mandatory.)

6.1 Acquisition requirements. Acquisition documents should specify the following:

a. Title, number, and date of the standard.

b. The required system cleanliness level (based on the cleanliness methods in accordance with SAE-AS4059 or ISO 4406) and the minimum flushing time, as necessary (see 5.6.e)

c. The maximum water content by volume for any single sample, as necessary (see 5.6.e).

d. The maximum average water content by volume for all samples, as necessary (see 5.6.e)

e. Flushing fluid sample locations, as necessary (see 5.6.2)

6.2 Subject term (key word) listing.

Hydrochloric acid

Hydrofluoric acid

Hydrostatic test

Long term (internal surfaces)

Nitric acid

Pickling test

Short term (internal surfaces)

Sodium dichromate

Sulfuric acid

System flushing

6.3 Changes from previous issue. Marginal notations are not used in this revision to identify changes with respect to the previous issue due to the extensiveness of the changes.

Custodians:
Army – CR4
Navy – SH

Preparing activity:
Navy – SH
(Project 4730-2009-014)

Review activities:
Army – MI
Navy – MC, MS, OS

NOTE: The activities listed above were interested in this document as of the date of this document. Since organizations and responsibilities can change, you should verify the currency of the information above using the ASSIST Online database at https//assist.daps.dla.mil.