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UNIFIED FACILITIES GUIDE SPECIFICATIONS

References are in agreement with UMRL dated January 2021
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SECTION 41 24 26

HYDRAULIC POWER SYSTEMS

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HYDRAULIC POWER SYSTEMS
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NOTE: This guide specification covers the requirements for hydraulic fluid power systems.

Adhere to UFC 1-300-02 Unified Facilities Guide Specifications (UFGS) Format Standard when editing this guide specification or preparing new project specification sections. Edit this guide specification for project specific requirements by adding, deleting, or revising text. For bracketed items, choose applicable item(s) or insert appropriate information.

Remove information and requirements not required in respective project, whether or not brackets are present.

Comments, suggestions and recommended changes for this guide specification are welcome and should be submitted as a Criteria Change Request (CCR).
****

PART 1 GENERAL

1.1 REFERENCES

****
NOTE: This paragraph is used to list the publications cited in the text of the guide specification. The publications are referred to in the text by basic designation only and listed in this paragraph by organization, designation, date, and title.

Use the Reference Wizard's Check Reference feature when you add a Reference Identifier (RID) outside of the Section's Reference Article to automatically place the reference in the Reference Article. Also use the Reference Wizard's Check Reference feature to update the issue dates.

References not used in the text will automatically be deleted from this section of the project specification when you choose to reconcile references in the publish print process.
****

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS (ASME)

ASME B1.1	(2003; R 2018) Unified Inch Screw Threads (UN and UNR Thread Form)
ASME B1.20.1	(2013; R 2018) Pipe Threads, General Purpose (Inch)
ASME B1.20.2M	(2006; R 2011) Pipe Threads, 60 Deg. General Purpose (Metric)
ASME B1.20.3	(1976; R 2013) Dryseal Pipe Threads (Inch)
ASME B16.5	(2017) Pipe Flanges and Flanged Fittings NPS 1/2 Through NPS 24 Metric/Inch Standard
ASME B16.11	(2016) Forged Fittings, Socket-Welding and Threaded
ASME B17.1	(1967; R 2017) Keys and Keyseats
ASME B17.2	(1967; R 2017) Woodruff Keys and Keyseats
ASME B18.2.1	(2012; Errata 2013) Square and Hex Bolts and Screws (Inch Series)
ASME B18.2.2	(2015) Nuts for General Applications: Machine Screw Nuts, Hex, Square, Hex Flange, and Coupling Nuts (Inch Series)
ASME B18.6.2	(1998; R 2010) Slotted Head Cap Screws, Square Head Set Screws, and Slotted Headless Set Screws: Inch Series
ASME B31.1	(2020) Power Piping
ASME B40.100	(2013) Pressure Gauges and Gauge Attachments
ASME BPVC SEC IX	(2017; Errata 2018) BPVC Section IX-Welding, Brazing and Fusing Qualifications
ASME BPVC SEC VIII D1	(2019) BPVC Section VIII-Rules for Construction of Pressure Vessels Division 1

ASSOCIATION FOR IRON AND STEEL TECHNOLOGY (AIST)

AIST PB-229	(2008) Stainless Steels: A Steel Products Manual

ASTM INTERNATIONAL (ASTM)

ASTM A36/A36M	(2019) Standard Specification for Carbon Structural Steel
ASTM A106/A106M	(2019a) Standard Specification for Seamless Carbon Steel Pipe for High-Temperature Service
ASTM A108	(2013) Standard Specification for Steel Bar, Carbon and Alloy, Cold-Finished
ASTM A182/A182M	(2020) Standard Specification for Forged or Rolled Alloy and Stainless Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High-Temperature Service
ASTM A234/A234M	(2019) Standard Specification for Piping Fittings of Wrought Carbon Steel and Alloy Steel for Moderate and High Temperature Service
ASTM A519/A519M	(2017) Standard Specification for Seamless Carbon and Alloy Steel Mechanical Tubing
ASTM A574	(2017) Standard Specification for Alloy Steel Socket-Head Cap Screws
ASTM A576	(2017) Standard Specification for Steel Bars, Carbon, Hot-Wrought, Special Quality
ASTM A659/A659M	(2012; R 2017) Standard Specification for Commercial Steel (CS), Sheet and Strip, Carbon (0.16 Maximum to 0.25 Maximum Percent), Hot-Rolled
ASTM B117	(2019) Standard Practice for Operating Salt Spray (Fog) Apparatus
ASTM D3951	(2015) Commercial Packaging

INDUSTRIAL FASTENERS INSTITUTE (IFI)

IFI 100/107	(2002) Prevailing Torque-Type Steel Hex and Hex Flange Nuts Regular and Light Hex Series

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION (ISO)

ISO 4406	(2017) Hydraulic Fluid Power - Fluids - Method for Coding the Level of Contamination by Solid Particles
ISO 5598	(2020) Fluid Power Systems and Components

- Vocabulary

ISO 9461 (1992) Hydraulic Fluid Power - Identification of Valve Ports, Subplates, Control Devices and Solenoids

ISO 10763 (2020) Hydraulic Fluid Power - Plain-end, Seamless and Welded Precision Steel Tubes - Dimensions and Nominal Working Pressures

ISO 11727 (1999) Pneumatic Fluid Power - Identification of Ports and Control Mechanisms of Control Valves and Other Components

MANUFACTURERS STANDARDIZATION SOCIETY OF THE VALVE AND FITTINGS INDUSTRY (MSS)

MSS SP-58 (2018) Pipe Hangers and Supports - Materials, Design and Manufacture, Selection, Application, and Installation

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)

NEMA ICS 1 (2000; R 2015) Standard for Industrial Control and Systems: General Requirements

NEMA ICS 2 (2000; R 2005; Errata 2008) Industrial Control and Systems Controllers, Contactors, and Overload Relays Rated 600 V

NEMA ICS 6 (1993; R 2016) Industrial Control and Systems: Enclosures

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

NFPA 70 (2020; ERTA 20-1 2020; ERTA 20-2 2020; TIA 20-1; TIA 20-2; TIA 20-3; TIA 20-4) National Electrical Code

NATIONAL FLUID POWER ASSOCIATION (NFLPA)

ANSI/NFLPA T3.16.2 (1997; Rev 1; Reapproved 2005) Hydraulic Fluid Power - Design for Nonintegral Industrial Reservoirs

NFLPA T2.13.1 (2007; 5th Ed) Recommended Practice – Hydraulic Fluid Power – Use Of Fire Resistant Fluids In Industrial Systems

NFLPA T3.5.1 (2002; R 2015) Hydraulic Fluid Power - Valves, Mounting Surfaces

NFLPA T3.28.9 (1989; R 2009; 2nd Ed) Fluid Power Systems and Products - Moving Parts Fluid Controls - Method of Diagramming

SOCIETY OF AUTOMOTIVE ENGINEERS INTERNATIONAL (SAE)

SAE AS598	(2012) Aerospace Microscopic Sizing and Counting of Particulate Contamination for Fluid Power Systems
SAE J514	(2012) Hydraulic Tube Fittings

UNDERWRITERS LABORATORIES (UL)

UL Electrical Appliance	(2012) Electrical Appliance and Utilization Equipment Directory

1.2 DEFINITIONS

The definitions of terms having a unique meaning in fluid power technology shall be those given in ISO 5598.

1.3 SUBMITTALS

****

NOTE: Review submittal description (SD) definitions in Section 01 33 00 SUBMITTAL PROCEDURES and edit the following list, and corresponding submittal items in the text, to reflect only the submittals required for the project. The Guide Specification technical editors have classified those items that require Government approval, due to their complexity or criticality, with a "G." Generally, other submittal items can be reviewed by the Contractor's Quality Control System. Only add a “G” to an item, if the submittal is sufficiently important or complex in context of the project.

For Army projects, fill in the empty brackets following the "G" classification, with a code of up to three characters to indicate the approving authority. Codes for Army projects using the Resident Management System (RMS) are: "AE" for Architect-Engineer; "DO" for District Office (Engineering Division or other organization in the District Office); "AO" for Area Office; "RO" for Resident Office; and "PO" for Project Office. Codes following the "G" typically are not used for Navy, Air Force, and NASA projects.

The "S" classification indicates submittals required as proof of compliance for sustainability Guiding Principles Validation or Third Party Certification and as described in Section 01 33 00 SUBMITTAL PROCEDURES.

Choose the first bracketed item for Navy, Air Force and NASA projects, or choose the second bracketed item for Army projects.

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Government approval is required for submittals with a "G" or "S" classification. Submittals not having a "G" or "S" classification are [for

Contractor Quality Control approval.][for information only. When used, a code following the "G" classification identifies the office that will review the submittal for the Government.] Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-02 Shop Drawings

Detail Drawings; G[, [_____]]

Installation; G[, [_____]]

SD-03 Product Data

Spare Parts; G[, [_____]]

Field Instructions; G[, [_____]]

SD-04 Samples

Hydraulic Fluid

SD-06 Test Reports

Field Tests and Cleaning of Hydraulic Lines

SD-07 Certificates

Welding

SD-10 Operation and Maintenance Data

Operation and Maintenance Manuals; G[, [_____]]

Field Tests and Cleaning of Hydraulic Lines; G[, [_____]]

1.4 QUALITY ASSURANCE

1.4.1 Welding

****
NOTE: If need exists for more stringent requirements for weldments, delete this first subparagraph and use the second.
****

Structural members shall be welded in accordance with Section 05 05 23.16 STRUCTURAL WELDING. Perform welding for piping in accordance with qualified procedures using performance qualified welders and welding operators. Procedures and welders shall be qualified in accordance with ASME BPVC SEC IX. Welding procedures qualified by others, and welders and welding operators qualified by another employer may be accepted as permitted by ASME B31.1. Notify the Contracting Officer 24 hours in advance of tests and the tests shall be performed at the work site if practicable. Apply the welder's or welding operator's assigned symbol near each weld made as a permanent record. Submit a copy of qualified procedures and a list of names and identification symbols of qualified welders and welding operators.

1.4.2 Stringent Requirements

Welding and nondestructive testing procedures for piping are specified in Section 40 05 13.96 WELDING PROCESS PIPING.

1.5 DELIVERY, STORAGE, AND HANDLING

Protect equipment delivered and placed in storage from the weather, humidity and temperature variation, dirt and dust, or other contaminants.

1.6 EXTRA MATERIALS

Submit spare parts data for each different item of material and equipment specified, after approval of detail drawings and not later than [_____] months prior to the date of beneficial occupancy. Include in the data a complete list of parts and supplies, including lubricants and fluids, current unit prices, sources of supply, and a list of the parts recommended by the manufacturer to be replaced after [1] [and] [3] year(s) of service.

PART 2 PRODUCTS

2.1 MATERIALS AND EQUIPMENT

2.1.1 Standard Products

Provide materials and equipment which are the standard products of a manufacturer regularly engaged in the manufacture of the products and that essentially duplicate items that have been in satisfactory use for at least 2 years prior to bid opening. Items of the same classification shall be identical, including equipment, assemblies, parts, and components. Equipment shall be supported by a service organization that is, in the opinion of the Contracting Officer, reasonably convenient to the site.

2.1.2 Nameplates

The manufacturer's name, address, and catalog number shall be permanently displayed on a plate securely attached to each major item of equipment. Electrical equipment listed in UL Electrical Appliance shall have UL label or registration plate securely attached to the item of equipment.

2.1.3 Prevention of Corrosion

Provide fasteners and nameplates of corrosion-resistant materials. Surfaces of products, such as pumps, cylinders, fluid motors, and similar components, of ferrous metal, where not otherwise specified, shall be given a corrosion-protective coating at the factory. Manufacturers' standard coatings are acceptable, provided that coatings for interior use can withstand continuous exposure to salt spray for 120 hours and coatings for exterior use for 504 hours. The fog test shall conform to ASTM B117. Immediately after completion of the test, coating shall show no signs of wrinkling, cracking, or loss of adherence, and the specimen shall show no signs of corrosion creepage beyond 3 mm l/8 inch on either side of the scratch mark made as specified. If coated samples have successfully withstood the salt spray test within the preceding 2 years, certificates will be acceptable in lieu of testing.

2.1.4 Equipment Guards and Access

Gears, couplings, projecting setscrews, keys, and other rotating parts shall be fully enclosed or properly guarded to preclude personnel contact.

2.2 HYDRAULIC PUMPS

Pump volumetric ratings, tests, type, application, and mounting provisions shall be in accordance with manufacturer's instructions and tested by approved methods for conformance with performance ratings. Pump rotation shall be as indicated. Pumps shall be rated for continuous operation at a discharge pressure equal to or greater than the pressure indicated. The rated discharge capacity of each pump shall not be less than indicated when the pump is operated at the design input speed and discharge pressure.

2.2.1 Gear Pumps

Gear pumps shall be [fixed] [variable] [or] [_____] type. Covers and center section shall be [high strength aluminum alloy die castings] [steel] [cast iron]. Thrust and wear plates shall be [heavy-duty bronze coated steel] [bronze] [or] [_____]. Manufacturer's [standard] [or] [_____] shaft seals shall be used for rotary pumps. Seals and wear plates and other wearing parts shall be replaceable and shall be suitable for the application, duty, and temperatures involved.

2.2.2 Vane Pumps

2.2.2.1 Fixed Displacement Vane Pumps

Fixed displacement vane pumps shall be hydraulically balanced types. Housing shall be [high tensile strength ductile iron] [cast iron] [_____]. Vanes shall be [heat treated high-speed tool steel] [_____]. Shaft and rotor shall be [case hardened steel] [_____]. Shaft shall ride in bearings at both ends. Cam ring shall be [high carbon chromium steel] [_____]. Double vane pumps shall be provided when indicated. Seals shall be [Buna N] [nitrile rubber] [fluoroelastomer] [_____].

2.2.2.2 Variable Displacement Vane Pumps

Variable displacement vane pumps shall incorporate means for varying the pump displacement from zero to the maximum rated quantity while the pump is operating against the system pressure indicated. Materials shall be as specified for fixed vane pumps. Pumps shall be arranged for adjustment of discharge volume by [mechanical] [electrical] [hydraulic] [pneumatic] means. The pump displacement shall be controlled by [integral automatic pressure compensation] [adjustment screw] control. The pump casing shall be provided with a tapped outlet for connection of an external drain line. Pump ports shall be [NPT] [tapped NPTF] [tapped for straight pipe threads] [drilled and faced for flange connections] [socket weld].

2.2.3 Piston Pumps

Piston pumps shall be [cylinder block in-line type which reverses flow direction and controls flow rate by means of external valve bank] [axial fixed] [axial variable] [or] [_____]. [Axial variable type shall be capable of providing reversed flow with constant direction of input shaft rotation.] [Axial variable type shall be suitable for control of displacement [and direction of flow] by [manual] [mechanical] [hydraulic] [electric] [pneumatic] devices.] [Manually adjustable maximum and minimum

limits of displacement in each direction of flow shall be provided.]

2.3 RESERVOIRS

Unless otherwise indicated, nonintegral reservoirs shall conform to the general requirements of ANSI/NFLPA T3.16.2.

2.3.1 Basic Construction

****

NOTE: Insert the appropriate number in the blanks. Variations in the fluid line connections are permitted at the designer's option.

****

Each reservoir shall be breather type of welded [carbon steel] [corrosion-resisting steel] construction with removable cleanout plates provided at each end. Cleanout plates shall have gaskets and shall be securely fastened to the reservoir end plates. Each reservoir shall be sloped to a drain plug located at the low point. The bottom of the reservoir shall have a minimum clearance of 150 mm 6 inches above the floor. The legs or base of floor-mounted reservoirs shall have suitable holes for fasteners. A minimum of one interior baffle shall be provided to separate the return line from the pump suction line. A filter breather cap and fill port with a [_____] mesh strainer shall be provided. Port cap shall have retaining chain. A separate steel mounting plate at least 19 mm 3/4 inch thick shall be provided to support the pumping unit.

2.3.2 Fluid Line Connections

The pump suction line shall extend as far as practicable below the low fluid level but shall clear the bottom of the tank by a distance equal to 1-1/2 times the nominal line size. The suction line shall be equipped with a [100 by 100] [_____] mesh externally mounted strainer having a rated capacity not less than twice the pump discharge capacity. Strainer material for filters at both the suction line and the fill inlet shall be [55-mesh nylon] [30-mesh brass] [or] [30-mesh stainless steel] material compatible with the reservoir material and the hydraulic fluid. Drain lines shall extend below fluid level. [Extra return and drain line connections shall be built into reservoir.]

2.3.3 Magnetic Separators

Manufacturer's standard magnetic separators shall be provided in the reservoir. Magnetic separator shall consist of a high-strength permanent magnet arranged for rigid mounting with the poles of the magnet exposed to the fluid in the reservoir. The magnet shall be [combined in the construction of the fill strainer] [mounted on a removable rod assembly installed through the top of the reservoir] [or] [incorporated in the bottom drain plug]. [The drain plug type installation shall incorporate an automatic valve arranged to permit removal of the magnetic separator for inspection without loss of fluid from the reservoir.] [The drain plug type installation shall include provisions for automatic chip detection without removal of the plug.]

2.3.4 Accessories

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NOTE: Thermometers may be deleted at the designer's

option. Where remote operation is anticipated, the design shall include a low-level alarm and pump cutoff device.
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Manufacturer's standard recessed or protected oil level indicator shall be mounted in a readily visible location in proximity to the filler opening. The fluid level gauge shall be clearly marked to indicate the maximum and minimum design operating levels and the fluid level when the system is idle. [Manufacturer's standard direct indicating thermometer shall be provided to indicate fluid temperature in the reservoir. Mercury shall not be used in thermometers. The thermometer shall be of the bimetallic type mounted directly on the reservoir top. The thermometer shall have 90 mm 3-1/2 inch diameter dial with black markings on a white or aluminum background. Case and stem shall be corrosion-resisting steel. Scale range shall be minus 7 to 115 degrees C 20 to 240 degrees F. The thermometer shall be remote reading, capillary tube-and-bulb type. The thermometer shall have a dial not less than 90 mm 3-1/2 inches in diameter with black figures on a white or aluminum background. Indicating head shall be of the [flush] [surface] mounting type. Case shall be [cast iron] [cast brass] with black enamel finish. Bulb and capillary tube shall be corrosion-resisting steel.] [A low-level alarm and pump cutoff device shall be provided as indicated.]

2.4 CYLINDERS

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NOTE: Unless the designer needs to make the choices, because of unique criteria situations, selection of materials and configurations should remain as Contractor's options and the brackets should be removed.
****

Hydraulic cylinder shall be one of the types listed in ISO 5598, and as specified or indicated, of tie rod design, square head standard construction. The pressure rating of the cylinder shall not be less than the maximum system pressure indicated. The manufacturer shall produce evidence that each cylinder was hydrostatically tested to 200 percent of the severest service rating and that dynamic seals are suitable for both frequent and infrequent operation and are capable of not less than 500,000 cycles of operation in systems properly maintained. Cylinders shall have bore, stroke, and rod diameter as indicated. NFPA mounting style shall be as indicated. The hydraulic cylinder shall have [adjustable] [nonadjustable] cushions on [cap end only] [rod end only] [both ends]. [Cushions shall have free reverse flow check valves.] Cylinders shall be provided with double end rods where indicated. Ports shall be [NPTF] [SAE straight-thread O-ring] [_____].

2.4.1 Cylinder Tube

Cylinder tube shall be machined from ASTM A519/A519M, Grade 1018, heavy wall seamless steel tubing and shall have the bore honed to a 254 to 381 nanometers 10 to 15 microinch rms surface finish.

2.4.2 Cylinder Heads and Caps

Cylinder heads and caps shall be fabricated from ASTM A576, Grade 1018, steel bar stock and machine-finished on all surfaces. The cylinder head

shall be equipped with rod seal and external dirt wiper and shall have rod bushing piloted into head to ensure concentricity. [Rod bushing shall be removable without the use of special tools and without removing tie rods or cylinder head.] Attachment of cylinder tube to head and cap shall be [by steel tie rods having a minimum yield strength of 690 MPa 100,000 psi] [or] [as indicated]. Removable attachments shall have the cylinder tube end seals arranged to seal with pressure and shall be designed to prevent shearing and extrusion and to provide axial metal backup.

2.4.3 Pistons

Pistons shall be precision fitted to the cylinder body bore. Pistons shall be [fine-grained cast iron] [_____] and shall be designed and equipped with [zero leakage cup-type seals] [bronze-filled polytetrafluoroethylene seals with phenolic wear rings] [automotive-type lap-sealed cast iron rings]. The design shall protect piston seals from blow-out and over squeeze. [Cups shall be self-regulating and shall automatically compensate for wear.]

2.4.4 Piston Rods

Piston rods shall be made of [medium carbon steel of yield strengths of 620 to 690 MPa 90,000 to 100,000 psi for rods 16 through 102 mm 5/8 through 4 inches in diameter] [620 to 760 MPa 90,000 to 110,000 psi high tensile strength steel using ASTM A108, Type C 1045, for rods 16 to 64 mm 5/8 to 2-1/2 inches in diameter and ASTM A108, Type CR 4140 for rods 76 to 254 mm 3 to 10 inches in diameter]. Rods shall be case hardened to 50-54 Rockwell C, polished to 254 nanometers 10 microinch rms surface finish or better, and hard-chrome plated to 0.0003 minimum thickness.

2.5 FLUID MOTORS

2.5.1 Vane Motors

Fixed displacement vane motors shall be [hydraulically balanced] [high torque, low speed] [_____] type. Motors shall be rated for continuous operation at a system pressure equal to or greater than the pressure shown. The motors shall be capable of producing an actual output torque not less than shown when operating at the indicated supply pressure. Actual displacement shall not exceed the value shown. The shaft shall be [straight keyed] [threaded] [or] [splined]. Shafts shall be capable of rotation in either direction. The motor casing shall be provided with a tapped outlet for connection of an external drain line. Motor ports shall be [tapped NPTF] [tapped with straight pipe threads] [drilled and faced for flange connections]. Filtration shall be 10 microns or less. [Displacement selector valve shall be provided.]

2.5.2 Piston Motors

Piston motors shall be [axial inline] [or] [angle] type and shall be designed as [fixed] [variable] displacement type. Variable displacement type shall be capable of providing reversed rotation with constant direction of fluid flow. Variable displacement type shall be suitable for control of displacement and direction of rotation by [manual] [mechanical] [hydraulic] [electric] [pneumatic] [_____] devices. Manually adjustable maximum and minimum limits of displacement shall be provided. Manually adjustable maximum limits of displacement in each direction of rotation shall be provided. The drive shaft shall be supported by heavy-duty antifriction bearings. The motor casing shall be provided with a tapped

outlet for connection of an external drain line. Motor ports shall be [tapped NPTF] [tapped with straight pipe threads] [drilled and faced for flange connections]. Filtration shall be 10 microns.

2.6 ACCUMULATORS

Accumulators shall be [piston] [bladder] type and shall be [gas pressure] [_____] loaded. Accumulator fluid capacity shall not be less than indicated. Accumulators shall be designed for a rated working pressure not less than the maximum system pressure and shall have a safety factor of not less than four. Fluid ports shall be [tapped NPTF] [tapped for straight pipe threads] [drilled, tapped, and faced for flange connections]. Gas and accessories needed to recharge the accumulator with gas shall be provided as indicated.

2.6.1 Piston Type

Cylinder shall be [single] [double] wall type constructed from seamless steel tubing and wrought or forged steel end caps. Piston shall be [cast iron] [aluminum] [_____] and shall be equipped with O-ring type seals with antiextrusion backup guide rings. Accumulators 152 mm 6 inches and larger shall be designed and constructed in accordance with the requirements of ASME BPVC SEC VIII D1. The accumulator shall be equipped with a safety device to release excessive pressure before the burst pressure is reached. A high-pressure gas charging valve shall be provided. The charging valve shall be protected from damage by recessed type construction or by a protective cap. Safety bleed holes in the shell and a gas valve or other means shall be included to positively prevent disassembly of the accumulator until all gas and fluid pressures have been released.

2.6.2 Bladder Type

Shells shall be one-piece alloy steel construction without welds, seams, or joints. The fluid discharge port shall be provided with a spring-loaded poppet valve arranged to close automatically upon discharge of all of the fluid to prevent extrusion of the bladder. An antiextrusion ring shall be provided when recommended by the manufacturer. The design shall permit disassembly for repair without removing the accumulator from the system. The method of disassembly shall include provisions to prevent disassembly until all gas and fluid have been bled. A gas charging valve complete with protective cap and replaceable valve core shall be provided. The design shall incorporate suitable means to release excessive pressure before the burst pressure is reached.

2.7 VALVES

Valves used in the hydraulic system lines shall be specially designed and rated for use in hydraulic systems. Valves used in pneumatic lines, such as air-oil booster systems and gas-loaded accumulators, shall be specifically designed and rated for use in pneumatic systems. Valves shall have published pressure ratings not less than the maximum pressure ratings indicated for the circuit in which installed. Identification of ports, pilot and solenoid actuators and solenoid leads shall be as indicated by symbols conforming to ISO 9461 and ISO 11727.

2.7.1 Directional Control Valves

Directional control valves shall be [ball] [plug] [spool (plunger)]

[sliding plate] [linear sliding plate] [or] [rotating sliding plate] design as indicated. Directional control valves shall be [check] [four-way] [selector (diversion)] [straightway] [or] [three-way] functional type.

2.7.2 Flow Control Valves

Flow control valves shall be [ball] [diaphragm] [disc (globe)] [swing disc] [gate] [spreader gate] [wedge gate] [needle] [plug] [or] [poppet] design as indicated. Flow control valves shall be [shutoff] [sequence] [flow dividing] [flow dividing, compensated] [metering] [deceleration] [pressure compensated] [pressure-temperature compensated] functional type.

2.7.3 Pressure Control Valves

Pressure control valves shall be [counterbalance] [decompression] [load dividing] [pressure reducing] [relief] [safety relief] [or] [unloading] type as indicated.

2.7.4 Valve Actuators

Valve actuators shall be [manual] [mechanical] [solenoid] [or] [pilot] as indicated. [Pilot actuators shall be [barrier] [differential area] [differential pressure] [or] [solenoid controlled] as shown.]

2.7.5 Valve Mounting

Valve mounting provisions shall be [base] [in-line] [manifold] [or] [subplate] as indicated. Mounting surfaces, dimensional criteria, and general criteria of subplate mounted type valves for 20.7 MPa3,000 psi maximum hydraulic service shall conform to NFLPA T3.5.1.

2.7.6 Valve Materials and Components

2.7.6.1 Valve Bodies

Valve bodies shall be [steel] [brass] [cast iron] [aluminum] [or] [_____] as indicated. Valve body bores which contain pistons, poppets or spools shall be finished to 203 nanometers 8 microinch rms and shall be round and straight to within 1.3 micrometers 50 millionths of an inch.

2.7.6.2 Poppet Material

Poppet material shall be [soft seal (nitrile rubber)] [nylon] [solid metal] [or] [_____].

2.7.6.3 Port Style and Port Connections

Port style shall be [NPTF] [SAE straight thread] [flare tube] [or] [_____]. Port connections shall be for [tapped conductors] [or] [socket weld couplings].

2.7.6.4 Seal Compound

Seal compound shall be [Buna N] [nitrile rubber] [or] [fluoroelastomer].

2.7.6.5 Spools

Spools shall be steel case hardened to 50 Rockwell C, minimum. Spool

movement shall be by [manual actuation] [mechanical actuation] [hydraulic pilot] [air pilot] [or] [solenoid]. [Manual actuator shall be a [push button] [hand lever] [or] [foot pedal].] [Air pilot operated control valves shall have bronze housings and stainless steel spools.]

2.7.6.6 Solenoids

Solenoids shall be [ac] [or] [dc] [wet armature] type and [pull-in] [or] [drop-out] style. Solenoids shall be [spring offset, single] [spring centered, double] [or] [detented, double] model. Solenoids shall be moisture proof where indicated.

2.8 INTENSIFIERS (BOOSTERS)

Intensifiers Boosters shall be [oil-to-oil] [air-to-oil] type. The driving cylinder bore size and operating fluid medium, the mounting style, and a manufacturer's series identification (or equal) shall be as shown. [For cylinder-to-ram (piston) intensifiers, ram diameter shall be as shown.] [For cylinder-to-cylinder units, output cylinder bore shall be as indicated.] Inlet and outlet pressures and intensification ratio shall be as indicated. Intensifier shall be designed for use with petroleum base hydraulic fluid unless otherwise indicated. The manufacturer shall produce evidence that all dynamic seals are suitable for both frequent and infrequent operation and are capable of not less than 500,000 cycles of operation in systems properly maintained. The intensifier shall be capable of continuous operation under severe operating conditions at discharge pressures up to the indicated maximum circuit pressure.

2.9 FLUID COOLERS (HEAT EXCHANGERS)

Fluid coolers (Heat Exchangers) shall be [water-cooled] [or] [air-cooled] type and shall have the cooling capacity indicated.

2.9.1 Air-Cooled

Air-cooled type shall have a core of [oval-tube and plate-fin] [round-tube plate-fin] [or] [individual finned round tubes]. The cooler shall be equipped with an electric motor-driven fan, selected to provide the air flow volume through the core to ensure that the cooling requirements are met. Operating sound level of fan and motor shall not exceed 85 dBA.

2.9.2 Water-Cooled

Water-cooled type shall be [shell-and-tube] [plate type] construction. [Shell-and-tube type shall be arranged to handle water through the tubes and the hydraulic fluid through the shell.] [Shell-and-tube construction shall be arranged as [U-tube] [straight tube] [fixed tube bundle] [straight tube, removable bundle] type.]

2.10 FILTRATION EQUIPMENT

Fluid filters shall be located as indicated. Nominal and absolute ratings shall not exceed the values indicated. Filters shall be [depth] [surface] type. Pressure drop through each filter shall not exceed the value indicated at the given maximum flow rate. Elements for depth type filters shall be [resin-coated] [paper] [synthetic fiber] [vinyl membrane] type. Elements for surface filters shall be [wire cloth] [nylon cloth]. [Filter casings for installation in pressure lines shall have a working pressure rating in excess of the specified maximum pump discharge pressure.]

[Filter casing for separate filtration circuits shall have a rated working pressure in excess of the maximum pressure of the filter circuit.] Filters shall be provided with [adjustable] [nonadjustable] [internal] [external] bypass. [An indicator shall be provided to show when the bypass has opened.] The cracking pressure of the bypass on pressure filters shall be as indicated. The cracking pressure of the bypass on filters installed on the suction side of pumps shall be as required by the pump manufacturer.

2.11 LINES AND FITTINGS

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NOTE: Unless the designer needs to make the choices, because of unique criteria situations, selection of materials and configurations should remain as Contractor's options and the brackets should be removed.

The contents of these paragraphs are dependent on design requirements which may necessitate revision or expansion to cover different conditions and standards. In some cases, system design may permit combining test connections and drain or vent valves; in other cases, separate valves for each function will be required.

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Piping and tubing connections shall be designed and installed to permit quick removal and reassembly with hand tools.

2.11.1 Pipe

Unless otherwise indicated, hydraulic pipe shall be seamless steel pipe conforming to ASTM A106/A106M, Grade B. Piping weight class shall be [standard] [extra strong] [double extra strong] [Schedule 160]. Pipe shall conform to the cleanliness requirements of ISO 10763.

2.11.2 Pipe Fittings and Flanges

Pipe fittings shall be steel. Fittings that incorporate separate synthetic, or metal-to-metal seals, or seals that seal with pressure, shall be equipped with Unified National Fine (UNF) straight thread port connections. Fittings that incorporate synthetic, or metal-to-metal seals, or seals that seal with pressure, may be used with pipe thread port connections. Pipe flanges shall be steel, [_____] MPa psi steam working pressure rated, and shall be faced for use with metallic O-ring gaskets. Flange bolts shall be steel and shall have steel self-locking nuts. Mechanical connections, proven suitable for the pressure and service, may be used instead of flanged connections. The seals shall be compatible with the hydraulic fluid used in the system. Threaded fittings shall conform to ASME B16.11 forged carbon steel, pressure class Class [2000] [3000] [6000] [2000] [3000] [6000] pounds threaded in conformance with ASME B1.20.2MASME B1.20.1 or ASME B1.20.3. Welded fittings shall conform to ASTM A234/A234M, Grade WPB. Flanges shall conform to ASTM A182/A182M, grade suitable for pipe to which attached. Facing on flanges shall be in accordance with ASME B16.5.

2.11.3 Tubing and Fittings

Tubing shall be seamless or welded steel tubing conforming to ISO 10763.

2.11.3.1 Wall Thickness

Wall thickness for each size not otherwise indicated shall be selected to provide a safety factor of six based on the manufacturer's ratings for burst strength.

2.11.3.2 Fittings

Solderless steel fittings shall be used. Connections may be flared, flareless, self-flaring, or equivalent. When flared-type fittings are used, the tubing end of the connector body, nut, and sleeve when used, shall be 37 degrees from center (74 degrees included angle), and shall conform to SAE J514 for minimum performance requirements. Copies of test reports for all tubing fittings shall be submitted with detail drawings. Adapters for connecting tubing to threaded pipe ports shall be straight thread type with locknut, washer, and O-ring seal. Fittings that incorporate separate synthetic or metal-to-metal seals, or seals that seal with pressure shall have UNF straight-thread port connections. Fittings that incorporate synthetic, or metal-to-metal seals, or seals that seal with pressure may be used with pipe thread port connections.

2.11.4 Flexible Lines

Flexible hydraulic lines shall be wire reinforced, high-pressure type hose with synthetic rubber lining and outer cover. Synthetic rubber shall be selected for maximum compatibility with the hydraulic fluid specified for use in the system. Flexible hose shall be rated by the manufacturer for a working pressure not lower than the system operating pressure indicated. Fittings shall be specifically designed for use with the hose selected and shall be as recommended by the hose manufacturer. Fittings shall be [stainless steel] [carbon steel] and shall have straight or elbow ends as best suited to the installation conditions. Fittings shall be [reusable] [permanently attached] type. Each hose assembly shall be factory assembled using procedures and tools recommended by the manufacturer of the hose.

2.11.5 Manifolds

Provide manifolds where indicated. Each manifold must be [cast] [machined from solid plate] [constructed by laminating two or more plates together by furnace brazing]. Machine smooth ports and passages, free of burrs and sharp edges. Machine surfaces to which valves and other components will be mounted smooth and flat. Machine counterbores to hold O-ring port seals to dimensions recommended by the O-ring manufacturer.

2.12 HYDRAULIC FLUID

Supply a sufficient amount of hydraulic fluid, of the type specified and as recommended by the fluid manufacturer, to completely fill the system initially plus at least 10 percent additional reserve fluid. Also provide extra fluid to make up all losses resulting from venting operations, from servicing filtration equipment, from leakage and from all other causes before final acceptance. Check the fluid level and bring to the proper operating level immediately after satisfactory completion of final acceptance tests. Deliver the hydraulic fluid to the site in unopened

containers with factory seals intact. Clearly label containers in accordance with ASTM D3951. Hydraulic fluids must be certified by the manufacturer as fire-resistant in conformance with NFLPA T2.13.1. Fluid shall be [water-glycol] [synthetic] [water-in-oil emulsion] type. Fresh hydraulic fluid shall be filtered to 10 micron level.

2.13 PACKING, GASKETS, AND SEALS

Hydraulic components shall be equipped with seals, packings, gaskets, and O-rings selected and recommended by the respective manufacturers for maximum compatibility with the particular hydraulic fluid specified for use in the system.

2.13.1 Static Seals

Static-type seals shall be arranged to seal with pressure and shall be provided with backup rings or other approved confining devices to prevent material extrusion during expansion and contraction resulting from pressure and temperature changes. Static-type seals shall be continuous rings.

2.13.2 Dynamic Seals

Dynamic seals may be lip, cup, V-ring, U-ring, flange, or squeeze type, unless otherwise specified or indicated. Split metallic rings (automotive type) may be used only when specifically indicated.

2.14 ACCESSORIES

Accessories shall conform to the following:

2.14.1 Bolts, Nuts and Cap Screws

ASME B18.2.1, ASME B18.2.2, ASME B18.6.2 or ASTM A574, as applicable. All bolts, cap screws, and nuts not otherwise indicated or specified shall be medium carbon steel and shall be cadmium plated. Threads shall conform to ASME B1.1.

2.14.2 Locknuts

IFI 100/107 for hexagon locknuts, prevailing torque type, or a type standard with the manufacturer provided they meet or exceed the requirements of the IFI specifications.

2.14.3 Setscrews

ASME B18.6.2 unless otherwise indicated or specified. Setscrews shall not be used for transmitting torsion.

2.14.4 Methods of Securing Fasteners

All fasteners not secured by mechanical devices, such as lock washers, cotter pins, safety wire, or locknuts, shall have the threaded portion of the fastener coated with sealing/locking compound, Grade E or Grade B, as applicable, before installation. Fasteners shall be cleaned of all rust-inhibiting compounds and lubricants before applying the sealing/locking compound.

2.14.5 Keys and Keyways

ASME B17.1 or ASME B17.2, unless otherwise specified or required.

2.14.6 Pipe Hangers and Supports

MSS SP-58.

2.15 SHAFT COUPLINGS

Shaft Couplings shall have strength equal to the full strength of the shafting which they connect and shall be pressed and keyed thereon. In determining the coupling capacity, the manufacturer's rating shall be divided by a service factor of [1.5] [_____].

2.15.1 Flexible Couplings

Unless otherwise indicated, flexible couplings shall be of forged steel and shall transmit torque by [a steel grid spring fitted into grooves in the periphery of the coupling's hubs] [external gear teeth on hubs engaging in internal gear teeth in the coupling sleeves] [or] [flexible annular discs bolted alternately to the end flanges and center member by body bound bolts]. [Flexible couplings of the [geared] [or] [grid] type shall be fully enclosed and sealed to retain lubricant and shall be oil-tight under both static and operating conditions.]

2.15.2 Rigid Couplings

Rigid couplings shall be cast or forged steel and shall be flanged or compression type with recessed bolts.

2.16 PRESSURE GAUGES

Pressure Gauges shall conform to ASME B40.100 with [black enameled corrosion-resisting metal case] [phenolic case]. The scale range of the gauge shall be approximately twice the maximum pressure of the circuit in which installed. Gauges shall be safety type with solid fronts and blowout backs. Each gauge shall be provided with an approved gauge snubber. All permanently installed gauges shall have a shutoff valve arrangement to permit isolation of the gauge and snubber from the rest of the system.

2.17 SHIMS

Shims shall be provided in graduated thicknesses which shall permit adjustment in increments of 0.13 mm 0.005 inches from 0 to 6.4 mm 0 to 1/4 inch. Shims for use between machinery components, subassemblies, or machinery bases and mounting brackets and unfinished surfaces of structural member shall provide adjustment in increments of 0.79 mm 1/32 inch from 6.4 mm 1/4 inch to 150 percent of the shim allowance indicated. Tapered shims shall be provided as required to accurately align machinery components and bases which are mounted directly on unfinished structural steel surfaces. Field measurements shall be taken to determine the exact amount of taper required to obtain proper alignment. Material for all shims shall be AIST PB-229, Types 304 or 316 unless otherwise indicated.

2.18 EQUIPMENT BASES

Nonintegral equipment bases including brackets and mounts shall be

all-welded construction and shall be fabricated of ASTM A36/A36M steel. After installation and final adjustment of all the system components on the equipment bases in the shop, each piece of equipment shall be positively secured in place by dowels to ensure accurate location during installation in the field. Shear blocks may only be used where installation of dowels is completely impractical.

2.19 CONTROL COMPONENTS

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NOTE: Where it is desired to control, coordinate, and program components of a hydraulic fluid power system to achieve synchronization of cylinders or components or to achieve a sequence of operations in several modes, system requirements and specifications shall be tailored for the job.

a. The programmed controller is used in modern fluid power systems where a series of operations is to be performed in a sequential order on each cycle. It can be programmed to cause a number of hydraulic cylinders or motors to follow a sequential order of operations, extending and retracting, starting and stopping, during each cycle.

b. The controller can be programmable, consisting of a console plugged into Central Processing Unit (CPU), or a specialized microcomputer system that can be custom programmed to control a wide variety of electronic and electrohydraulic systems and components, and has the capability to interface with other controls and transducers.

c. To counter unwanted oscillation in some types of actuators, where axis movement or load change causes actuator deflection coupled with the mass of the actuator system and results in damaging or undesired oscillation, microcomputer-based electronic modules can be programmed to compute velocity and acceleration dampening oscillation and permitting faster operating speed and greater accuracy. This eliminates the need for actuator sensors to provide position, speed, and acceleration feedback, and eliminates harnesses and connectors associated with sensors.

d. Electronic control components are used to build electrohydraulic control systems and include power supplies and amplifier modules to supply proper input to the various servo valves, control pumps, pressure valves, and flow control valves that comprise an electrohydraulic controlled system.

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2.19.1 Control Devices and Wiring

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NOTE: When explosion proof enclosures are required, fill in the blanks indicating the hazard

classification. Where more than one type of enclosure is required, expand the sentence to indicate where or how each type is used.
****

Manual or automatic control protective or signal devices required for the specified operation and all control wiring for these controls and devices shall be provided whether indicated or not. Electrical control devices shall have minimum current and voltage ratings in accordance with the requirements of NEMA ICS 2 contact rating designation A 300, as applicable, unless larger ratings are indicated or required. Control devices shall be provided with the number and arrangement of contacts required to perform the specified control functions. Devices shall be provided with or installed in [general purpose] [weatherproof] [NEMA Type 4 for [exterior] [interior] [hazardous] [nonhazardous] application] [corrosion-resistant] [NFPA 70 Class [_____] Division [_____], explosion-proof] enclosures as indicated. Components shall be electronically and electrohydraulically controlled as indicated.

2.19.2 Pressure Switches

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NOTE: Where differential pressure limits are essential to the design, the particular limits should be stated on the drawings. Where specific types of actuators are required, include the applicable type or types. Where more than one type is used, expand the sentence to include where or how each type is used. Where adjustable-setting switches are used, delete the brackets from the sentence regarding the upper limit of adjustment. If manual reset switches are used, indicate on the drawings those switches which are included, and delete the brackets from the last sentence.
****

Pressure switches shall have the operating pressure [settings] [and] [ranges] [and maximum allowable differentials] indicated. Actuators shall be of the [bellows] [piston] [Bourdon tube] [diaphragm] type [indicated] [required for the operating conditions]. Actuators shall have a rated proof or shall withstand pressure of not less than 150 percent of the maximum possible pressures for the systems in which they are installed. [The maximum setting for switches with an adjustable range of operating pressures shall be limited to 80 percent of the proof pressure ratings.] Actuators shall be fabricated from materials which are compatible with the fluids employed. Switches shall be the automatic reset type [except where manual reset type are indicated].

2.19.3 Limit Switches

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NOTE: Where a very critical switch operation is required, such as a safety stop, positive drive switch installations are sometimes used. If a normally-closed contact should weld closed accidentally, the positive drive will either break the weld and open the circuit or destroy itself in the attempt. Where such drives are required, delete the brackets in the appropriate sentence and include

suitable information on the drawings. If manual reset switches are used, indicate them on the drawings and delete the brackets from the last sentence of paragraph "Pressure Switches."
****

Limit switches shall have activating mechanisms of the [roller arm] [push rod] [plunger] [fork] type [indicated] [required to detect the particular positions]. Except where manual reset type is specifically indicated, activating mechanisms and switch mountings shall be arranged so that over travel of the monitored member will not damage the activator and switch.

2.19.4 Manual Switches

Manually-operated switches, including pushbutton switches, selector switches and key-operated switches, shall be heavy-duty oil-tight type conforming to the requirements of NEMA ICS 1. Switches shall be momentary contact type with standard operators [except where maintained contacts or special operators, such as mushroom head, illuminated button, and latching button are indicated].

2.19.5 Relays

Relays used in control circuits shall be industrial magnetic control relays conforming to NEMA ICS 2 contact rating designation A 300, except where other ratings are indicated. Relays shall be applied in control circuits in such a manner that proper control functions shall be obtained regardless of whether the contacts are overlapping or nonoverlapping.

2.19.6 Timers

Timing devices shall be electrically-activated [synchronous motor] [oil dashpot] [pneumatically] [electrically] [_____] -timed type with adjustable timing ranges as indicated. Where the adjustment range is not indicated, range shall be adjustable from at least 50 to 150 percent of the delay setting indicated, specified, or required. Timers shall provide time delay on energizing and shall be of the automatic reset type unless otherwise indicated.

2.19.7 Indicating Lights

Indicating lights shall be the oil-tight type with jewel color as indicated. Light unit shall be the integral transformer type with 6-8 volt lamp and shall be fitted with a glass color cap.

2.20 CONTROL CONSOLES AND VALVE AND GAUGE PANELS

2.20.1 Control Console Construction

The control console shall include a basic frame with metal panels fully custom-fabricated as specified, or may consist of custom modules using standardized components where available to meet the dimensional and functional characteristics indicated and specified. Unless otherwise indicated, the console shall be constructed of steel meeting the requirements of NEMA ICS 6. Steel sheet shall conform to ASTM A659/A659M. Removable panels shall be secured in place using captive, spring loaded, self-locking spring nuts and hardened sheet metal screws. Screws and nuts shall be corrosion-resistant material or shall have corrosion-resistant protective coating. Access panels shall be secured with spring loaded

quarter turn fasteners with studs held captive in the removable panel. The console shall be equipped with adequate louvered panels to ventilate the interior and dissipate the heat generated within the console. Special equipment supports and guides shall be provided as required to support the equipment and other components within the console. Unless otherwise specified, interior and exterior surfaces shall be finished with one coat of primer and two coats of manufacturer's standard finish.

2.20.2 Valve and Gauge Panels Construction

Valve and gauge panels shall be constructed of steel plate thick enough to provide rigid support for the valves and other components mounted thereon. All piping shall be terminated with bulkhead type connections in a position convenient for the connection of external lines. Primer and finish shall be manufacturer's standard coating.

2.20.3 Nameplates and Instruction Plates

Nameplates shall be provided for each device on the control console, valve panels and gauge panels. Nameplates shall clearly indicate the function of each device and, in the case of manually-operated controls, shall indicate the condition established for each position of the control. Instruction plates shall clearly indicate the proper procedures and sequences of operations to activate the system, to operate the system, and to secure the system after completion of operation. Lettering on nameplates shall be machine-engraved on plastic laminate with white characters on a black background. Instruction plates shall contain permanent black letters on a white background. Instruction plates shall be mounted on a rigid backing and covered with clear, rigid plastic sheeting. Instruction plates shall be mounted in a location easily visible to an operator stationed at the console or panel.

2.20.4 Security Provisions

Control consoles shall be constructed and installed to prevent unauthorized or accidental operation of the system. [The main power control switch mounted on the control console shall be a key-operated type with provision for removal of the key only when the switch is in the "OFF" position.] [The control console shall be provided with a hinged cover with a key-operated lock arranged to automatically lock the cover in the closed position.]

2.20.5 Weather Protection

Control consoles and valve and gauge panels exposed to the weather or subjected to water or dirt in the atmosphere shall be NEMA Type 4 for exterior [hazardous] [nonhazardous] application. Enclosures shall have hinged and latched covers. Hinges shall be separable type to permit complete removal of the cover for maintenance. Hinges and latches shall be constructed of corrosion-resistant steel or approved nonferrous metals.

2.21 TEMPORARY CORROSION PROTECTION

Unpainted metal surfaces shall be protected from corrosion during shipment, storage at the site, and during construction operations so that the surfaces are free of corrosion until application of final field finish. The temporary coating shall be completely removed and the surfaces properly prepared for final finishing as specified in Section 09 90 00 PAINTS AND COATINGS. Products, including pumps, reservoirs,

cylinders, and similar assemblies, shall not be provided unpainted or with temporary coating, but shall be factory finished as specified.

2.22 ELECTRIC MOTORS AND CONTROLS

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NOTE: Where motor starters are provided in motor control centers, delete the reference to motor starters.

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Electric motor-driven equipment shall be provided complete with motors [motor starters] and controls. Electric equipment and wiring is specified in [Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM.] [Section 33 71 02 UNDERGROUND ELECTRICAL DISTRIBUTION.] [Section 33 71 01 OVERHEAD TRANSMISSION AND DISTRIBUTION.] Electrical characteristics shall be as indicated or specified. [Motor starters shall be provided complete with properly sized thermal overload protection and other appurtenances necessary for the motors specified.] Manual or automatic control and protective or signal devices required for the operation, and any control wiring required for controls and devices but not shown on the electrical drawings, shall be provided. Where two-speed or variable-speed motors are indicated, solid-state variable speed controller may be provided to accomplish the speed function. Each motor shall be sized large enough to drive the equipment at the specified capacity without exceeding the nameplate rating of motor when operating at proper electrical system voltage.

PART 3 EXECUTION

3.1 EXAMINATION

After becoming familiar with all details of the work, verify dimensions in the field and advise the Contracting Officer of any discrepancy before performing the work.

3.2 INSTALLATION

Installation of hydraulic components shall be in accordance with the manufacturer's written instructions and under the direction of the hydraulics technician. Complete units or assemblies shall be installed without disassembly. Necessary supports for all appurtenances, pumps, motors, heat exchangers and other equipment or components shall be provided. Floor-mounted equipment shall be anchored to concrete pads by dowels set in the concrete. Shear blocks may only be used where installation of dowels is completely impractical. Concrete for foundations shall be as specified in Section 03 30 00 CAST-IN-PLACE CONCRETE. Drain lines shall be installed from the reservoir to each component requiring a drain connection. All valves and other fluid control devices shall be mounted as indicated. Mounting subplates shall be installed on rigid supporting surfaces in a manner that will preclude imposition of forces on the piping and tubing other than those created by fluid pressure alone. Shims shall be provided at locations required to permit proper adjustment, alignment, and position of system components and assemblies. Components shall be marked to indicate pertinent operational requirements, warnings, and limitations such as maximum allowable operating pressure, temperature, velocity, range of adjustment, flow capacity, stroke, direction of flow, rotation or motion, safety precautions, and materials compatibility. The markings shall be by

stamping or embossing on the component or on an attached plate or tag which shall, barring mutilation, remain affixed and legible for the life of the component.

3.2.1 Installation Drawing Submittal

Submit drawings consisting of a complete list of equipment and materials, including manufacturer's descriptive and technical literature; catalog cuts; performance charts and curves; and installation instructions. Drawings shall also contain complete wiring and schematic diagrams and other details required to demonstrate that the system has been coordinated and will properly function as a unit. Drawings for motors, actuators, cylinders, pumps, controls, and other components shall be included. Moving parts fluid control diagrams shall follow the methods in NFLPA T3.28.9. Drawings shall show proposed layout and anchorage of equipment and appurtenances, and equipment relationship to other parts of the work including clearances required for maintenance and operation. Details shall include loadings and types of frames, brackets, stanchions and other supports, and pipe anchors for supported pipe and equipment. Foundation drawings shall include bolt setting information for equipment indicated or required to have concrete foundations.

3.2.2 Components and Subassemblies

Components shall be securely mounted to the supporting surface. Care shall be exercised that fastenings are not overtightened to the extent that component bodies are distorted or damaged. Pivot type mountings shall be carefully aligned to ensure free operation throughout the entire range of movement. Cylinders shall be carefully aligned so that no side loads are imposed on the piston rod at any point in the full stroke. Subassemblies shall be mounted and braced independently of the connecting lines.

3.2.3 Connections to Mechanisms

Pumps and motors shall be carefully aligned with the mechanisms to be operated and shall be shimmed as necessary to eliminate angular and radial misalignment between the mating shafts. Shaft couplings which require lubrication shall be lubricated at the time of installation. Pivot-type connections shall be lubricated at assembly.

3.2.4 Rigid Conductors

Hydraulic pipe and tubing shall be securely mounted and anchored to structural members. Supports and anchors shall be located as indicated. Guards shall be provided at all locations where the structure does not provide protection for the lines from damage due to movement of personnel and equipment. Seals shall not be removed from pipe and tubing assemblies or from ports on components until the lines are ready for connection. Provisions, including but not limited to providing portable screens and shelters, shall be taken to minimize the entrance of abrasives, dirt, metal chips, and other foreign materials into the hydraulic system through open ends of lines and ports of components.

3.2.5 Flexible Conductors

Flexible conductors shall be installed in accordance with the manufacturer's recommendations. Special care shall be exercised to avoid imparting any twist in the conductors during tightening of fittings.

Supports shall be provided and located to prevent conductors from contacting and chafing against fixed members. Clamps and straps used to support hoses shall be provided with soft resilient sleeves, linings or bushings to prevent cutting and abrading of the hose. The routing of flexible hoses shall be arranged to preclude imparting a twist in the hose due to relative motion between the components to which the hose is connected. The minimum bend radius of the hose shall not be less than that recommended for the particular hose size and maximum system operating pressure. Heat shields or insulating jackets shall be provided where hose passes close to heated surfaces.

3.2.6 Installation of Tubing

Tubing shall be cut square using tube cutters specifically designed for the material to be cut. The use of hacksaws or other chip-producing equipment will not be permitted. Burrs shall be completely removed after the tubing is cut and the inside diameter of the tube shall be chamfered slightly. After the cutting and deburring operations, all metal fragments shall be removed from the tubing interior and from sealing surfaces. Tube benders designed and recommended by the manufacturer shall be used for bending stainless steel tubing of the wall thicknesses and sizes specified for the installation. Bends shall be accurately made to the proper angle so that fittings align properly and mate without application of force or springing of the tube or fitting and alignment shall be true enough so that threads may be engaged and hand turned not less than three turns. Bends shall be completely free from wrinkling, and flattening shall not exceed 5 percent of the outside diameter. Tube benders shall be provided with necessary radius blocks, slide blocks, and special close radius blocks, as required to adapt the bending tools to the requirements of the work. Where necessary to ensure properly fabricated bends, internal mandrels of proper diameter for the size and wall thickness of the tubing shall be used.

3.2.7 Test Connections

Test connections and test valves shall be provided at each location indicated. Unless otherwise indicated, all test connections shall be 6.4 mm 1/4 inch size.

3.2.8 Welded Installation

Hydraulic pipe weldments shall be as indicated. Changes in direction of piping shall be made with welding fittings only; mitering or notching pipe to form elbows and tees or other similar type construction will not be permitted. Branch connection may be made with either welding tees or forged branch outlet fittings. Branch outlet fittings shall be forged, flared for improvement of flow where attached to the run, and reinforced against external strains. Beveling, alignment, heat treatment, and inspection of welds shall conform to ASME B31.1. Weld defects shall be removed and repairs made to the weld, or the weld joints shall be entirely removed and rewelded at no additional cost to the Government. After filler metal has been removed from its original package, it shall be protected or stored so that its characteristics or welding properties are not adversely affected. Electrodes that have been wetted or that have lost any of their coating shall not be used.

3.3 MANUFACTURERS' FIELD SERVICES

Provide services of a manufacturer's representative who is experienced in

the installation, adjustment, and operation of the equipment specified. The representative shall supervise the installation, adjustment and tests of equipment.

3.3.1 Hydraulic Technician

Provide services of a hydraulics technician to coordinate and supervise the installation, adjustments, tests, and field instructions for the hydraulic system. The hydraulics technician shall have at least 3 years of current experience in the installation and operation of similar systems and shall be recommended by the system supplier or may be the manufacturer's representative.

3.3.2 Field Instructions Preparation

Submit proposed diagrams, instructions, and other sheets, before posting. Wiring and control diagrams showing the complete layout of the entire system including equipment piping, valves, and control sequence, framed under glass or in laminated plastic, shall be posted where indicated for local operator and maintenance assistance. In addition, condensed operating instructions explaining preventive maintenance procedures, methods of checking the system for normal safe operation, and procedures for safely starting and stopping the system shall be typed, framed as specified for the wiring and control diagrams, and posted beside the diagrams. Post the framed instructions before acceptance testing of the systems.

3.4 FIELD TESTS AND CLEANING OF HYDRAULIC LINES

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NOTE: If the hydraulic system is delivered as a self-contained packaged unit, tested, sealed, and certified by the manufacturer, delete the second paragraph under SD-06, Repair Requirements, under paragraph SUBMITTALS and also this paragraph and its subparagraphs in their entirety.

****

Secure the services of a hydraulic engineer or technician, as approved by the Contracting Officer, for [_____] working days to monitor the final cleaning and testing of the hydraulic system.

a. Submit test reports in booklet form showing field tests performed to adjust each component and field tests performed to prove compliance with the specified performance criteria, upon completion and testing of the installed system. Indicate in each test report the final position of any system controls.

b. As a portion of the cleaning procedure, submit details of the sampling and testing operations and the possible locations for withdrawing hydraulic fluid samples.

3.4.1 Proof Testing

****

NOTE: If the work involves modifications to existing hydraulic systems, delete the brackets in the first sentence. Otherwise, delete the expression within the brackets and the brackets.

****

All lines [including reinstalled existing lines], except component drain lines, shall be proof tested to not less than 150 percent of design operating pressure. Component drain lines shall be proof tested to 150 percent of the design working pressure or 690 kPa 100 psi, whichever is the greater. All welded, flanged, flared, and threaded connections shall be carefully examined for leakage and all lines shall be inspected for evidence of deflection caused by inadequate anchorage. The proof test medium shall be either the fluid approved for use in the system or a flushing compound specifically approved for use by the manufacturer of the fluid approved for use in the system. Proof test pressure shall be maintained long enough to permit thorough and complete inspection but in no case less than 1 hour for each test.

3.4.2 Field Cleaning

****

NOTE: If the work involves modifications to existing hydraulic systems, delete the brackets in the first sentence. Otherwise, delete the expression within the brackets and the brackets.

The allowable limit of contamination in this paragraph is subject to the specific project design requirements which may necessitate revision or expansion to cover varying standards of acceptance. The amount and sizes of particles which any given component can tolerate is a function of the clearances between moving parts, the frequency and speed of operation, and the materials of construction. Tolerances range from low pressure gear pumps which may give satisfactory performance with dirt levels typically found in new fluid (ISO 4406) to servo control valves which require oil eight times cleaner (ISO 4406). General guidelines are as follows:

System Type	Code Level
Low pressure - manual control	18/15 or better
Low to medium pressure - electrohydraulic controls	17/14 or better
Systems with servo or proportional control valves	17/14 or better
High pressure - servo controlled	15/12 or better

Hydraulic fluid power equipment is rated according to maximum pressure. Generally low pressure is 0 to 4.1 MPa 0 to 600 psi, medium pressure to 21 MPa 3000 psi, and high pressure to 35 MPa 5000 psi.

Results of microscopic particle count in accordance

with SAE AS598 are reported as the number of particles per milliliter greater than indicated sizes as ordinates on a graph where particle size in microns is the abscissa. Segments of the ordinate are assigned code levels and the code level for particle sizes greater than 15 microns is reported as the numerator and the code level for particle sizes greater than 5 microns is reported as the denominator in the pair of range numbers in the ISO (International Organization for Standardization) Solid Contaminant Code, as identified in ISO 4406. Higher code levels indicate higher particle counts per milliliter. Example: 15/12 means a code level of 15 for particles greater than 5 microns and a code level of 12 for particles greater than 15 microns. Filter manufacturing firms can be the source of information regarding determination of contamination levels and analysis and have available portable kits for more general detection of contamination.

****

After proof tests have been satisfactorily completed, field installed hydraulic lines [including reinstalled existing lines] shall be cleaned in place. Submit a detailed field cleaning procedure for approval in accordance with paragraph SUBMITTALS not less than [_____] days before start of cleaning operations. The procedure shall include detailed description of equipment, materials, formulations of cleaning agents, solution temperatures, duration of each phase of the cleaning operation, method of removal of cleaning agents, and method of drying after cleaning. The procedure shall free the system of particles so that the contamination level shall be below 15/12 [_____] in accordance with ISO 4406. Collection of samples and conduct of tests shall be performed by an approved independent testing laboratory selected by the Contractor. The samples shall be examined for particle size and population count by the millipore or equivalent method in accordance with SAE AS598. Tabulation of particle size and population shall be in accordance with the size groupings in accordance with ISO 4406; and to the extent possible, particles shall be visually identified as metallic or nonmetallic, magnetic or nonmagnetic, and by color and composition. Fluid shall be circulating in the system at not less than system design fluid operating velocity during withdrawal of the samples. Three 500 milliliter size samples shall be taken at random locations in each flushing of the system. If any sample does not comply with the permissible contamination limits, the system shall be recleaned and reinspected. Accessible interior portions of the system shall also be subjected to visual and wipe tests and any evidence of contaminants exceeding allowable limits shall require recleaning of the system.

3.4.3 Field Training

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NOTE: The blank will be filled with the appropriate number of hours required for giving instructions.

****

Provide a field training course for designated operating staff members. Training shall be provided for a total period of [_____] hours of normal working time and shall start after the system is functionally complete but

prior to final acceptance tests. Field training shall cover items contained in the Operation and Maintenance Manuals.

3.4.3.1 Operation Manual

Submit operating instructions outlining the step-by-step procedures required for system startup, operation, and shutdown. The instructions shall include the manufacturer's name, model number, service manual, parts list, and brief description of all equipment and their basic operating features. Field cleaning procedures designed to clean the system to the requirements specified.

3.4.3.2 Maintenance Manual

Submit maintenance instructions listing routine maintenance procedures, possible breakdowns and repairs, and troubleshooting guides. The instructions shall include equipment layout and simplified wiring and control diagrams of the system as installed.

3.4.4 Hydraulic System Final Acceptance Tests

3.4.4.1 Preparation

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NOTE: The requirement for preliminary tests by the Contractor before the final acceptance tests may be deleted for those systems for which the Corps of Engineers has the sole responsibility for acceptance of the system or for simple systems which can be acceptance-tested in one working day and require only one inspector to observe the test.

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In preparation for the final acceptance tests, and after completion of installation, lubrication, and adjustment, operate the hydraulic system to prove acceptability. Complete this test not less than 10 days before beneficial occupancy. Conduct preliminary tests at minimum pressures and velocities until initial adjustments have been proven safe for normal operation. Details of all operations shall be constantly monitored for signs of impending trouble and corrections made as necessary to prevent damage to equipment. [A written statement that the hydraulic system has been field tested and meets all operational requirements shall be furnished to the Contracting Officer before scheduling the final acceptance tests.]

3.4.4.2 Conducting Final Acceptance Tests

At such time as the Contracting Officer may direct, conduct the following complete acceptance tests on the hydraulic system for approval. All tests shall be conducted in the presence of the Contracting Officer. Each deficiency or maladjustment disclosed by the tests shall be corrected immediately and the test repeated until satisfactory results are obtained. No subsequent tests will be permitted until all preceding tests have been completed satisfactorily.

3.4.4.2.1 Initial Start-Up

The hydraulic reservoirs shall be inspected to ensure that fluid is at the proper level. [It shall be verified that the fluid equalizing valve is

fully open.] [The reservoir pressurization system shall be inspected to ensure that all valves are open and that the pressure regulating valve is adjusted to provide the specified pressure in the reservoirs.] [The accumulator precharge pressure shall be inspected and adjusted to specified value.] The hydraulic pumps shall be started using the controls at the control console. The operation of the pumps shall be inspected for proper operation and discharge pressure. [The pressure compensator shall be adjusted as required.] [The pressure compensators shall be adjusted to equalize the discharge pressures.] The discharge pressure of [the] [each] pump shall be read and recorded. [The pressure relief valve shall be adjusted to limit system pressure to the specified value.] [The unloading valve shall be adjusted to unload the pumps to the reservoir when the accumulator has been charged to the specified pressure.] Hydraulic lines and components which are under pressure shall be inspected for evidence of leakage and for evidence of distortion because of inadequate or improper support. [Branch circuit pressure reducing valve and relief valve settings shall be inspected and adjusted as required to obtain specified values.]

3.4.4.2.2 Combined System Tests

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NOTE: The contents of this paragraph are dependent upon the size and complexity of the systems covered by this specification. Complete testing of the entire system may necessitate expansion by including additional appropriate paragraphs if the system involves several subsystems which warrant individual testing.

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Tests and inspections of [the hydraulic system] [each branch of the hydraulic system] shall be performed concurrently with the testing specified under other sections which test the mechanism operated by the hydraulic system. During each test operation hydraulic lines and devices shall be inspected for leakage and for evidence of distortion due to inadequate or improper support. The pressure in the supply and return lines for each direction of operation shall be read and recorded. Response of components to operation of applicable controls [on the control console] shall be inspected to ensure that all connections have been made properly. [Flow control valves shall be checked and adjusted as required to conform to indicated operating time requirements.] [Sequence valves shall be inspected and adjusted as required to obtain the indicated sequence of operation.] [Chokes in pilot circuits of pilot-operated valves shall be adjusted to obtain smooth, shock-free operation.] [Restriction in externally piloted counterbalance valves shall be adjusted to obtain smooth operation without vibration.]

3.4.4.2.3 Test Logs

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NOTE: Edit the list as required.

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Prepare and complete a test log showing in detail the results of the tests. Three copies of the completed test log shall be delivered to the Contracting Officer not more than 48 hours after completion of the tests. Prepare a complete and detailed tabulation showing values of pressures, flow rates, and all adjustments recorded during final tests, adjustment,

and calibration of the entire system. During each test run, the following data and observations shall be recorded:

a. Control operation

b. Voltages

c. Currents

d. Hydraulic pressures

e. Speeds and times

f. Flow control valve settings

g. Alignment and operating clearances

h. Excessive vibration, by component

i. Temperature of motors and hydraulic fluid

j. Pertinent observations regarding such events as unusual sounds, malfunctions or difficulties encountered, and adjustments required.

3.5 PAINTING AND COLOR CODING

3.5.1 Painting

All exposed exterior surfaces of assemblies and equipment except corrosion-resistant steel, synthetic rubber, and plastic, shall be shop primed and coated as specified: Complete system, including color coding and piping, shall be painted as specified in Section 09 90 00 PAINTS AND COATINGS. Insofar as practicable, the complete coating system shall be applied to individual components and items before assembly to ensure complete coverage and maximum protection against corrosion.

3.5.2 Pipe Color Code Marking

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NOTE: Designer will coordinate color code marking with Section 09 90 00. Color code marking for piping not listed in Table I of Section 09 90 00 will be added to the table.

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Color code marking of piping shall be as specified in Section 09 90 00 PAINTS AND COATINGS.

3.5.3 Field Touch-Up

Chips, scratches, and other damage to shop-applied painted surfaces shall be repainted in the field. Finish field colors shall match those of marred finishes.

-- End of Section --