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UNIFIED FACILITIES GUIDE SPECIFICATIONS

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SECTION 41 24 26

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

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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.

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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	(2020) 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	(2022) Nuts for General Applications: Machine Screw Nuts, and Hex, Square, Hex Flange, and Coupling Nuts (Inch Series)
ASME B18.6.2	(2020) 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	(2021) 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	(2021) 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	(2018) 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	(2021) 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 2020) 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; TIA 22-1; ERTA 1 2022) 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 2021) 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 are 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.

****

Weld structural members 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. Use qualified procedures and welders 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 perform the tests 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. Ensure items of the same classification are identical, including equipment, assemblies, parts, and components. Provide equipment supported by a service organization that is, in the opinion of the Contracting Officer, reasonably convenient to the site.

2.1.2 Nameplates

Display the manufacturer's name, address, and catalog number permanently on a plate securely attached to each major item of equipment. For electrical equipment listed in UL Electrical Appliance, attach UL label or registration plate securely to the item of equipment.

2.1.3 Prevention of Corrosion

Provide fasteners and nameplates of corrosion-resistant materials. Give surfaces of products, such as pumps, cylinders, fluid motors, and similar components, of ferrous metal, where not otherwise specified, 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. Perform fog test conforming to ASTM B117. Immediately after completion of the test, ensure coating shows no signs of wrinkling, cracking, or loss of adherence, and the specimen shows 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

Fully enclose or properly guard gears, couplings, projecting setscrews, keys, and other rotating parts to preclude personnel contact.

2.2 HYDRAULIC PUMPS

Ensure pump volumetric ratings, tests, type, application, and mounting provisions are in accordance with manufacturer's instructions and tested

by approved methods for conformance with performance ratings. Indicate pump rotation. Ensure pumps are rated for continuous operation at a discharge pressure equal to or greater than the pressure indicated. The rated discharge capacity of each pump is not allowed to be less than indicated when the pump is operated at the design input speed and discharge pressure.

2.2.1 Gear Pumps

Provide [fixed] [variable] [or] [_____] type gear pumps. Provide covers and center section consisting of [high strength aluminum alloy die castings] [steel] [cast iron]. Thrust and wear plates must be [heavy-duty bronze coated steel] [bronze] [or] [_____]. Use manufacturer's [standard] [or] [_____] shaft seals for rotary pumps. Provide replaceable seals and wear plates and other wearing parts suitable for the application, duty, and temperatures involved.

2.2.2 Vane Pumps

2.2.2.1 Fixed Displacement Vane Pumps

Provide fixed displacement vane pumps that are the hydraulically balanced types. Provide housing consisting of [high tensile strength ductile iron] [cast iron] [_____]. Provide [heat treated high-speed tool steel] [_____] vanes. Provide shaft and rotor consisting of [case hardened steel] [_____]. Shaft must ride in bearings at both ends. Provide cam ring consisting of [high carbon chromium steel] [_____]. Provide double vane pumps when indicated. Provide [Buna N] [nitrile rubber] [fluoroelastomer] [_____] seals.

2.2.2.2 Variable Displacement Vane Pumps

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

2.2.3 Piston Pumps

Piston pumps must 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] [_____]. [Provide axial variable type which is capable of providing reversed flow with constant direction of input shaft rotation.] [Provide axial variable type which is suitable for control of displacement [and direction of flow] by [manual] [mechanical] [hydraulic] [electric] [pneumatic] devices.] [Provide manually adjustable maximum and minimum limits of displacement in each direction of flow.]

2.3 RESERVOIRS

Unless otherwise indicated, provide nonintegral reservoirs conforming 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 must be breather type of welded [carbon steel] [corrosion-resisting steel] construction with removable cleanout plates provided at each end. Provide cleanout plates with gaskets and securely fasten to the reservoir end plates. Slope each reservoir to a drain plug located at the low point. Ensure the bottom of the reservoir has a minimum clearance of 150 mm 6 inches above the floor. Provide legs or base of floor-mounted reservoirs with suitable holes for fasteners. Provide a minimum of one interior baffle to separate the return line from the pump suction line. Provide a filter breather cap and fill port with a [_____] mesh strainer. Provide port cap with retaining chain. Provide a separate steel mounting plate at least 19 mm 3/4 inch thick to support the pumping unit.

2.3.2 Fluid Line Connections

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

2.3.3 Magnetic Separators

Provide manufacturer's standard magnetic separators in the reservoir. Provide magentic separator consisting of a high-strength permanent magnet arranged for rigid mounting with the poles of the magnet exposed to the fluid in the reservoir. Ensure the magnet is [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 must 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 must 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, include a low-level alarm and pump cutoff device in the design.

****

Mount manufacturer's standard recessed or protected oil level indicator in a readily visible location in proximity to the filler opening. Mark the

fluid level gauge clearly to indicate the maximum and minimum design operating levels and the fluid level when the system is idle. [Provide manufacturer's standard direct indicating thermometer to indicate fluid temperature in the reservoir. Do not use mercury in thermometers. Provide bimetallic type thermometer mounted directly on the reservoir top. Provide thermometer with 90 mm 3-1/2 inch diameter dial with black markings on a white or aluminum background. Provide case and stem composed of corrosion-resisting steel. Scale range is minus 7 to 115 degrees C 20 to 240 degrees F. Ensure thermometer is remote reading, capillary tube-and-bulb type. Provide thermometer with a dial no less than 90 mm 3-1/2 inches in diameter with black figures on a white or aluminum background. Provide [flush] [surface] mounting type indicating head. Provide [cast iron] [cast brass] case with black enamel finish. Provide bulb and capillary tube composed of corrosion-resisting steel.] [Provide a low-level alarm and pump cutoff device 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 must be one of the types listed in ISO 5598, and as specified or indicated, of tie rod design, square head standard construction. Ensure pressure rating of the cylinder id not less than the maximum system pressure indicated. 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 no less than 500,000 cycles of operation in systems properly maintained. Provide cylinders with bore, stroke, and rod diameter as indicated. Use NFPA mounting style as indicated. Provide hydraulic cylinder with [adjustable] [nonadjustable] cushions on [cap end only] [rod end only] [both ends]. [Provide cushions with free reverse flow check valves.] Provide cylinders with double end rods where indicated. Provide [NPTF] [SAE straight-thread O-ring] [_____] ports.

2.4.1 Cylinder Tube

Machine cylinder from ASTM A519/A519M, Grade 1018, heavy wall seamless steel tubing and hone the bore to a 254 to 381 nanometers 10 to 15 microinch rms surface finish.

2.4.2 Cylinder Heads and Caps

Fabricate cylinder heads and caps from ASTM A576, Grade 1018, steel bar stock and machine-finish on all surfaces. Equip cylinder head with rod seal and external dirt wiper and pilot rod bushing into head to ensure concentricity. [Ensure rod bushing is removable without the use of special tools and without removing tie rods or cylinder head.] Attach cylinder tube to head and cap [by steel tie rods having a minimum yield strength of 690 MPa 100,000 psi] [or] [as indicated]. Arrange cylinder tube end sealsof removal attachments to seal with pressure and design to prevent shearing and extrusion and to provide axial metal backup.

2.4.3 Pistons

Precision fit pistons to the cylinder body bore. Ensure pistons are [fine-grained cast iron] [_____] and designed and equipped with [zero leakage cup-type seals] [bronze-filled polytetrafluoroethylene seals with phenolic wear rings] [automotive-type lap-sealed cast iron rings]. Protect piston seals from blow-out and over squeeze. [Provide self-regulating cups, which automatically compensate for wear.]

2.4.4 Piston Rods

Make piston rods 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]. Provide rods that are 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 must be [hydraulically balanced] [high torque, low speed] [_____] type. Provide motors rated for continuous operation at a system pressure equal to or greater than the pressure shown. Ensure motors are capable of producing an actual output torque not less than shown when operating at the indicated supply pressure. Do not allow actual displacement to exceed the value shown. Provide [straight keyed] [threaded] [or] [splined] shaft. Ensure shafts are capable of rotation in either direction. Provide motor casing with a tapped outlet for connection of an external drain line. Use motor parts that are [tapped NPTF] [tapped with straight pipe threads] [drilled and faced for flange connections]. Filtration must be 10 microns or less. [Provide displacement selector valve.]

2.5.2 Piston Motors

Provide [axial inline] [or] [angle] type piston motors designed as [fixed] [variable] displacement type. Ensure variable displacement type is capable of providing reversed rotation with constant direction of fluid flow. Provide variable displacement type suitable for control of displacement and direction of rotation by [manual] [mechanical] [hydraulic] [electric] [pneumatic] [_____] devices. Provide manually adjustable maximum and minimum limits of displacement. Provide manually adjustable maximum limits of displacement in each direction of rotation. Support drive shaft by heavy-duty antifriction bearings. Provide motor casing with a tapped outlet for connection of an external drain line. Ensure motor ports are [tapped NPTF] [tapped with straight pipe threads] [drilled and faced for flange connections]. Filtration must be 10 microns.

2.6 ACCUMULATORS

Provide [piston] [bladder] type accumulators that are [gas pressure] [_____] loaded. Ensure accumulator fluid capacity is not less than indicated. Design accumulators for a rated working pressure no less than the maximum system pressure and with a safety factor of no less than four. Provide fluid ports that are [tapped NPTF] [tapped for straight

pipe threads] [drilled, tapped, and faced for flange connections]. Provide gas and accessories needed to recharge the accumulator with gas as indicated.

2.6.1 Piston Type

Provide [single] [double] wall type cylinder constructed from seamless steel tubing and wrought or forged steel end caps. Provide [cast iron] [aluminum] [_____] piston and equip with O-ring type seals with antiextrusion backup guide rings. Design and construct accumulators 152 mm 6 inches and larger in accordance with the requirements of ASME BPVC SEC VIII D1. Equip the accumulator with a safety device to release excessive pressure before the burst pressure is reached. Provide a high-pressure gas charging valve. Protect charging valve from damage by recessed type construction or by a protective cap. Include safety bleed holes in the shell and a gas valve or other means to positively prevent disassembly of the accumulator until all gas and fluid pressures have been released.

2.6.2 Bladder Type

Provide shells consisting of one-piece alloy steel construction without welds, seams, or joints. Provide fluid discharge port with a spring-loaded poppet valve arranged to close automatically upon discharge of all of the fluid to prevent extrusion of the bladder. Provide an antiextrusion ring when recommended by the manufacturer. Permit disassembly for repair without removing the accumulator from the system. Include provisions to prevent disassembly until all gas and fluid have been bled. Provide a gas charging valve complete with protective cap and replaceable valve core. Incorporate suitable means to release excessive pressure before the burst pressure is reached in the design.

2.7 VALVES

Use valves in the hydraulic system lines which are specially designed and rated for use in hydraulic systems. Use valves in pneumatic lines, such as air-oil booster systems and gas-loaded accumulators, which are specifically designed and rated for use in pneumatic systems. Use valves with published pressure ratings no less than the maximum pressure ratings indicated for the circuit in which installed. Identify ports, pilot and solenoid actuators and solenoid leads as indicated by symbols conforming to ISO 9461 and ISO 11727.

2.7.1 Directional Control Valves

Provide directional control valves of the [ball] [plug] [spool (plunger)] [sliding plate] [linear sliding plate] [or] [rotating sliding plate] design as indicated. Provide directional control valves of the [check] [four-way] [selector (diversion)] [straightway] [or] [three-way] functional type.

2.7.2 Flow Control Valves

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

2.7.3 Pressure Control Valves

Provide pressure control valves of the [counterbalance] [decompression] [load dividing] [pressure reducing] [relief] [safety relief] [or] [unloading] type as indicated.

2.7.4 Valve Actuators

Provide [manual] [mechanical] [solenoid] [or] [pilot] valve actuators as indicated. [Provide [barrier] [differential area] [differential pressure] [or] [solenoid controlled] pilot actuators as shown.]

2.7.5 Valve Mounting

Valve mounting provisions must 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 must conform to NFLPA T3.5.1.

2.7.6 Valve Materials and Components

2.7.6.1 Valve Bodies

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

2.7.6.2 Poppet Material

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

2.7.6.3 Port Style and Port Connections

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

2.7.6.4 Seal Compound

Provide [Buna N] [nitrile rubber] [or] [fluoroelastomer] seal compound.

2.7.6.5 Spools

Provide spools that are steel case hardened to 50 Rockwell C, minimum. Ensure spool movement is by [manual actuation] [mechanical actuation] [hydraulic pilot] [air pilot] [or] [solenoid]. [Provide a [push button] [hand lever] [or] [foot pedal] manual actuator.] [Provide air pilot operated control valves with bronze housings and stainless steel spools.]

2.7.6.6 Solenoids

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

2.8 INTENSIFIERS (BOOSTERS)

Provide [oil-to-oil] [air-to-oil] type intensifiers boosters. Provide driving cylinder bore size and operating fluid medium, the mounting style, and a manufacturer's series identification (or equal) as shown. [For cylinder-to-ram (piston) intensifiers, use ram diameter as shown.] [For cylinder-to-cylinder units, provide output cylinder bore as indicated.] Use inlet and outlet pressures and intensification ratio as indicated. Design intensifier for use with petroleum base hydraulic fluid unless otherwise indicated. Produce evidence that all dynamic seals are suitable for both frequent and infrequent operation and are capable of no less than 500,000 cycles of operation in systems properly maintained. Ensure intensifier is 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) must be [water-cooled] [or] [air-cooled] type with the cooling capacity indicated.

2.9.1 Air-Cooled

Provide air-cooled type with a core of [oval-tube and plate-fin] [round-tube plate-fin] [or] [individual finned round tubes]. Equip the cooler with an electric motor-driven fan, selected to provide the air flow volume through the core to ensure that the cooling requirements are met. Do not allow fan and motor to exceed an operating sound level of 85 dBA.

2.9.2 Water-Cooled

Provide water-cooled type consisting of [shell-and-tube] [plate type] construction. [Arrange shell-and-tube type to handle water through the tubes and the hydraulic fluid through the shell.] [Arrange shell-and-tube construction as [U-tube] [straight tube] [fixed tube bundle] [straight tube, removable bundle] type.]

2.10 FILTRATION EQUIPMENT

Locate fluid filters as indicated. Nominal and absolute ratings exceeding the values indicated are prohibited. Use [depth] [surface] type filters. Pressure drop through each filter is not allowed to exceed the value indicated at the given maximum flow rate. Provide elements for depth type filters of the [resin-coated] [paper] [synthetic fiber] [vinyl membrane] type. Provide [wire cloth] [nylon cloth] elements for surface filters. [Ensure filter casings for installation in pressure lines have a working pressure rating in excess of the specified maximum pump discharge pressure.] [Ensure filter casing for separate filtration circuits have a rated working pressure in excess of the maximum pressure of the filter circuit.] Provide filters with [adjustable] [nonadjustable] [internal] [external] bypass. [Provide an indicator to show when the bypass has opened.] Provide cracking pressure of the bypass on pressure filters as indicated. Provide cracking pressure of the bypass on filters installed on the suction side of pumps as required by the pump manufacturer.

2.11 LINES AND FITTINGS

****

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.

****

Design and install piping and tubing connections to permit quick removal and reassembly with hand tools.

2.11.1 Pipe

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

2.11.2 Pipe Fittings and Flanges

Provide steel pipe fittings. Equip fittings that incorporate separate synthetic, or metal-to-metal seals, or seals that seal with pressure, 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. Provide steel pipe flanges, [_____] MPa psi steam working pressure rated, that are faced for use with metallic O-ring gaskets. Provide steel flange bolts with steel self-locking nuts. Mechanical connections, proven suitable for the pressure and service, may be used instead of flanged connections. Use seals that are compatible with the hydraulic fluid used in the system. Provide threaded fittings conforming 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. Provided welded fittings conforming to ASTM A234/A234M, Grade WPB. Provide flanges conforming to ASTM A182/A182M, grade suitable for pipe to which attached. Provide facing on flanges in accordance with ASME B16.5.

2.11.3 Tubing and Fittings

Provide seamless or welded steel tubing conforming to ISO 10763.

2.11.3.1 Wall Thickness

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

2.11.3.2 Fittings

Use solderless steel fittings. 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, must be 37 degrees from center (74 degrees included angle), and must conform to

SAE J514 for minimum performance requirements. Submit copies of test reports for all tubing fittings with detail drawings. Use adapters for connecting tubing to threaded pipe ports that are the straight thread type with locknut, washer, and O-ring seal. Provide fittings that incorporate separate synthetic or metal-to-metal seals, or seals that seal with pressure with 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 must be wire reinforced, high-pressure type hose with synthetic rubber lining and outer cover. Select synthetic rubber for maximum compatibility with the hydraulic fluid specified for use in the system. Use flexible hose rated by the manufacturer for a working pressure not lower than the system operating pressure indicated. Provide fittings specifically designed for use with the hose selected and as recommended by the hose manufacturer. Provide [stainless steel] [carbon steel] fittings with straight or elbow ends as best suited to the installation conditions. Provide [reusable] [permanently attached] type fittings. Ensure each hose assembly is 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 must be [water-glycol] [synthetic] [water-in-oil emulsion] type. Filter fresh hydraulic fluid to 10 micron level.

2.13 PACKING, GASKETS, AND SEALS

Equip hydraulic components 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

Arrange static-type seals to seal with pressure and provide 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 must 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

Provide accessories conforming 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 must be medium carbon steel and cadmium plated. Provide threads conforming 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. Do not use setscrews for transmitting torsion.

2.14.4 Methods of Securing Fasteners

Ensure all fasteners not secured by mechanical devices, such as lock washers, cotter pins, safety wire, or locknuts, have the threaded portion of the fastener coated with sealing/locking compound, Grade E or Grade B, as applicable, before installation. Clean fasteners 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

Provide shaft couplings with strength equal to the full strength of the shafting which they connect and pressed and keyed thereon. In determining the coupling capacity, divide the manufacturer's rating by a service factor of [1.5] [_____].

2.15.1 Flexible Couplings

Unless otherwise indicated, provide flexible couplings composed of forged steel that 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]. [Fully enclose and seal flexible couplings of the [geared] [or] [grid] type to retain lubricant and make oil-tight under both static and operating conditions.]

2.15.2 Rigid Couplings

Provide rigid couplings consisting of cast or forged steel of the flanged or compression type with recessed bolts.

2.16 PRESSURE GAUGES

Provide pressure gauges conforming to ASME B40.100 with [black enameled corrosion-resisting metal case] [phenolic case]. Ensure the scale range of the gauge is approximately twice the maximum pressure of the circuit in which installed. Provide safety type gauges with solid fronts and blowout backs. Provide each gauge with an approved gauge snubber. Provide all permanently installed gauges with a shutoff valve arrangement to permit isolation of the gauge and snubber from the rest of the system.

2.17 SHIMS

Provide shims in graduated thicknesses which permit adjustment in increments of 0.13 mm 0.005 inches from 0 to 6.4 mm 0 to 1/4 inch. Use shims between machinery components, subassemblies, or machinery bases and mounting brackets and unfinished surfaces of structural member to 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. Provide tapered shims as required to accurately align machinery components and bases which are mounted directly on unfinished structural steel surfaces. Take field measurements to determine the exact amount of taper required to obtain proper alignment. Material for all shims must be AIST PB-229, Types 304 or 316 unless otherwise indicated.

2.18 EQUIPMENT BASES

Provide nonintegral equipment bases including brackets and mounts consisting of all-welded construction and fabricated of ASTM A36/A36M steel. After installation and final adjustment of all the system components on the equipment bases in the shop, secure each piece of equipment positively 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

****

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, tailor system requirements and specifications 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.

****

2.19.1 Control Devices and Wiring

****

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.

****

Provide manual or automatic control protective or signal devices required for the specified operation and all control wiring for these controls and devices whether indicated or not. Provide electrical control devices with 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. Provide control devices with the number and arrangement of contacts required to perform the specified control functions. Provide devices with or install in [general purpose] [weatherproof] [NEMA Type 4 for [exterior] [interior] [hazardous] [nonhazardous] application] [corrosion-resistant] [NFPA 70 Class [_____] Division [_____], explosion-proof] enclosures as indicated. Provide electronically and electrohydraulically controlled components as indicated.

2.19.2 Pressure Switches

****

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.

****

Provide pressure switches with the operating pressure [settings] [and] [ranges] [and maximum allowable differentials] indicated. Actuators must be of the [bellows] [piston] [Bourdon tube] [diaphragm] type [indicated] [required for the operating conditions]. Ensure actuators have a rated proof or withstand pressure of no less than 150 percent of the maximum possible pressures for the systems in which they are installed. [Limit the maximum setting for switches with an adjustable range of operating pressures to 80 percent of the proof pressure ratings.] Fabricate actuators from materials which are compatible with the fluids employed. Provide automatic reset type switches [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."

****

Provide limit switches with 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, arrange activating mechanisms and switch mountings 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, must be heavy-duty oil-tight type conforming to the requirements of NEMA ICS 1. Provide momentary contact type switcheswith standard operators [except where maintained contacts or special operators, such as mushroom head, illuminated button, and latching

button are indicated].

2.19.5 Relays

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

2.19.6 Timers

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

2.19.7 Indicating Lights

Provide oil-tight type indicating lights with jewel color as indicated. Provide integral transformer type light unit with 6-8 volt lamp and fit with a glass color cap.

2.20 CONTROL CONSOLES AND VALVE AND GAUGE PANELS

2.20.1 Control Console Construction

Provide control console including 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, construct the console of steel meeting the requirements of NEMA ICS 6. Use steel sheet conforming to ASTM A659/A659M. Secure removable panels in place using captive, spring loaded, self-locking spring nuts and hardened sheet metal screws. Use screws and nuts composed of corrosion-resistant material or with corrosion-resistant protective coating. Secure access panels with spring loaded quarter turn fasteners with studs held captive in the removable panel. Equip console with adequate louvered panels to ventilate the interior and dissipate the heat generated within the console. Provide special equipment supports and guides as required to support the equipment and other components within the console. Unless otherwise specified, finish interior and exterior surfaces with one coat of primer and two coats of manufacturer's standard finish.

2.20.2 Valve and Gauge Panels Construction

Construct valve and gauge panels of steel plate thick enough to provide rigid support for the valves and other components mounted thereon. Terminate all piping with bulkhead type connections in a position convenient for the connection of external lines. Provide manufacturer's standard coating primer and finish.

2.20.3 Nameplates and Instruction Plates

Provide nameplates for each device on the control console, valve panels

and gauge panels. Clearly indicate the function of each device and, in the case of manually-operated controls, indicate the condition established for each position of the control. Provide instruction plates to 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. Provide nameplates with machine-engraved lettering on plastic laminate with white characters on a black background. Provide instruction plates with permanent black letters on a white background. Mount instruction plateson a rigid backing and cover with clear, rigid plastic sheeting. Mount instruction plates in a location easily visible to an operator stationed at the console or panel.

2.20.4 Security Provisions

Construct and install control consoles to prevent unauthorized or accidental operation of the system. [The main power control switch mounted on the control console must be a key-operated type with provision for removal of the key only when the switch is in the "OFF" position.] [Provide control console 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 must be NEMA Type 4 for exterior [hazardous] [nonhazardous] application. Provide enclosures with hinged and latched covers. Provide separable type hinges to permit complete removal of the cover for maintenance. Construct hinges and latches of corrosion-resistant steel or approved nonferrous metals.

2.21 TEMPORARY CORROSION PROTECTION

Protect unpainted metal surfaces 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. Remove the temporary coating completely and properly prepare the surfaces for final finishing as specified in Section 09 90 00 PAINTS AND COATINGS. Do not provide unpainted products, or products with temporary coatings, including pumps, reservoirs, cylinders, and similar assemblies. Provide factory finished products 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.
****

Provide electric motor-driven equipment 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 are as indicated or specified. [Provide motor starters complete with properly sized thermal overload protection and other appurtenances necessary for the motors specified.] Provide 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. Where two-speed or variable-speed motors are indicated, solid-state variable speed controller may be provided to accomplish the speed function. Each motor must 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

Install hydraulic components in accordance with the manufacturer's written instructions and under the direction of the hydraulics technician. Install complete units or assemblies without disassembly. Provide necessary supports for all appurtenances, pumps, motors, heat exchangers and other equipment or componentsd. Anchor floor-mounted equipment to concrete pads by dowels set in the concrete. Shear blocks may only be used where installation of dowels is completely impractical. Use concrete for foundations as specified in Section 03 30 00 CAST-IN-PLACE CONCRETE. Install drain lines from the reservoir to each component requiring a drain connection. Mount all valves and other fluid control devices as indicated. Install mounting subplates 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. Provide shims at locations required to permit proper adjustment, alignment, and position of system components and assemblies. Mark components 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 must be by stamping or embossing on the component or on an attached plate or tag which must, 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 must 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. Include drawingsfor motors, actuators, cylinders, pumps, controls, and other components. Moving parts fluid control diagrams must follow the methods in NFLPA T3.28.9. 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. Include loadings and types of frames, brackets, stanchions and other supports, and pipe anchors for supported pipe and equipment. Include bolt setting information for equipment indicated or required to have concrete foundations.

3.2.2 Components and Subassemblies

Mount components securely to the supporting surface. Exercise care that

fastenings are not overtightened to the extent that component bodies are distorted or damaged. Aligh pivot type mountings carefully to ensure free operation throughout the entire range of movement. Align cylinders carefully so that no side loads are imposed on the piston rod at any point in the full stroke. Mount and brace subassemblies independently of the connecting lines.

3.2.3 Connections to Mechanisms

Aligh pumps and motors carefully with the mechanisms to be operated and shim as necessary to eliminate angular and radial misalignment between the mating shafts. Lubricate shaft couplings which require lubrication at the time of installation. Lubricate pivot-type connections at assembly.

3.2.4 Rigid Conductors

Securely mount and anchor hydraulic pipe and tubing to structural members. Locate supports and anchors as indicated. Provide guards at all locations where the structure does not provide protection for the lines from damage due to movement of personnel and equipment. Do not remove seals from pipe and tubing assemblies or from ports on components until the lines are ready for connection. Take provisions, including but not limited to providing portable screens and shelters, 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

Install flexible conductors in accordance with the manufacturer's recommendations. Exercise special care to avoid imparting any twist in the conductors during tightening of fittings. Provide and locate supports to prevent conductors from contacting and chafing against fixed members. Provide clamps and straps used to support hoses with soft resilient sleeves, linings or bushings to prevent cutting and abrading of the hose. Arrange the routing of flexible hoses to preclude imparting a twist in the hose due to relative motion between the components to which the hose is connected. Ensure the minimum bend radius of the hose is not less than that recommended for the particular hose size and maximum system operating pressure. Provide heat shields or insulating jackets where hose passes close to heated surfaces.

3.2.6 Installation of Tubing

Cut tubing 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. Remove burrs completely after the tubing is cut and chamfer the inside diameter of the tube slightly. After the cutting and deburring operations, remove all metal fragments from the tubing interior and from sealing surfaces. Use tube benders designed and recommended by the manufacturer for bending stainless steel tubing of the wall thicknesses and sizes specified for the installation. Make bends accurately to the proper angle so that fittings align properly and mate without application of force or springing of the tube or fitting and ensure alignment is true enough so that threads may be engaged and hand turned no less than three turns. Ensure bends are completely free from wrinkling, and flattening does not exceed 5 percent of the outside diameter. Provide tube benders 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, use internal mandrels of proper diameter for the size and wall thickness of the tubing.

3.2.7 Test Connections

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

3.2.8 Welded Installation

Provide hydraulic pipe weldments as indicated. Make changes in direction of piping 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 must be forged, flared for improvement of flow where attached to the run, and reinforced against external strains. Perform beveling, alignment, heat treatment, and inspection of welds conforming to ASME B31.1. Remove weld defects and make repairs to the weld, or remove the weld joints entirely and reweld at no additional cost to the Government. After filler metal has been removed from its original package, protect or store it so that its characteristics or welding properties are not adversely affected. Do not use electrodes that have been wetted or that have lost any of their coating.

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. 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. Ensure the hydraulics technician has at least 3 years of current experience in the installation and operation of similar systems and is 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. Post 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, where indicated for local operator and maintenance assistance. In addition, type 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, frame as specified for the wiring and control diagrams, and post 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

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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.

****

Proof test all lines [including reinstalled existing lines], except component drain lines, to no less than 150 percent of design operating pressure. Proof test component drain lines to 150 percent of the design working pressure or 690 kPa 100 psi, whichever is the greater. Carefully examine all welded, flanged, flared, and threaded connections for leakage and inspect all lines for evidence of deflection caused by inadequate anchorage. The proof test medium must 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. Maintain proof test pressure 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, clean field installed hydraulic lines [including reinstalled existing lines] in place. Submit a detailed field cleaning procedure for approval in accordance with paragraph SUBMITTALS not less than [_____] days before start of cleaning operations. 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. Free the system of particles so that the contamination level is below 15/12 [_____] in accordance with ISO 4406. Collect samples and conduct tests by an approved independent testing laboratory selected by the Contractor. Examine the samples for particle size and population count by the

millipore or equivalent method in accordance with SAE AS598. Tabulate particle size and population in accordance with the size groupings in accordance with ISO 4406; and to the extent possible, visually identify particles as metallic or nonmetallic, magnetic or nonmagnetic, and by color and composition. Circulate fluid in the system at no less than system design fluid operating velocity during withdrawal of the samples. Take three 500 milliliter size samples at random locations in each flushing of the system. If any sample does not comply with the permissible contamination limits, reclean and reinspect the system. Also, subject accessible interior portions of the system to visual and wipe tests. Any evidence of contaminants exceeding allowable limits requires recleaning of the system.

3.4.3 Field Training

****
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. Provide training for a total period of [_____] hours of normal working time and start after the system is functionally complete but prior to final acceptance tests. 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. 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. 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

****
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.
****

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. Monitor details of all operations constantly for signs of impending trouble and make corrections as necessary to prevent damage to equipment. [Furnish a written statement that the hydraulic system has been field tested and meets all operational requirements 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. Conduct all tests in the presence of the Contracting Officer. Correct each deficiency or maladjustment disclosed by the tests immediately and repeat the test 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

Inspect the hydraulic reservoirs to ensure that fluid is at the proper level. [Verify that the fluid equalizing valve is fully open.] [Inspect the reservoir pressurization system to ensure that all valves are open and that the pressure regulating valve is adjusted to provide the specified pressure in the reservoirs.] [Inspect the accumulator precharge pressure and adjust to specified value.] Start the hydraulic pumps using the controls at the control console. Inspect the operation of the pumps for proper operation and discharge pressure. [Adjust the pressure compensator as required.] [Adjust the pressure compensators to equalize the discharge pressures.] Read and record the discharge pressure of [the] [each] pump. [Adjust the pressure relief valve to limit system pressure to the specified value.] [Adjust the unloading valve to unload the pumps to the reservoir when the accumulator has been charged to the specified pressure.] Inspect hydraulic lines and components which are under pressure for evidence of leakage and for evidence of distortion because of inadequate or improper support. [Inspect branch circuit pressure reducing valve and relief valve settings and adjust as required to obtain specified values.]

3.4.4.2.2 Combined System Tests

****

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.

****

Perform tests and inspections of [the hydraulic system] [each branch of the hydraulic system] concurrently with the testing specified under other sections which test the mechanism operated by the hydraulic system. During each test operation, inspect hydraulic lines and devices for leakage and for evidence of distortion due to inadequate or improper support. Read and record the pressure in the supply and return lines for each direction of operation. Inspect response of components to operation of applicable controls [on the control console] to ensure that all

connections have been made properly. [Check flow control valves and adjust as required to conform to indicated operating time requirements.] [Inspect sequence valves and adjust as required to obtain the indicated sequence of operation.] [Adjust chokes in pilot circuits of pilot-operated valves to obtain smooth, shock-free operation.] [Adjust restriction in externally piloted counterbalance valves to obtain smooth operation without vibration.]

3.4.4.2.3 Test Logs

****
NOTE: Edit the list as required.
****

Prepare and complete a test log showing in detail the results of the tests. Deliver three copies of the completed test log 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, record the following data and observations:

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

Shop prime and coat all exposed exterior surfaces of assemblies and equipment except corrosion-resistant steel, synthetic rubber, and plastic as specified: Paint complete system, including color coding and piping, as specified in Section 09 90 00 PAINTS AND COATINGS. Insofar as practicable, apply the complete coating system 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.

****

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

3.5.3 Field Touch-Up

Repaint chips, scratches, and other damage to shop-applied painted surfaces in the field. Finish field colors must match those of marred finishes.

-- End of Section --