CHAPTER 7—HYDRAULIC DESIGN

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LIST OF FIGURES

7.1—GENERAL REQUIREMENTS

7.1.1—Design Objectives

The following shall supplement *A7.1.1*.

This chapter contains information and criteria related to the design of movable bridge projects. It sets forth the basic Louisiana Department of Transportation and Development (LADOTD) design criteria exceptions and/or additions to those specified in the latest edition of *AASHTO LRFD Movable Highway Bridge Design Specifications*, including all interim revisions.

Construction specifications shall be the latest edition of the *Louisiana Standard Specifications for Roads and Bridges (Standard Specifications)*. *Standard Specifications* are subject to amendment whenever necessary by supplemental specifications and special provisions to specific contracts. In the absence of specific information in the *Standard Specifications*, follow the *AASHTO LRFD Bridge Construction Specifications*.

7.2—DEFINITIONS

The following shall supplement *A7.2*.

Pipe Spool–A prefabricated section of a piping system that includes the pipe, fittings and flanges that are pre-assembled in the fabrication facility and then transported to the field.

Positive Displacement Pump—A hydraulic pump that has an expanding cavity on the suction side and a decreasing cavity on the discharge side. Liquid flows into the pump as the cavity on the suction side expands and the liquid flows out of the discharge as the cavity collapses. The volume is constant, given each cycle of operation.

Fixed Displacement Pump—A hydraulic pump that cannot be adjusted to increase or decrease the amount of liquid that is moved in a one pump cycle.

Variable Displacement Pump—A hydraulic pump in which the displacement or amount of fluid pumped per revolution of the pump's input shaft can be varied while the pump is running.

Pressure-Compensated Pump—A hydraulic pump that has an adjustable pressure compensator that will decrease the pump’s output to 0 gpm when the system pressure equals the pressure setting of the compensator.

The following definitions shall replace those in *A7.2*.

Design Pressure (DP)—The established criteria for maximum working pressure allowed by design. This is the pressure value which is also known as *Maximum Allowable Working Pressure* (*MAWP*). MAWP of a vessel is to be the pressure that will create stresses in the shell that equal the allowable stresses given in the material section of the code. The piping code has similar criteria, but it calls this the Design Pressure (DP); therefore, DP is the allowable pressure given by the governing codes. In this case, it is 3,000 psi for the piping and fittings, etc., 5,000 psi for hoses and hose fittings, and higher for the cylinders.

Maximum Pressure (MP)—The highest pressure at which the system or part of the system is intended to operate in a steady state of conditions without amplification due to impact; a physically established value – controlled and limited by physical devices such as relief valves. This is the pressure for which the system relief valve is set (approximately 2,600 psi). This pressure is, for example, the pressure where the holding valves are set. When the span is pushed by a barge, this will cause the holding valves to open and relieve the system.

Normal Pressure (NP)—The pressure at which the system or part of the system is intended to operate in a steady state of conditions without amplification due to impact, as established by the design setting of a relief valve. NP differs from MP in that it is established by setting an adjustable relief valve to a specific pressure lower than the maximum pressure setting. For example, the pressure for the counterbalance valve setting is 1,500 psi. If a non-adjustable relief valve is used, the normal working pressure and maximum working pressure will be the same. For example, the end wedge system has a relief valve set at 2,600 psi. This pressure is the NP and the MP.

7.4—DESIGN LOADING CRITERIA

7.4.2—Machinery Design Criteria and Limit States

The following shall replace the last paragraph in *A7.4.2*.

Seismic design shall not be required for hydraulic machinery in Louisiana.

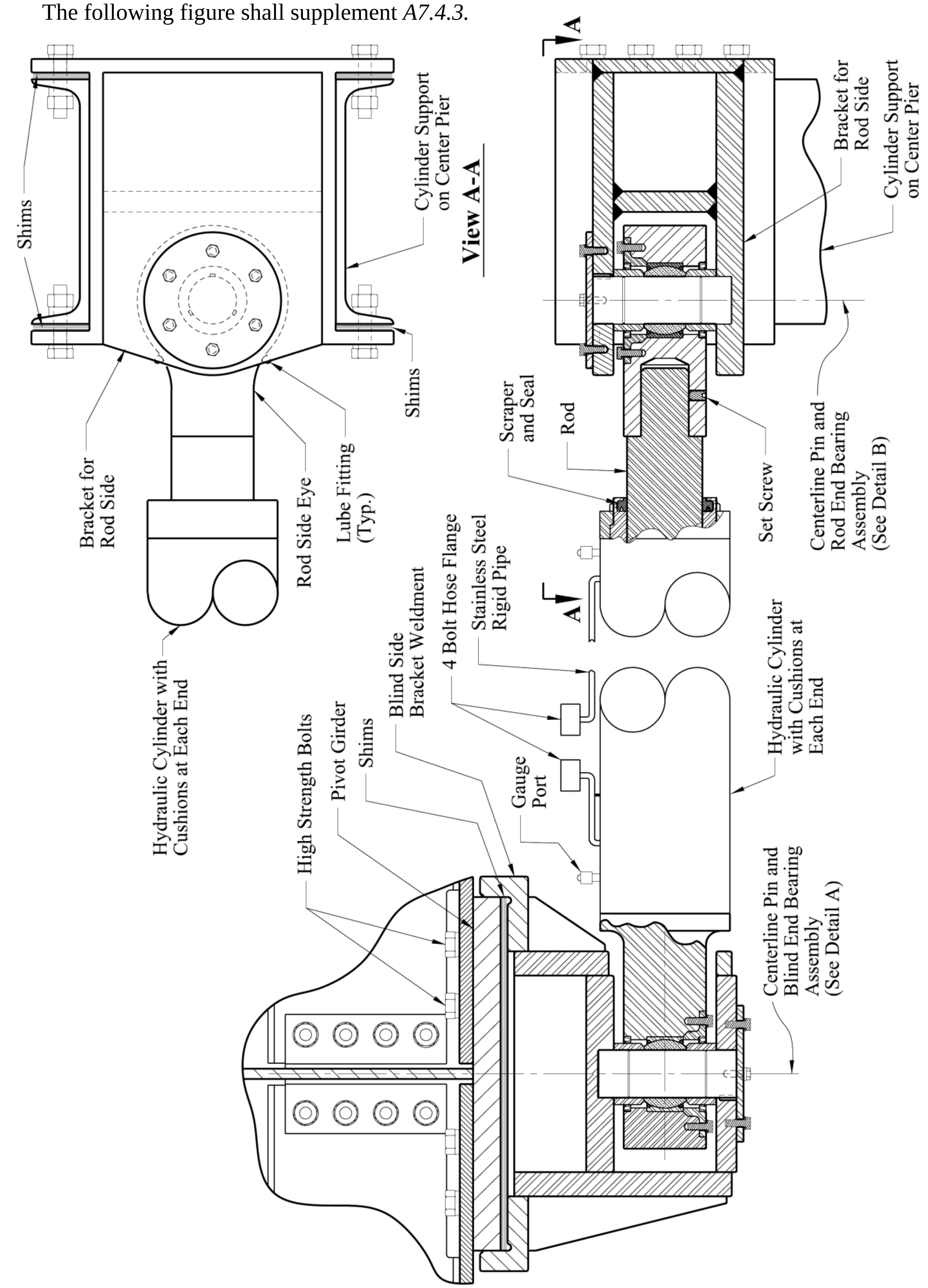
The following shall supplement *A7.4.2*.

For hydraulic swing spans, the span drive system located between the pump and valve manifold should be designed, sized, and proportioned such that it can operate the span within the normal operating loads described in *A5.4.1*, *A5.4.2*, *A5.4.3*, *A5.4.4*, *D5.4.1*, *D5.4.2*, *D5.4.3*, and *D5.4.4*, and with NP between 1,200 psi and 1,500 psi. The relief valves shall be set at this NP to prevent the system pressure rising.

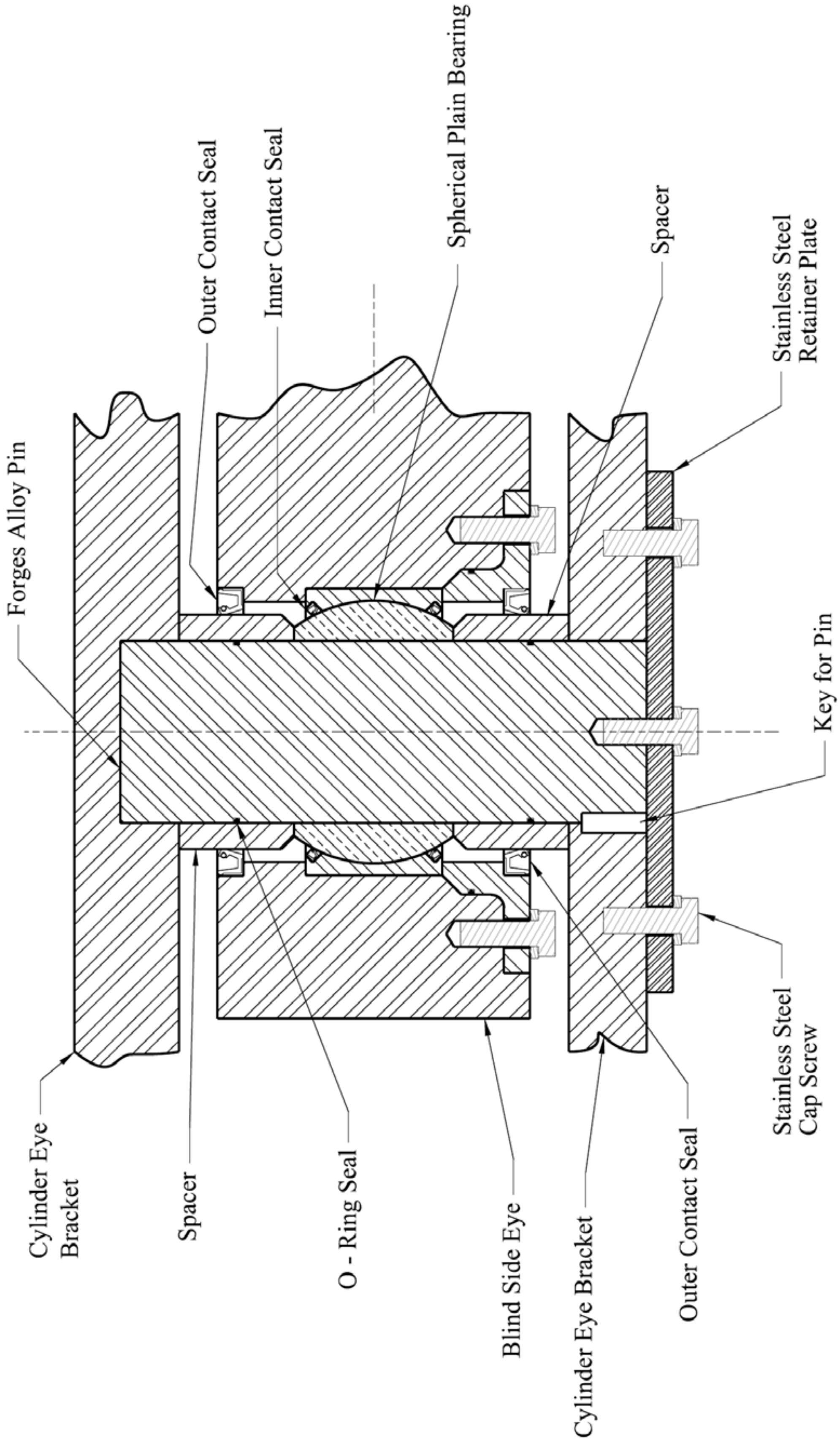
Once this is established, the span drive hydraulic system shall also fulfill the holding requirements of *A5.5* and *D5.5*, with a pressure below 3,000 psi, but above the NP (usually about 2,500 psi); therefore, a second set of relief valves, located at or on the end lifts, shall be set at the maximum pressure (MP) and shall come into play only during a holding situation.

7.4.3—Hydraulic Cylinder Connections

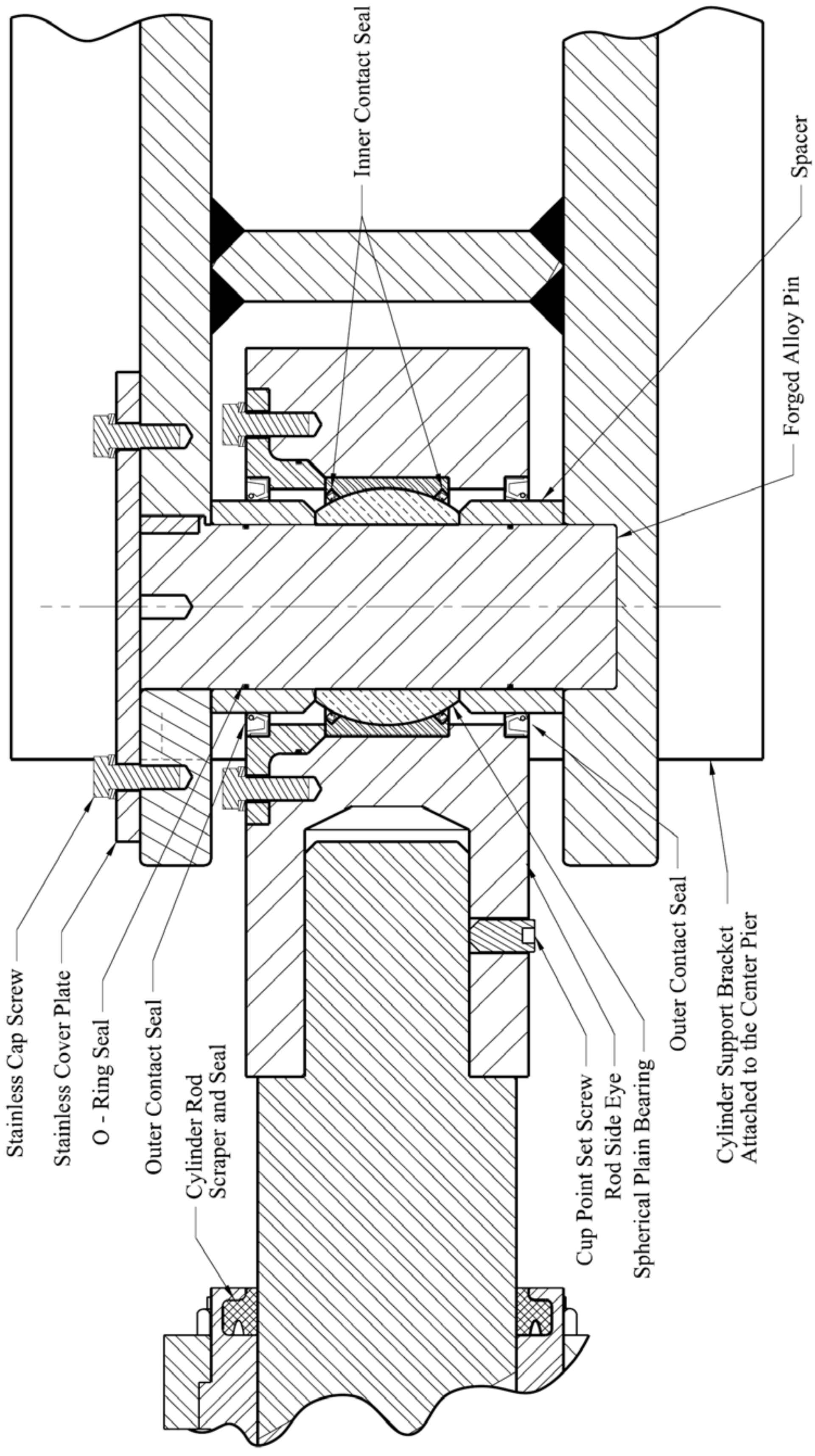
The following figure shall supplement *A7.4.3.*



Example Span Drive Hydraulic Cylinder and Connections for Swing Span Bridges



Detail A – Blind End Bearing Assembly



Detail B – Rod End Bearing Assembly

7.5—COMPONENTS

7.5.1—Hydraulic Fluid

The following shall supplement *A7.5.1*.

Readily biodegradable hydraulic fluids are not recommended for movable bridges in Louisiana.

C.7.5.1

Biodegradable hydraulic fluids have a shorter life than conventional hydraulic fluids. It should be assumed that the hydraulic fluid will not be replaced for 10 to 20 years.

The viscosity of a normal oil can be 10 times or higher at 32 degrees Fahrenheit than at 75 degrees Fahrenheit. Therefore, a thermally stable fluid should be considered by the designer.

7.5.2—Electric Motors

7.5.2.1—General

The following shall replace the 2nd paragraph in *A7.5.2.1*.

All hydraulic pump motors used for driving hydraulic pumping equipment shall be specified as: 1,800 nominal rpm, 240 or 480 VAC, TEFC or TENV, squirrel-cage induction motors, heavy-duty cast-iron frame, an oversized rotatable junction box, re-greaseable bearings, premium shaft seals, class F insulation, epoxy-coated winding treatment, copper windings, stainless-steel hardware, and a stainless-steel or aluminum nameplate. They shall be foot-mounted and have all joints gasketed, sealed, and shall be painted on the inside and outside with an epoxy paint system suitable for harsh environments.

Electric squirrel-cage induction motors of 480 volts and larger shall meet or exceed the IEEE-841 standard for severe duty applications.

Electric squirrel-cage induction motors of 1 horsepower to 200 horsepower shall include:

- NEMA Continuous Duty
- 1,800 rpm at synchronous speed
- 3 phase, 60 hertz
- NEMA design B
- NEMA TEFC
- Enclosure meets or exceeds IEC IP54
- Epoxy paint system
- Zinc-plated or stainless-steel hardware

- Cast-iron frame, fan cover, and conduit box
- Class F insulation according to NEMA MG1-2006, part 31.
- 1.15 service factor
- NEMA Class B temperature rise at 1.0 service factor
- Re-greasable double-shielded bearings on output and fan shafts
- Automatically resetting thermal overloads
- Stainless-steel nameplate

Electric squirrel-cage induction motors less than 1 horsepower shall include:

- NEMA continuous duty
- 1,800 rpm at synchronous speed
- 3 phase, 60 hertz
- NEMA design B
- NEMA premium efficiency
- NEMA TEFC or TENV
- Epoxy paint system
- Cast-iron frame, fan cover, and conduit box
- Class F insulation according to NEMA MG1-2006, part 31.
- 1.15 service factor
- Ball bearings
- Automatically resetting thermal overloads
- Stainless-steel nameplate

Horsepower, rpm, voltage, phase, and hertz, shall be shown on the plans.

The following shall supplement *A7.5.2.1*.

Hydraulic Pump motors shall be sized and rated for continuous operation at 110 percent of the selected pump capacity when operating at the pump's highest relief valve setting while pumping the hydraulic oil at 32° Fahrenheit.

For variable capacity pumps, the driver shall be sized and rated for continuous operation at the lesser of either: 1) the maximum pump capacity, 2) 100 percent capacity at the system pressure valve setting at NP, or 3) design flow at the pump pressure valve setting and the maximum system relief valve setting.

7.5.2.2—Open Loop Systems

The following shall supplement *A7.5.2.2*.

For open-loop variable-volume pressure-compensated pumps, the 20 percent uplift will be checked for satisfactory performance against the full volume capacity of the installed pump and the resultant developed head or system relief pressure setting.

C7.5.2.2

The objective is to provide the maximum practical horsepower for the motor frame being used that can/will handle possible future increased volume rates at design pressures.

7.5.2.3—Closed Loop Systems

The following shall supplement *A7.5.2.3.*

For hydraulic cylinder swing spans, the cylinder arrangement and geometry requires a boost pump to make up the flow differential between the pump output and the return.

7.5.5—Pumps

7.5.5.1—Main Drive System Pumps

The following shall supplement *A7.5.5.1*.

Span drive hydraulic pumps used to actuate cylinders shall be closed or open loop, axial piston type with swash plate design. They shall have a manual control lever for direction and flow control. They shall have an integral boost pump with a cold start valve, and integrated high-pressure relief and make-up valves. They shall be rated for continuous duty at 3,000 psi minimum.

7.5.5.2—Auxiliary Pumps

The following shall supplement *A7.5.5.2*.

Center wedge and end roller system hydraulic pumps shall be an open-loop, fixed displacement, balanced, pressure-compensated vane pump with SAE 4-bolt flange ports and shall be rated for continuous duty at 3,000 psi.

7.5.6—Control Valves

7.5.6.2—Directional and Speed Control Valves

The following shall supplement *A7.5.6.2.*

Maximum allowed system pressure drop, if used to provide span rotation, shall be 13 percent of pump internal relief valve setting or 15 percent of system relief valve setting when motor is operating at 100 percent design flow.

7.5.8—Fluid Reservoirs

The following shall supplement *A7.5.8.*

Hydraulic fluid reservoirs may serve as the platform for all of the components which serve as the hydraulic power unit (HPU).

Reservoir volume shall be shown on the plans.

C7.5.8

Although *AASHTO LRFD Movable Highway Bridge Design Specifications*, 2007 require the reservoir volume to be not less than 2.5 times the flow rate, the volume may be reduced if the heat buildup is determined not to be a problem and there is enough depth of fluid to completely submerge the suction strainer throughout the operation cycle of the bridge.

7.5.10—Filters

The following shall replace the 3rd paragraph in *A7.5.10*.

“Oversized” suction strainers with a bypass shall be permitted on the hydraulic power unit. These strainers shall be sized large enough as not to have more than a 5 psi pressure differential between the tank and the inlet at full pump capacity flow.

All filters shall have external indicators for bypass operation.

7.5.11—Hydraulic Motors

7.5.11.1—Hydraulic Motors for Span Operation

The following shall supplement *A7.5.11.1*.

The hydraulic pressure release system provided to the hydraulic span rotation motor shall be electrical fail safe design, but shall incorporate an adjustable minimum 10-second accumulator reservoir supply to allow for dynamic braking prior to full stop by the hydraulic motor brake unit.

For hydraulic braking, a pressure valve spill back shall be built into the hydraulic motor head. This spill back shall be rated at a DP of 3,000 psi.

7.5.12—Hydraulic Cylinders

7.5.12.1—Cylinders for Span Operation

The following shall supplement *A7.5.12.1*.

Span drive cylinders on a swing span bridge shall be designed such that they can be mounted horizontally without an intermediate support. This will require a stop tube. Span drive cylinders shall also be cushioned at both ends. Cushions shall be designed to stop the span even if the span is driving at full speed and is being driven by the HPU without exceeding 5,000 psi in the cushions.

7.5.12.2—Cylinders for Auxiliary Devices

The following shall supplement *A7.5.12.2*.

Wedge and lock cylinders shall be designed for hard stop/lock positioning when fully driven & fully retracted. Cushions are not needed for these cylinders.

7.6—GENERAL DESIGN PROVISIONS

7.6.9—Fluid Conductors

7.6.9.2—Pipe and Pipe Fittings

The following shall supplement *A7.6.9.2*.

Socket weld fittings for pipe shall be specified.

SAE code 61 or 62 4-bolt flange fittings with O-ring seals shall be specified for pipes.

7.8—FABRICATION AND CONSTRUCTION

7.8.4.2—Shop Tests

The following shall supplement *A7.8.4.2*.

Shop fabricated pipe spools will be shop hydro-tested to 1.5 times the system design pressure or 1.5 times the component maximum pressure rating, whichever is greater.

Shop assemblies of mechanical items (pumps, valves, manifold, etc.) shall be shipped as one unit and shall be shop hydro-tested to 1.5 times design pressure.

7.8.4.2.1—Power Units

C7.8.4.2.1

The hydraulic system up to the hydraulic cylinders or motors is limited to the pressure valve settings (approximately 90 percent of the MP or about 2,700 psi).

The internal spill back at the motor is usually set at 80 percent or 2,400 psi.

7.8.4.2.2—Hydraulic Cylinders

C7.8.4.2.2

Hydraulic cylinders will go to the system relief valve setting, which is less than the internal pump spillback setting.

7.9—MATERIALS

7.9.1.2—Tubing and Tube Fittings

The following shall supplement *A7.9.1.2*.

Tubing on pressure lines integral to the power unit (everything on the HPU side of the manifold) may be used if the tubing is properly sized for flow, is pressure-rating rated (3,000 psi), and utilizes O-ring seals at all connections/fittings.

Tubing on low pressure (tank) lines that are part of the HPU can use compression fittings and can be rated for low pressure service (1,000 psi).

7.9.1.3—Hose and Hose Fittings

The following shall supplement *A7.9.1.3*.

SAE code 62 4-bolt flange fittings with O-ring seals shall be specified for all hose connections. For the hose connections associated with auxiliary systems, such as end lift cylinders and center wedge cylinders, compression fittings with O-ring seals may be used.

7.9.1.4—Quick Disconnects

The following shall supplement *A7.9.1.4*.

Quick disconnects shall only be used to connect auxiliary power units (see *A7.6.9.5*). Permanent pressure gauges shall be installed with a gauge cock and snubber. Stainless-steel quick-disconnect gauge ports with "no mess" check valves and protective caps attached by chains should also be provided.

7.9.1.5—Manifolds

The following shall replace *A7.9.1.5*.

Manifold material for hydraulic valves shall be specified as type 304 or 316 stainless steel, or carbon steel possessing the necessary strength for the system pressure, including safety factors. Carbon-steel manifolds shall be painted for protection, per the requirements of machinery steel paint system. The pressure drop across the manifold shall not be greater than 75 psi each way at full port flow.

REFERENCES

AASHTO LRFD Bridge Construction Specifications, Latest Edition, American Association of State Highway and Transportation Officials, Washington D.C.

AASHTO LRFD Movable Highway Bridge Design Specifications, Latest Edition, American Association of State Highway and Transportation Officials, Washington D.C.

AASHTO Standard Specifications for Movable Highway Bridges, Latest Edition, MHB 5, American Association of State Highway and Transportation Officials, Washington D.C.

Louisiana Standard Specifications for Roads and Bridges, Latest Edition, State of Louisiana Department of Transportation and Development, Baton Rouge, LA

Applicable Codes and Standards:

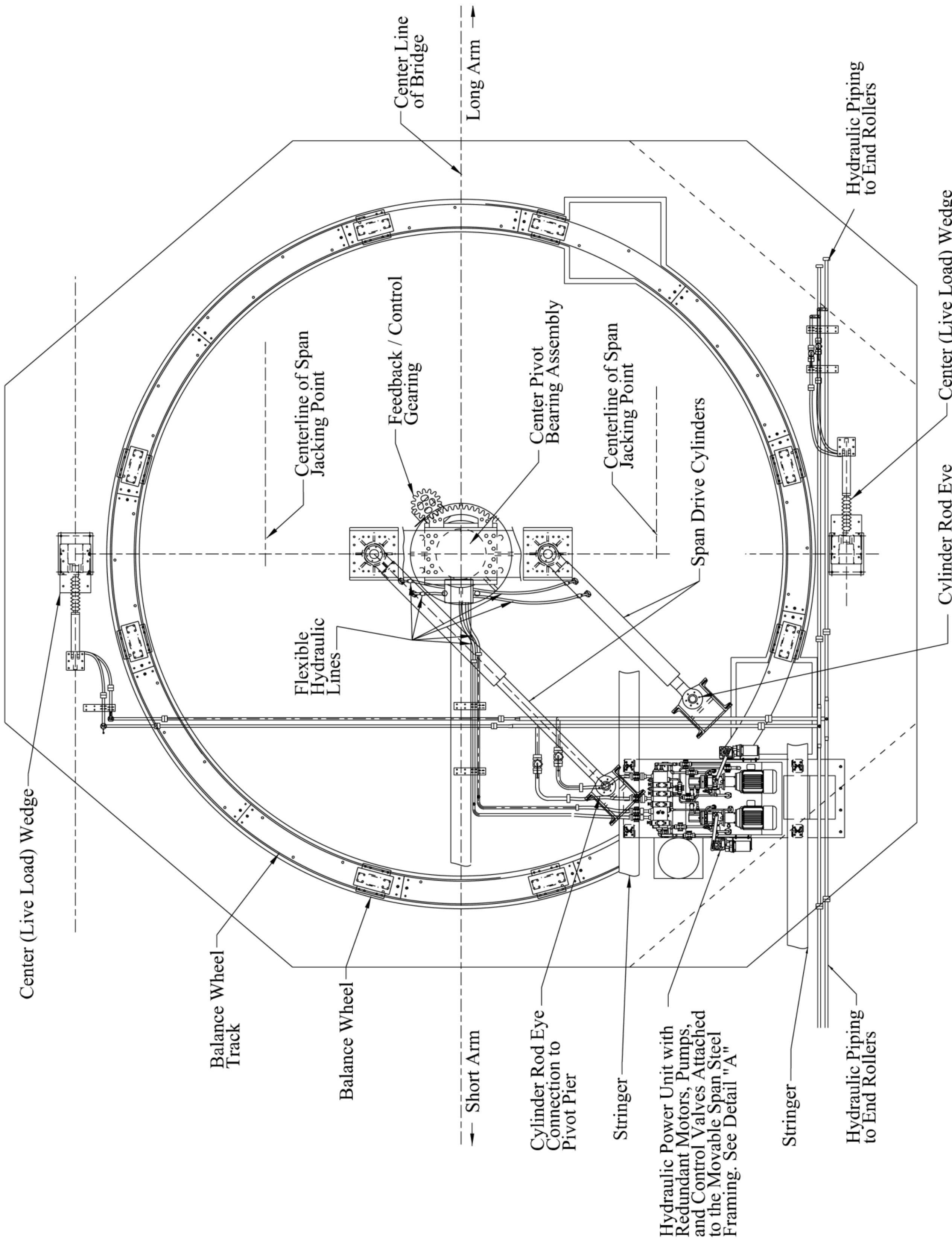
IEC—International Electrotechnical Commission

IEEE—Institute of Electrical and Electronics Engineers

NEMA—National Electrical Manufacturers Association

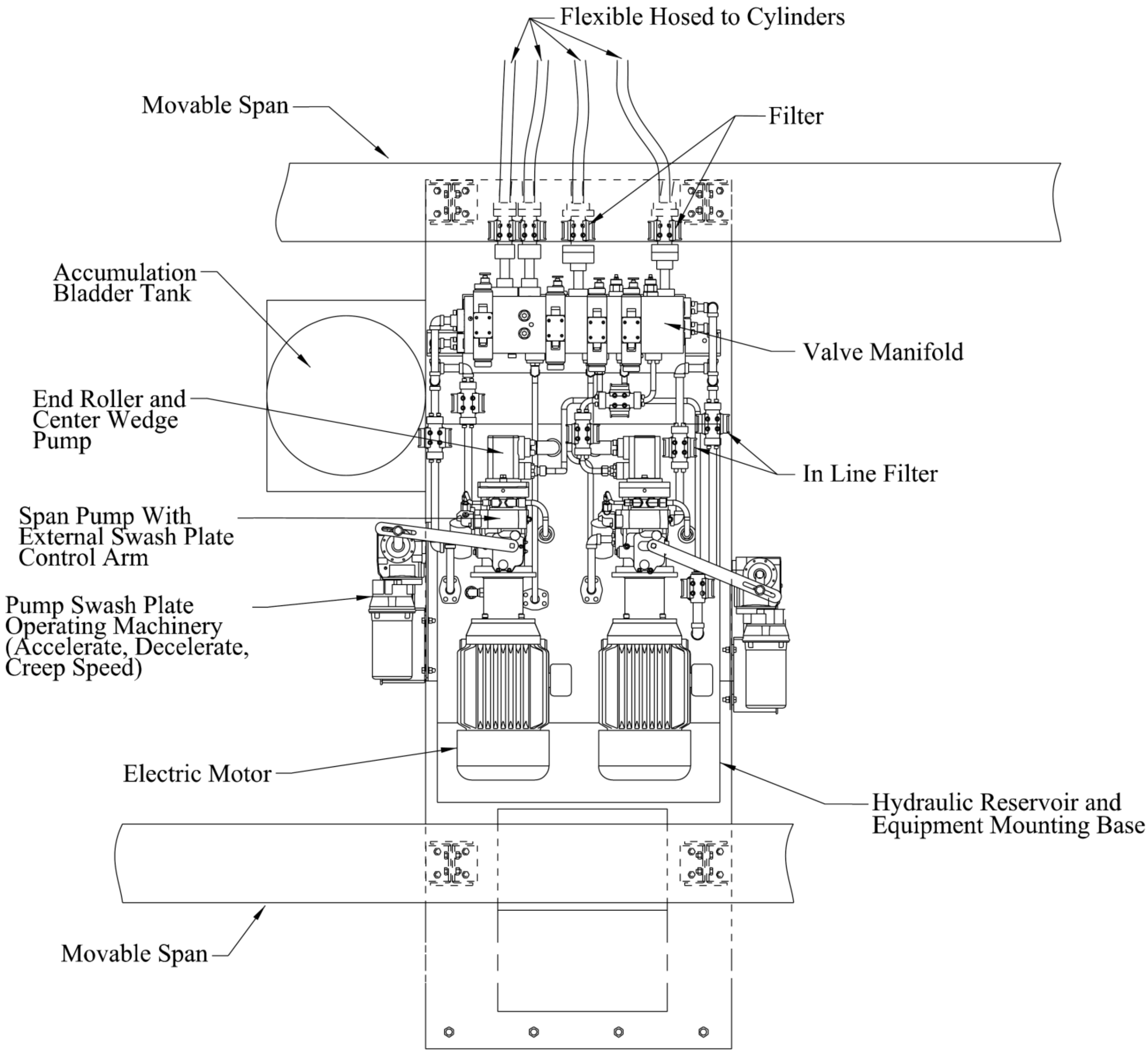
SAE—SAE International (Formally the Society of Automotive Engineers)

APPENDIX—EXAMPLE SPAN DRIVE MACHINERY LAYOUT FOR HYDRAULIC SWING SPAN BRIDGE



Example Span Drive Machinery Layout For Hydraulic Swing Span Bridge

APPENDIX—EXAMPLE HYDRAULIC POWER UNIT (HPU) FOR SWING SPAN BRIDGE



Example Hydraulic Power Unit (HPU) For Swing Span Bridge