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HEAVY MOVABLE STRUCTURES
MOVABLE BRIDGES AFFILIATE

3RD BIENNIAL SYMPOSIUM

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ST. PETERSBURG HILTON & TOWERS
ST. PETERSBURG, FLORIDA

SESSION
WORKSHOP NOTES

Session (4-5)
"Replace Electr. Torque Control Drive
..with Auto Hydr. Speed Control ..",
J.A. Schultz, Hazelet & Erdal, Il.

"REPLACE ELECTRICAL TORQUE CONTROL DRIVE SYSTEM WITH AN AUTOMATIC HYDRAULIC SPEED CONTROL SYSTEM"

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EXISTING TORQUE CONTROL DRIVE SYSTEMS

There are many hundreds of existing bridges where the bridge drives provide manual control for variation of the secondary resistance of their wound rotor motors. This type of system provides Torque Control. There is no control of the speed, it depends only on the external load. The motors always try to accelerate to synchronous speed. An overhauling force will rotate the span motors beyond synchronous speed.

The motors are usually 900 RPM with a motor brake mounted on one end of the rotor and the other end coupled to the high speed shaft of a speed reducer. The low speed shaft of the speed reducer is coupled thru one or two open gear trains, to drive the operating pinion along a rack. Whether the bridge is a rolling lift or a trunnion bascule, a vertical lift or a swing bridge, (See top half of Figures 1 thru 4) the high speed motor and speed reducer or high speed gear train could be replaced with a Low Speed High Torque (LSHT) hydraulic motor as shown in Figure 5. (Shown in detail as connected in Figure 1). The bridge could continue to be operated with the existing controls while the hydraulic power units and all the electrical controls are installed and checked out. New pinion E shafts could then be installed using the existing bearings. The LSHT hydraulic motors and the disc brakes are mounted on opposite ends of this shaft.

HYDRAULIC SYSTEM RETROFIT OF EXISTING BRIDGES

Each bridge to be reconditioned could be retrofitted with hydraulic drives - one drive to operate each rack pinion. Each hydraulic drive would be a combination hydraulic-mechanical system consisting of a Hydraulic Power Unit (HPU), low speed high torque (LSHT) fluid motor and a hydraulically operated brake. The LSHT motor would be coupled to one of the pinions of the existing open gear train, providing that the existing gearing is in satisfactory condition to justify being reused. Otherwise, suitable new gearing would have to be provided. At some bridges a speed reducer may have to also be provided if the existing open gearing does not have the required amount of gear reduction. If speed reducers are required, either LSHT motors or conventional High-Speed Low-Torque (HSLT) hydraulic motors could be used.

A detailed procedure for the replacement of each of the systems shown in Figures 1 thru 4 could be as follows:

Figure 1. The conversion procedure for each leaf of a Rolling Lift Bascule Bridge could be as follows:

<u>Step 1</u>. Deliver tested HPU's and LSHT hydraulic motors to the bridge when the new electrical controls have been installed and tested.

<u>Step 2</u>. Remove the existing machinery that has been cross-hatched on only one side of the centerline of the bridge. Continue to operate the bridge with the other half of the existing machinery.

<u>Step 3</u>. Install the new pinion E. with its bearings, LSHT hydraulic motor, machinery brake with half of adjacent coupling, and the HPU. Test new controls and operation of the bridge.

<u>Step 4</u>. Remove the existing speed reducer, gear couplings, motors, motor brakes, and the same equipment removed in Step 2 on the other side of the centerline.

<u>Step 5</u>. Complete installation of the new hydraulic equipment and test operation of the bridge with both HPU's and each HPU separately, one at a time.

Figure 2. The conversion procedure for each leaf of a Trunnion Bascule Bridge could be as follows:

<u>Step 1</u>. Deliver tested HPU's and LSHT hydraulic motors to the bridge when the new electrical controls have been installed and tested.

<u>Step 2</u>. Remove the existing machinery that has been corss-hatched on only one side of the moving leaf. Continue to operate the bridge with the machinery on the other side of the moving leaf.

<u>Step 3</u>. Install the new Pinion E with its bearings, LSHT hydraulic motor, machinery brake (or reinstall existing), and the HPU. Test new controls and operation of the bridge.

<u>Step 4</u>. Remove the same mechanical equipment on the other side of the bridge.

<u>Step 5</u>. Complete installation of the new hydraulic equipment and test operation of the equipment installed in this step and then both HPU's together.

Figure 3. The conversion procedure for each tower drive of vertical lift bridge or for a span drive vertical lift bridge could be as follows:

<u>Step 1</u>. Deliver tested HPU and LSHT hydraulic motors to the bridge when the new electrical controls have been installed and tested.

<u>Step 2</u>. Install the two new Pinions E with their bearings. Pinions E must remain free to rotate while existing equipment remains in use to operate the bridge. Continue to install the new LSHT hydraulic motors, machinery brakes, shaft at centerline of bridge with its bearings, and floating shafts with their couplings, always keeping pinion E free to rotate as stated above.

<u>Step 3</u>. Release existing motor and emergency brakes, and test new hydraulic controls and operation of the bridge.

<u>Step 4</u>. Remove the existing machinery that has been cross-hatched. This includes speed reducer, motors, motor brakes, gear couplings, machinery brakes. and Pinion E with their bearings.

Figure 4. The conversion proceudre for a swing bridge that has at least two drive pinions could be a follows:

<u>Step 1</u>. Delivery tested HPU's, LSHT hydraulic motors, and all other equipment needed for the conversion to the bridge when the new electrical controls have been installed and tested.

<u>Step 2</u>. Remove the existing machinery that has been cross hatched, namely beveled Pinion C, shaft c-d with its bearings, and the floating shaft with its couplings.

<u>Step 3</u>. Install the new beveled Pinion C on shaft c-d, with its bearings, machinery brake, LSHT hydraulic motor, and the HPU, but not the floating shaft. Test new controls anf operation of the bridge.

Step 4. Remove the existing speed reducer, motor, disc brake, beveled Pinion C, shaft c-d, bearings and coupling.

Step 5. Complete installation of the hydraulic equipment and test operation of this HPU. Install floating shaft and test both HPU together.

One LSHT motor would normally drive each Rack Pinion but one LSHT hydraulic motor could drive two rack pinions if necessary. One hydraulically operated brake would be provided as a parking (machinery) brake for each Rack Pinion. Motor brakes would not be needed because each hydraulic drive would provide dynamic-regenerative braking action during leaf deceleration. The parking brakes would be set after the bridge comes to rest to hold against maximum wind loads or they can be used as emergency stopping brakes, if necessary, to bring the bridge to a stop faster than dynamic- regenerative braking action can provide. During normal operation the result would be much lower shock loads on the machinery and structure.

Controls for the hydraulic system would be solid-state proportional electro-hydraulic servo valve type control. The controls would provide pre-set rate of acceleration and deceleration of the movable span. The existing control console could be modified to provide for either automatic operation (using pushbuttons) and/or manual operation (using the existing master switch(es) or existing drum controller(s) replaced by new master switch(es)). The minor modifications required at the existing operator's console at each bridge could most likely be done in place at the bridge, to accommodate the hydraulic control systems. Motor controls would have to be modified or replaced, depending on their type and condition, to operate the electric motors which drive the pumps of the hydraulic power units.

The new motor starters would be simpler and less expensive than replacing the existing because the new electric motors would be NEMA B Squirrel Cage type AC motors requiring only one direction of rotation. The hydraulic circuitry would provide the necessary fluid flow direction to open or close the movable span(s).

The cost to retrofit a bridge with hydraulic drive would vary depending on the size of the bridge and the amount of work which may be required at the bridge.

DEVELOPMENT OF THE HYDRAULIC CIRCUIT

The complete hydraulic circuit for one Hydraulic Power Unit (HPU) including the Low-Speed High-Torque (LSHT) hydraulic motor and the mechanically applied-hydraulically released brake is shown in Figure 6. There would normally be two sets of Operating Machinery with their HPU for each bascule leaf, each vertical lift tower drive, each span drive vertical lift, or each swing span. In the event of a malfunction in any portion of one of the two HPU's the blocking valve (Key No. 19) and the free wheeling valve (Key No. 23) (described here-in-after) are deactivated allowing the hydraulic motor to rotate with the gear train while the other power unit does the driving.

A "Key to Hydraulic Equipment" with the quantity of each item required for one Hydraulic Power Unit (HPU) is given.

The hydraulic circuit is developed as equipment is added in sequenced numbered steps within the corresponding numbered areas. The areas are formed by the limits indicated horizontally and vertically by the area numbers.

TWO AREAS 1. Basic Hydraulic Closed Loop Circuit with a variable volume piston pump driven by a 1800 RPM synchronous electric motor. The swash plate can be varied in both directions to reverse the flow in the closed loop circuit. The hydraulic motor which drives a portion of the movable bridge will turn in either direction at the speed determined by the volume of flow of hydraulic fluid from the pump. When a movable brdige exerts an overhauling force (due to a wind load and/or out of balance load) that tries to drive the movable bridge faster will cause the hydraulic motor to act as a hydraulic pump. The oil will be forced through the piston pump which in turn will act as a hydraulic motor and drive the electric motor faster than synchronous speed. At speeds greater than synchronous speed, the motor will act as a generator which will supply power back into the electrical power source. The restraining force of the electric motor will vary with the magnitude of the speed above synchronous speed. This is called regenerative braking.

TWO AREAS 2. To make up for lost hydraulic fluid in the closed loop circuit a constant volume <u>Charge Pump</u> is provided that will provide hydraulic fluid which will maintain a minimum pressure in the loop. The Charge Pump is provided with an intake filter to insure that "Clean Fluid" is always introduced into the closed loop circuit.

AREA 3. Filters have been added on each side of the loop that will filter the circulating oil before it enters the hydraulic pump. The higher pressure fluid leaving the pump will by-pass the filter which is only a one direction unit.

AREA 4. Crossover relief valves are placed across the hydraulic motor. The machinery must be capable of operating under the torque that will need to be developed to cause the relief valves to limit the pressure differential across the LSHM Hydraulic Motor to their setting. A third relief valve is across the loop in the direction needed to "Wind-UP" the machinery while the brakes are set. This relief valve is set approximately 60% lower than the other two valves. This is done in order to reduct the torque that is applied to the machinery during "Wind-Up" when there is no need to apply maximum torque.

FIVE AREAS 5. The speed controls are broken down into five parts as follows:

AREA 5-1. The speed control signals are sent directly to the servo control unit adjacent to the variable piston pump.

AREA 5-2. Filters are provide for fluid going to the servo controls because they are very sensative to contamination.

AREA 5-3. An addition constant volumn control pump to provide a higher pressure for more accurate servo control.

AREA 5-4. The servo pressure pump is also provided with an intake filter to protect small volume pump.

AREA 5-5. The servo output is delivered to the swash plate control on the variable piston pump.

AREA 6. There are times when the LSHT hydraulic motor should be able to rotate without hydraulic pressure being applied to motor. This is accomplished by placing a two position flow control valve across the LSHT hydraulic motor. The pressure that is needed in the LSHT hydraulic motor during rotation is supplied from the HPU that is driving the span.

AREA 7. The swash plate has been mechanically set to a creep speed setting in the Raise Direction. The speed of the bridge will be constant at a creep speed when the electric motor is started from the control console. A low voltage starter is being used to reduce the in-rush of current to the motor since it is being started under load. The change in direction is accomplished with the use of a three-way valve. Energizing the solenoid on one end of the spool will "open" the movable bridge and energizing the solenoid on the other end will "close" the movable bridge. When neither end is energized the spool is centered by the spring and completes the loop on the pump side so that the fluid can continue to circulate through the pump. The hydraulic motor side is blocked to apply the "hydraulic brakes" at the value of the crossover pressure relief valves.

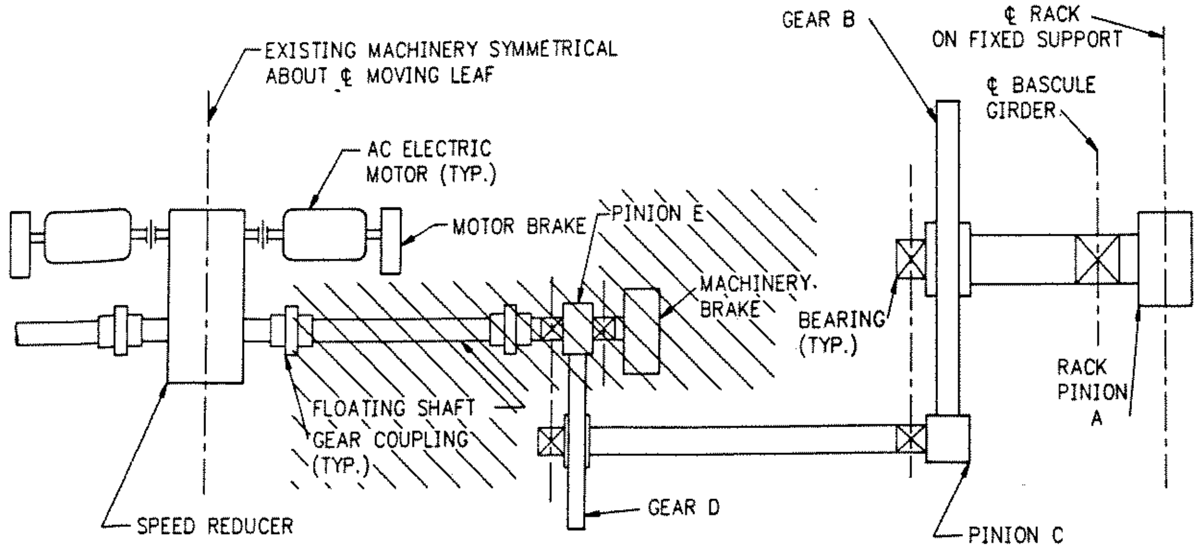
FOUR AREAS 8. A drain is provided form the LSHT Hydraulic Motor case back to the reservoir to return any fluid that passes thru the seals as the motor is operated. With LSHT hydraulic motors that have a large case volume it may improve speed control during a complete range in ambient temperatures if the fluid is circulated thru the casing in advance of operating the bridge. Some hydraulic motors need cooling especially when the electric motor is kept energized and fluid is pumped over the charge pump relief valve by means of circulating oil through the outer casing of the LSHT hydraulic motors.

THREE AREAS 9. Accessories are provided at each hydraulic power unit to provide interlocks in the electric motor control circuit and warnings given to the bridge operator, via the warning indicating lights.

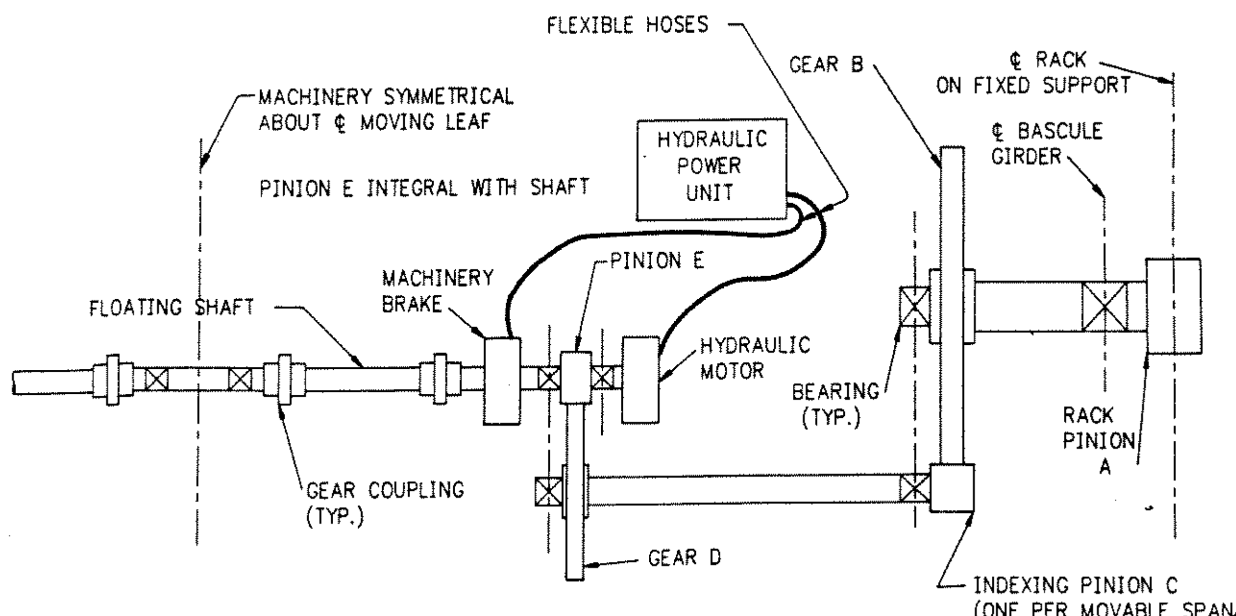
AREA 10. If the pressure in the LSHT hydraulic motor portion of the loop drops below the setting of the "Low System Pressure" Switch, due to leakage in the loop, such as a broken hose, the brakes will set.

AREA 11. The hydraulic fluid (from the servo pressure pump) is used to release the brakes. The control circuit is shown in AREA 11.

TWO AREAS 12. When two HPU's are on the same movable span or are on the substructure unit that supports the movable span, more redundance could be obtained by providing cross-over lines between the two units. One is shown between the two reservoirs. Since there is very little difference between their fluid levels to equalize by gravity, it may be necessary to provide a reverseable motor and fixed displacement pump. An "Overflow Prevention" switch will turn the pump ON and a "Reservoirs Equalized" switch will turn the pump OFF.

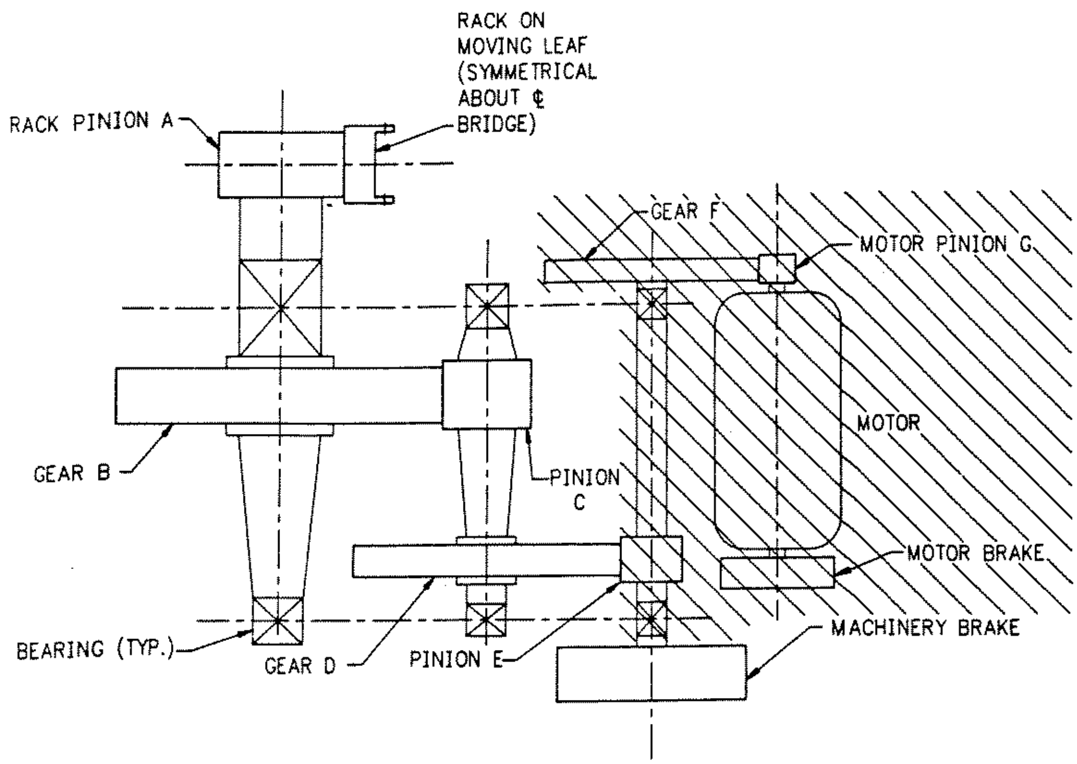


EXISTING
ROLLING LIFT BASCULE BRIDGE DRIVE
MACHINERY IS ON MOVING LEAF

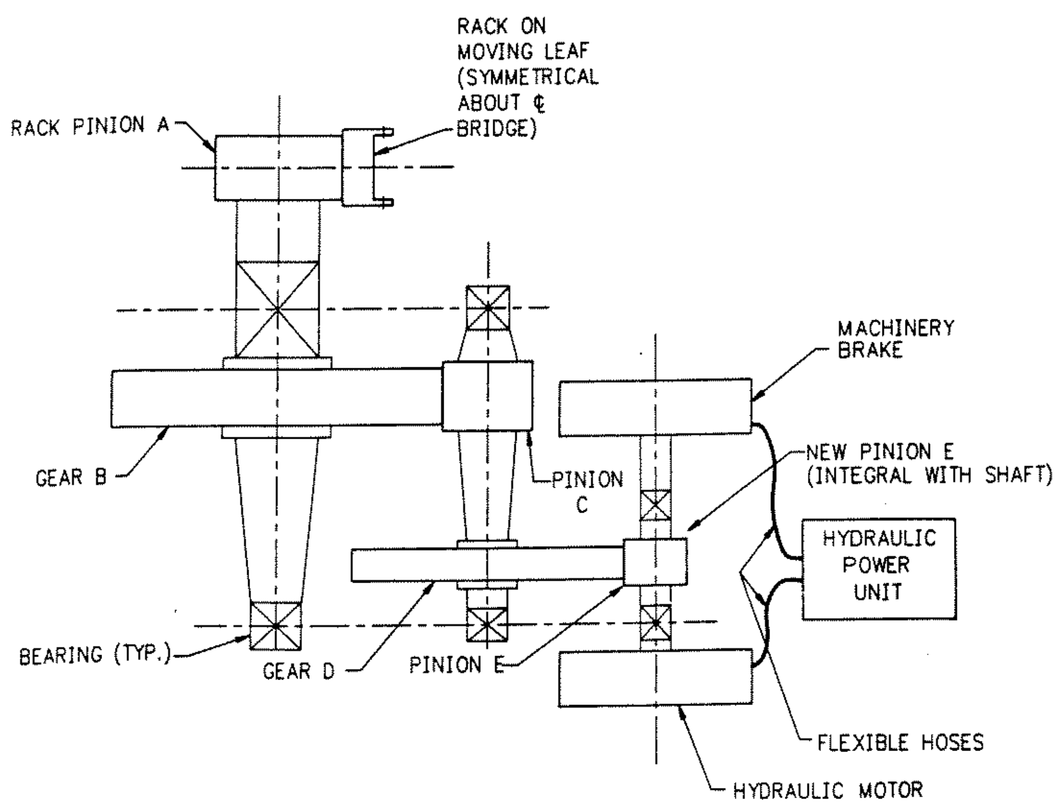


REHABILITATED
ROLLING LIFT BASCULE BRIDGE DRIVE
MACHINERY IS ON MOVING LEAF

FIGURE 1

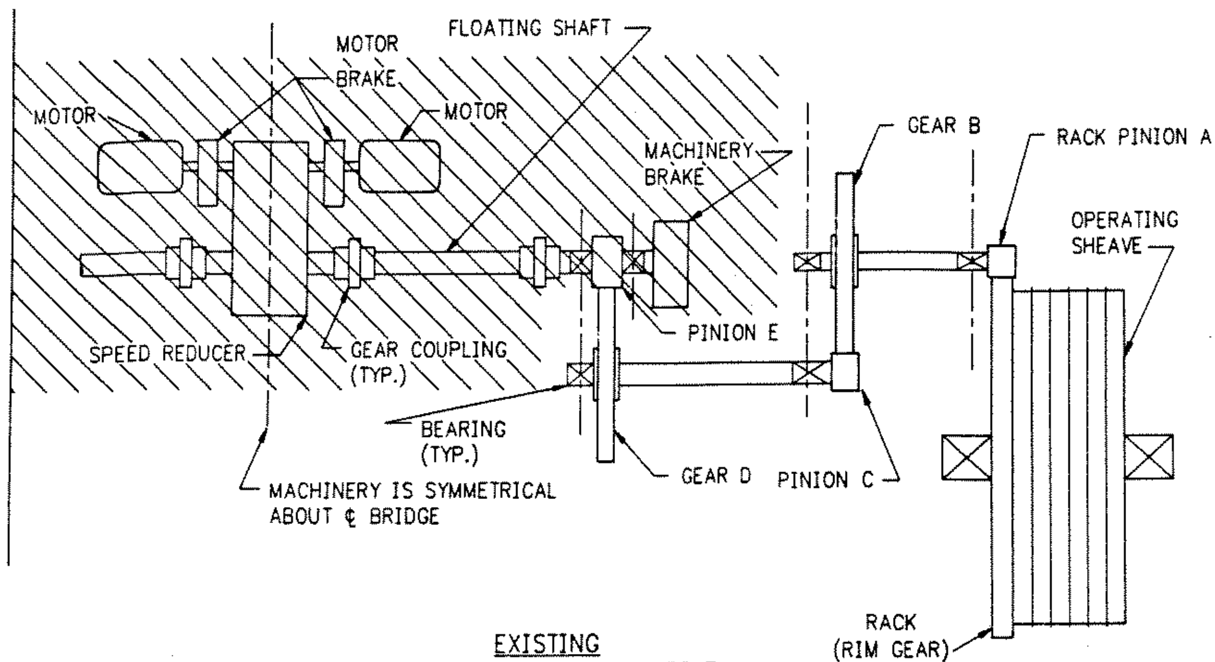


EXISTING
TRUNNION BASCULE BRIDGE DRIVE
MACHINERY IS ON THE PIER

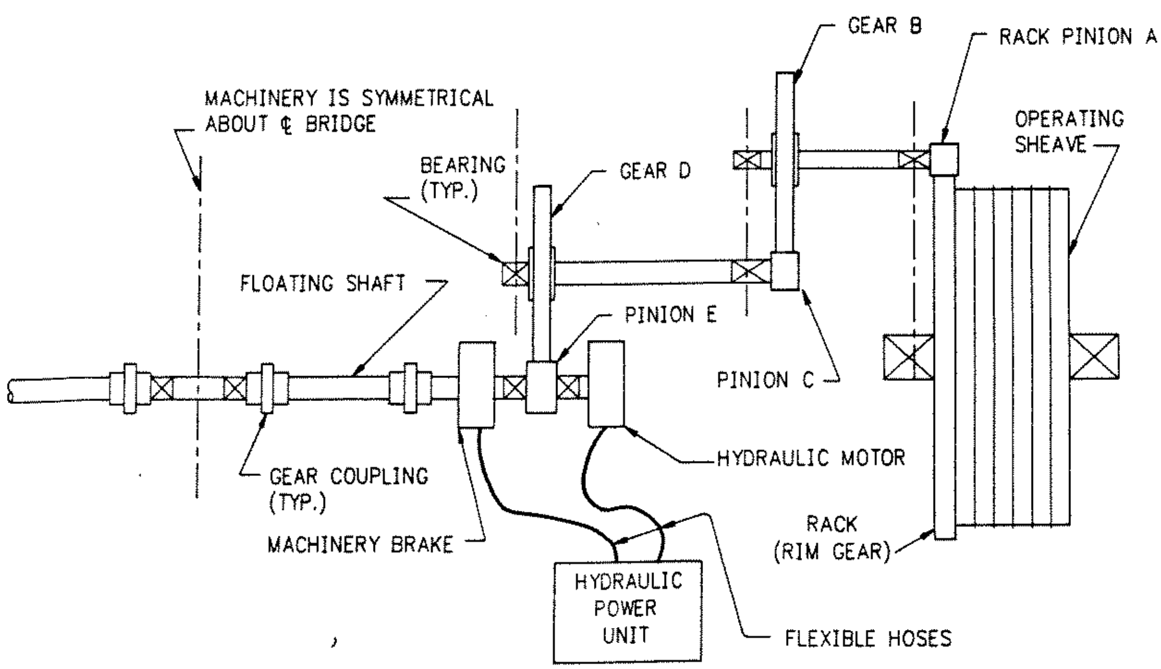


REHABILITATED
TRUNNION BASCULE BRIDGE DRIVE
MACHINERY IS ON THE PIER

FIGURE 2

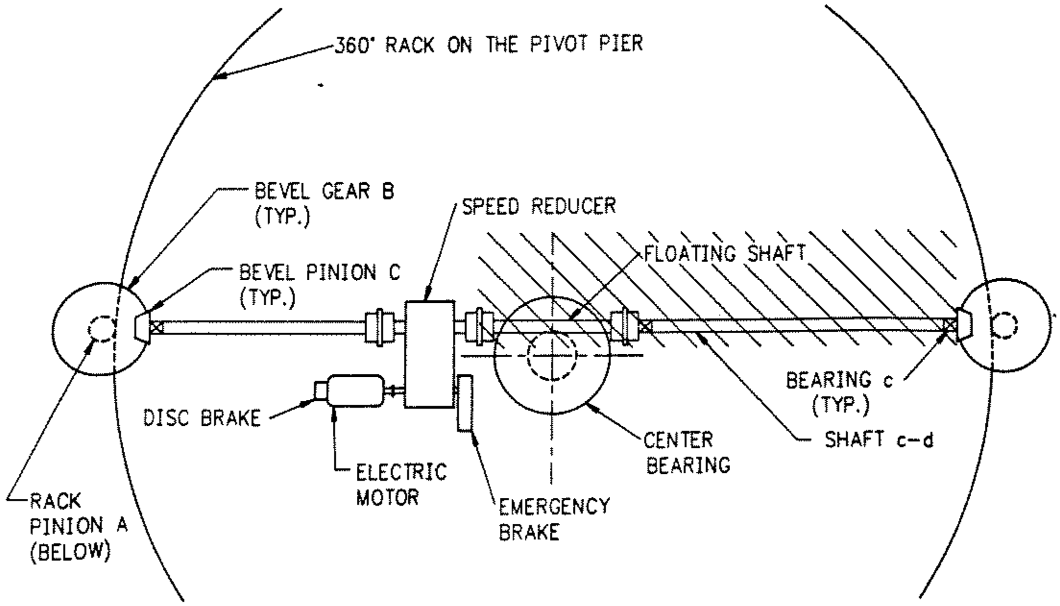


EXISTING
VERTICAL LIFT BRIDGE DRIVE
MACHINERY IS IN THE TOWER

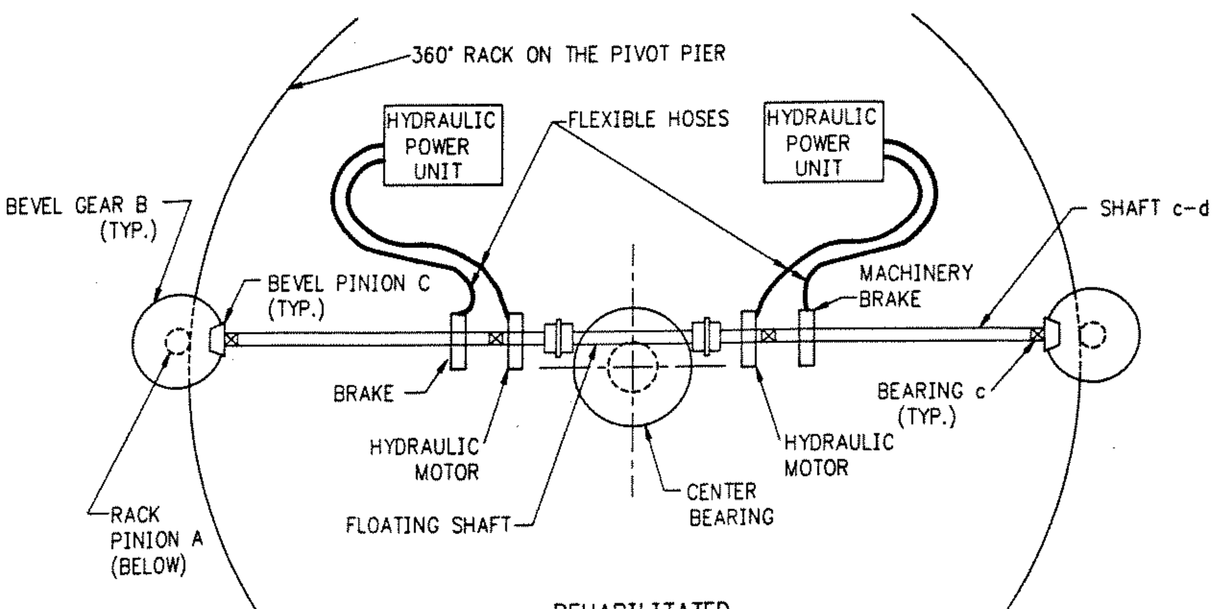


REHABILTATED
VERTICAL LIFT BRIDGE DRIVE
MACHINERY IS IN THE TOWER

FIGURE 3

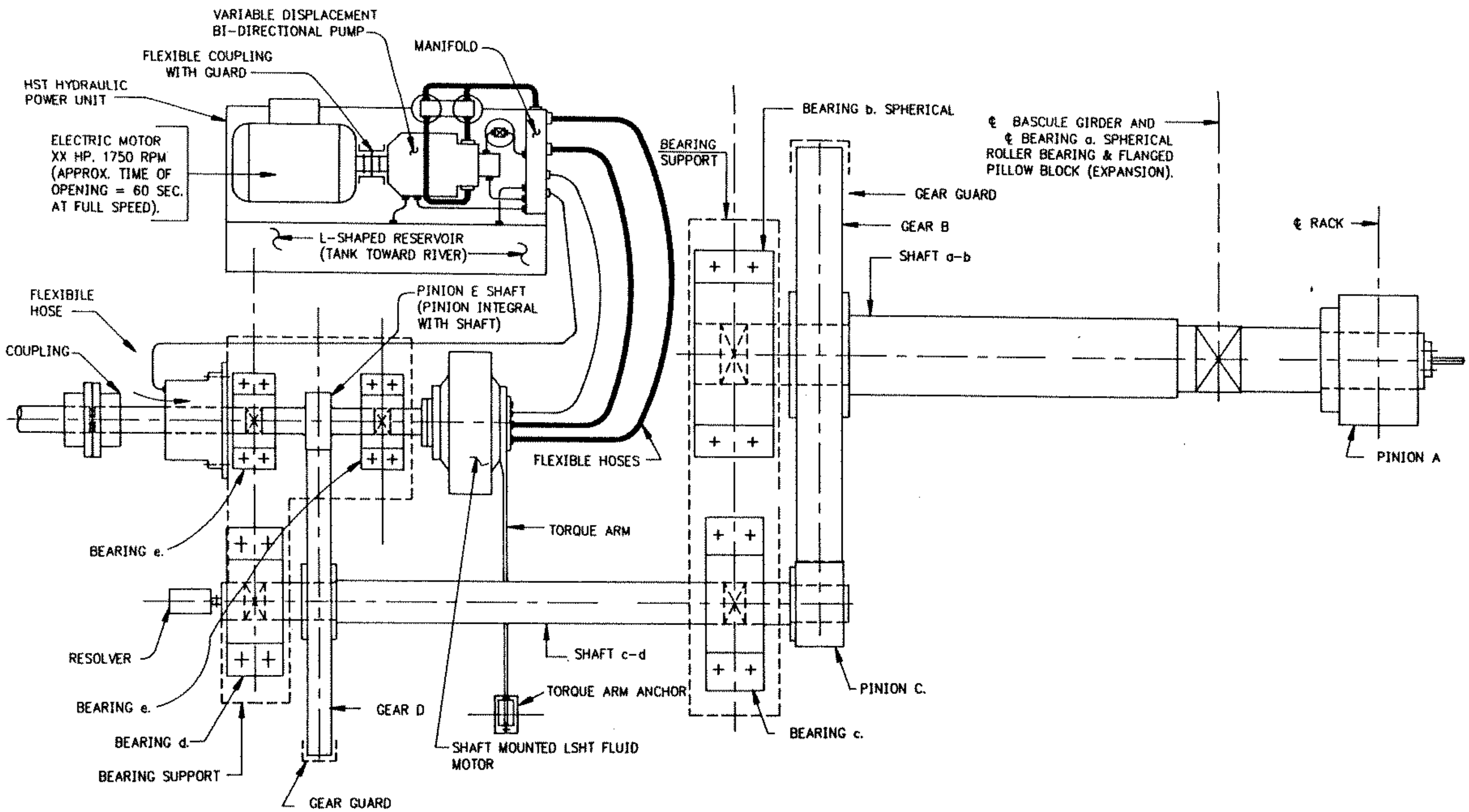


<u>EXISTING</u>
<u>SWING BRIDGE DRIVE</u>
<u>MACHINERY ON THE SWING SPAN</u>



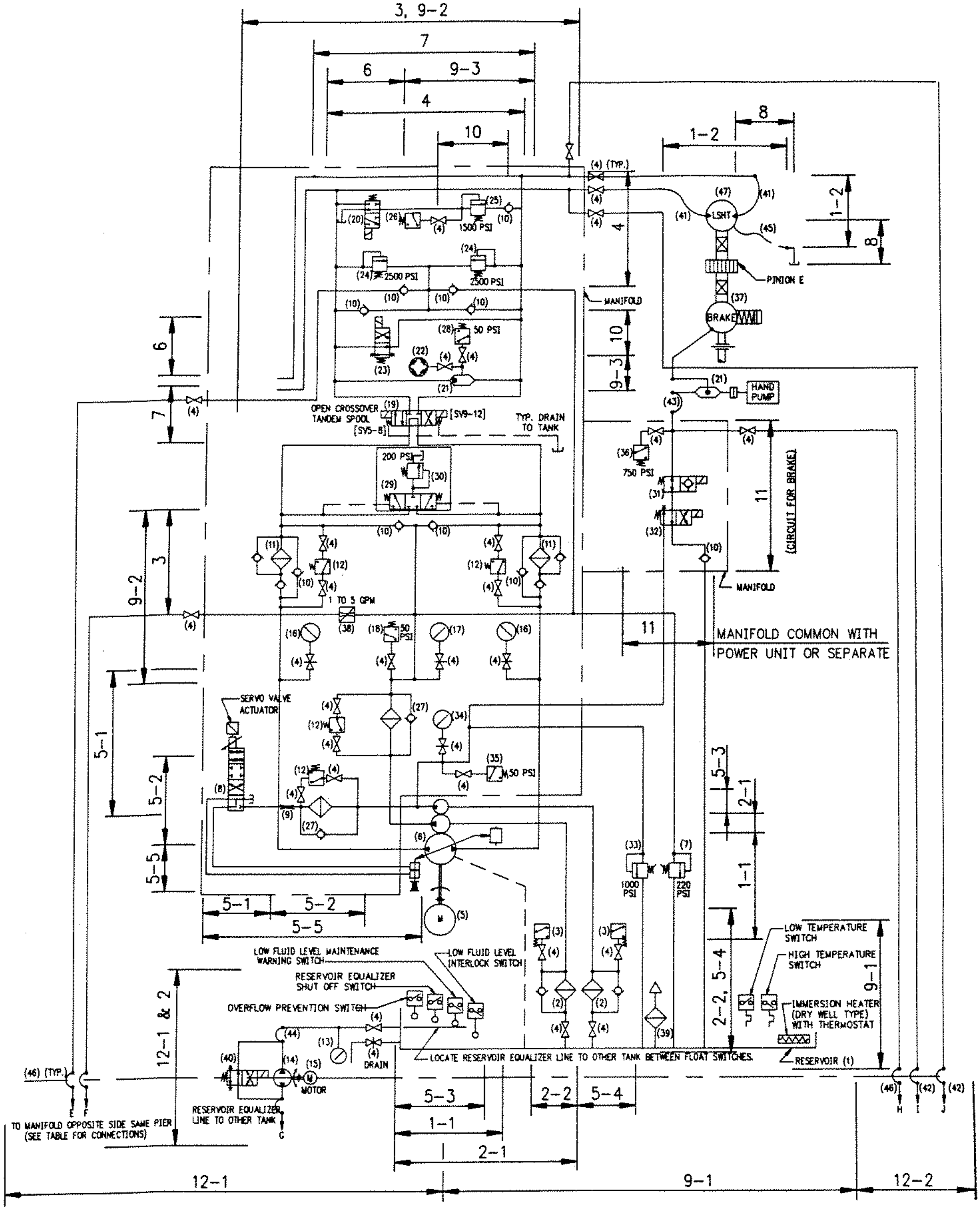
<u>REHABILITATED</u>
<u>SWING BRIDGE DRIVE</u>
<u>MACHINERY ON THE SWING SPAN</u>

FIGURE 4



PLAN OF OPERATING MACHINERY
DRIVEN BY LSHT HYDRAULIC MOTOR

FIGURE 5



CONNECTIONS BETWEEN OPPOSITE UNITS

LINE SHOWN THIS MANIFOLD	E	F	G	H	I	J
CONNECT TO MANIFOLD OTHER SIDE OF ℄ BRIDGE	F	E	G	H	J	I

HYDRAULIC CIRCUIT FOR ONE HYDRAULIC POWER UNIT (HPU)

NOTE: SEE KEY TO HYDRAULIC EQUIPMENT

SYMPOSUM\HY-CIRCT

"REPLACE ELECTRICAL TORQUE CONTROL DRIVE SYSTEM WITH AN AUTOMATIC HYDRAULIC SPEED CONTROL SYSTEM"
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"KEY TO HYDRAULIC EQUIPMENT"

KEY	QTY.	DESCRIPTION
(1)	1	RESERVOIR WITH ACCESSORIES
(2)	2	CHARGE OR CONTROL SUCTION LINE FILTER W/BYPASS
(3)	2	CHARGE OR CONTROL VACUUM SWITCH
(4)	29	SHUT-OFF VALVE (INCLUDES ALL SIZES)
(5)	1	ELECTRIC MOTOR
(6)	1	VARIABLE DISPLACEMENT PUMP WITH INTERNAL CHARGE & CONTROL FIXED DISPLACEMENT PUMPS
(7)	1	CHARGE PRESSURE RELIEF VALVE
(8)	1	ELECTRICALLY OPERATED SERVO VALVE
(9)	1	FLOW CONTROL VALVE (CONTROLS FLOW TO SERVO VALVE)
(10)	11	CHECK VALVE (INCLUDES ALL SIZES AND SETTINGS)
(11)	2	RETURN LINE FILTER W/PRESSURE FREE FLOW
(12)	4	DIFFERENTIAL PRESSURE SWITCH (FILTER SERVICE NEEDED)
(13)	1	RESERVOIR EQUALIZER PRESSURE GAUGE
(14)	1	BI-DIRECTIONAL GEAR PUMP (RESERVOIR EQUALIZER - 1 FOR 2 HPU's)
(15)	1	ELECTRIC MOTOR (RESERVOIR EQUALIZER - 1 FOR 2 HPU's)
(16)	2	HIGH PRESSURE GAUGE
(17)	1	CHARGE PRESSURE GAUGE
(18)	1	CHARGE PUMP PRESSURE SWITCH
(19)	1	DIRECTIONAL CONTROL VALVE (3-POS./4-WAY) (BLOCKING VALVE)
(20)	1	DIRECTIONAL CONTROL VALVE (2-POS./4-WAY) (WIND-UP REDUCED PRESSURE)
(21)	2	SHUTTLE VALVE
(22)	1	PRESSURE TRANSDUCER (HIGH SYSTEM PRESSURE)
(23)	1	DIRECTIONAL CONTROL VALVE (2-POS./4-WAY) (FREE WHEELING VALVE)
(24)	2	HIGH PRESSURE RELIEF VALVE (MAXIMUM SYSTEM PRESSURE)
(25)	1	WIND-UP PRESSURE RELIEF VALVE
(26)	1	WIND-UP PRESSURE SWITCH
(27)	2	CHARGE OR SERVO VALVE FILTER W/BYPASS
(28)	1	LOW SYSTEM PRESSURE SWITCH
(29)	1	DIRECTIONAL CONTROL VALVE (3-POS./3-WAY) (PILOT OPERATED)
(30)	1	PRESSURE RELIEF VALVE (MIN PRESSURE IN RETURN TO PUMP)
(31)	1	DIRECTIONAL CONTROL VALVE (2-POS. /2-WAY, ONE WITH CHECK VALVE)
(32)	1	DIRECTIONAL CONTROL VALVE (2-POS. /4-WAY) (BRAKE CONTROL)
(33)	1	CONTROL PRESSURE RELIEF VALVE
(34)	1	CONTROL PRESSURE GAUGE
(35)	1	CONTROL PUMP PRESSURE SWITCH
(36)	1	BRAKE RELEASE PRESSURE SWITCH
(37)	1	EMERGENCY BRAKE
(38)	1	FLOW CONTROL VALVE (PRESSURE COMPENSATED)
(39)	1	FILTER (FOR ADDING FLUID TO RESERVOIR) W/CAP
(40)	1	DIRECTIONAL CONTROL VALVE (RESERVOIR EQUALIZER - 1 FOR 2 HPU's)
(41)	2	1.50" I.D. 5000 PSI W.P. FLEXIBLE HOSE (HIGH PRESSURE)
(42)	2	0.75" I.D. 5000 PSI W.P. FLEXIBLE HOSE (CROSS-OVER HIGH PRESSURE)
(43)	1	0.25" I.D. 2000 PSI W.P. FLEXIBLE HOSE (BRAKE RELEASE CIRCUIT)
(44)	1	1.00" I.D. 2000 PSI W.P. FLEXIBLE HOSE (RESERVOID EQUALIZER)
(45)	1	0.75" I.D. 2000 PSI W.P. FLEXIBLE HOSE (LSHT HYD. MOTOR CASE DRAIN)
(46)	3	0.25" I.D. 2000 PSI W.P. FLEXIBLE HOSE (CROSS-OVER BRAKE RELEASE & CHARGE PRESSURE)
(47)	1	LOW SPEED HIGH TORQUE (LSHT) HYDRAULIC MOTOR

NOTES:

1. ELECTRICAL SOLENOIDS ARE NOT NUMBERED
2. EQUIPMENT WITH SAME OR DIFFERENT NUMBER MUST HAVE SIZE AND/OR SETTING SELECTED BY FUNCTION IN HYDRAULIC CIRCUIT.