Heavy Movable Structures, Inc.

SEVENTH BIENNIAL SYMPOSIUM

November 4 - 6, 1998

Grosvenor Resort
Walt Disney World Village
Lake Buena Vista, Florida

"Hydraulic System for a Large Movable Bridge"

by

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Hydraulic System for a Large Moveable Bridge

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ABSTRACT

The design of a hydraulic system for a large bascule bridge with regards to efficiency, low initial cost and versatiltiy is explored. The specific system includes four (4) cylinders which require flows greater than 350 gpm. The output flow of the hydraulic pumps is regulated by means of an electrically operated proportional valve in order to conserve the horsepower required. Bridge movement is controlled with the use of logic valves in a meter - out circuit.

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Hydraulic System for a Large Moveable Bridge

The Donald Ross Road Bridge which crosses over the Intercoastal Waterway in Palm Beach County, Florida features a "Rolling Lift" design to best accommodate a span length of 140 feet. Because of the benefits gained, both for the initial construction and throughout its lifetime, a hydraulic drive was selected to facilitate bridge operation. The hydraulic system provides low initial cost, versatility, and safety features such as inherent redundancies. In addition, due to the large size of this bridge, special considerations were made to optimize the hydraulic system's efficiency. (See Figure 1).

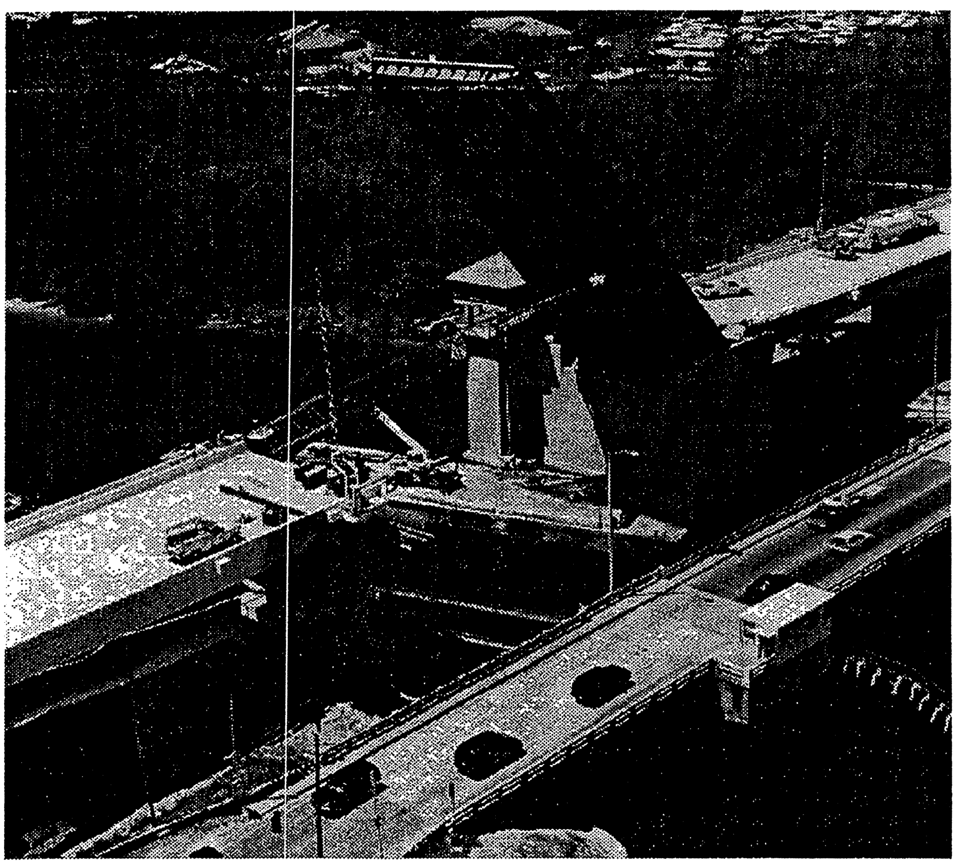

Figure 1

LOW INITIAL COST

A hydraulic drive system offers lower initial costs than a mechanical drive. A hydraulic power unit is a customized arrangement of standard "off-the-shelf" components. Since no one item requires a special design, both the total cost is decreased, and spare parts are readily available. Even the hydraulic cylinders are a standard design with only a customized stroke length. The flexibility of the hydraulic system's layout results in an overall lower initial cost during installation. Power transmission is achieved with pressurized oil. Consequently, there is almost no restriction in the location of the hydraulic power unit in relation to the cylinders. As you can see in the figure 2 below, the hydraulic power unit is located approximately 30 feet away, above the cylinders. Piping from the reservoir is brought through the floor and connected to the cylinders with hoses. Because no rigid connection is required, alignment issues during construction are greatly simplified.

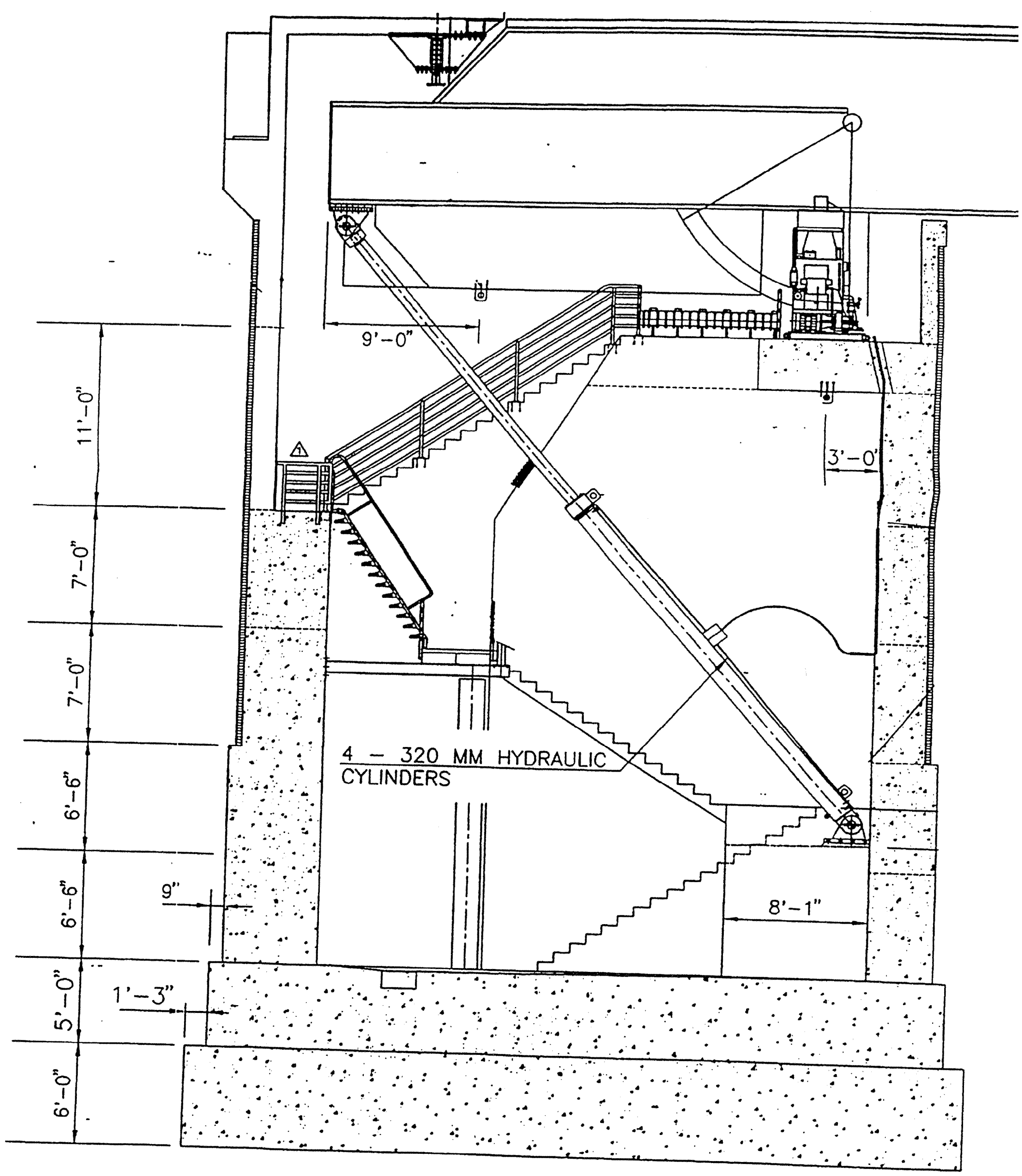

Figure 2

FLEXIBILITY OF LAYOUT

Flexibility extends to the design of the hydraulic power unit since individual items can be arranged to best suite the exact mounting location. For example, the termination ports of the manifold can be made from the most convenient side. All items such as filters or manual valves which require adjustment or replacement are mounted at the most accessible locations. Moreover, the layout can be almost any shape to conform to space restrictions. (Figures 3 and 4).

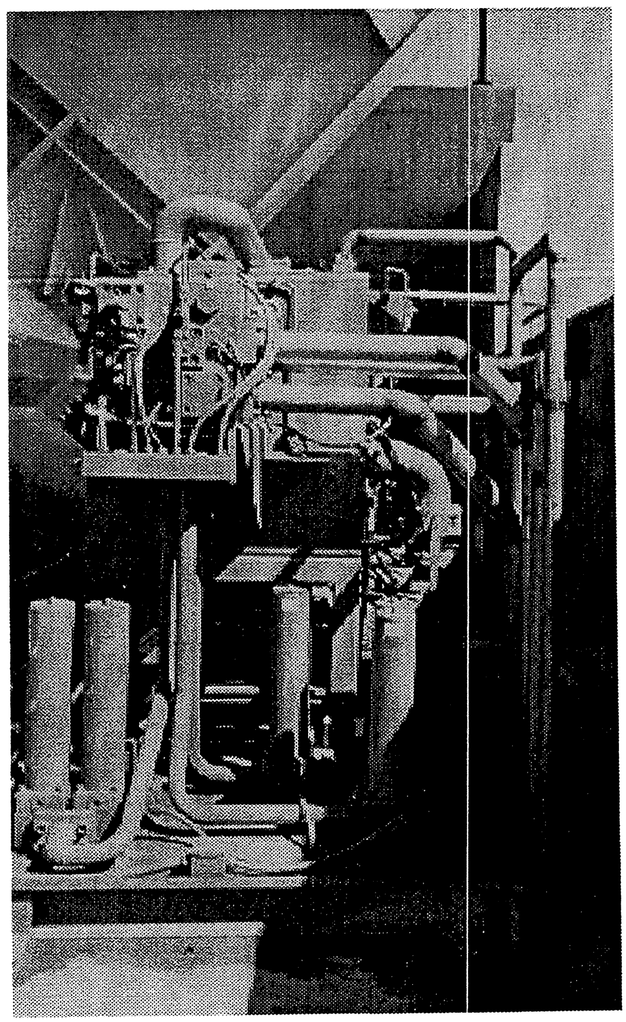

Figure 3

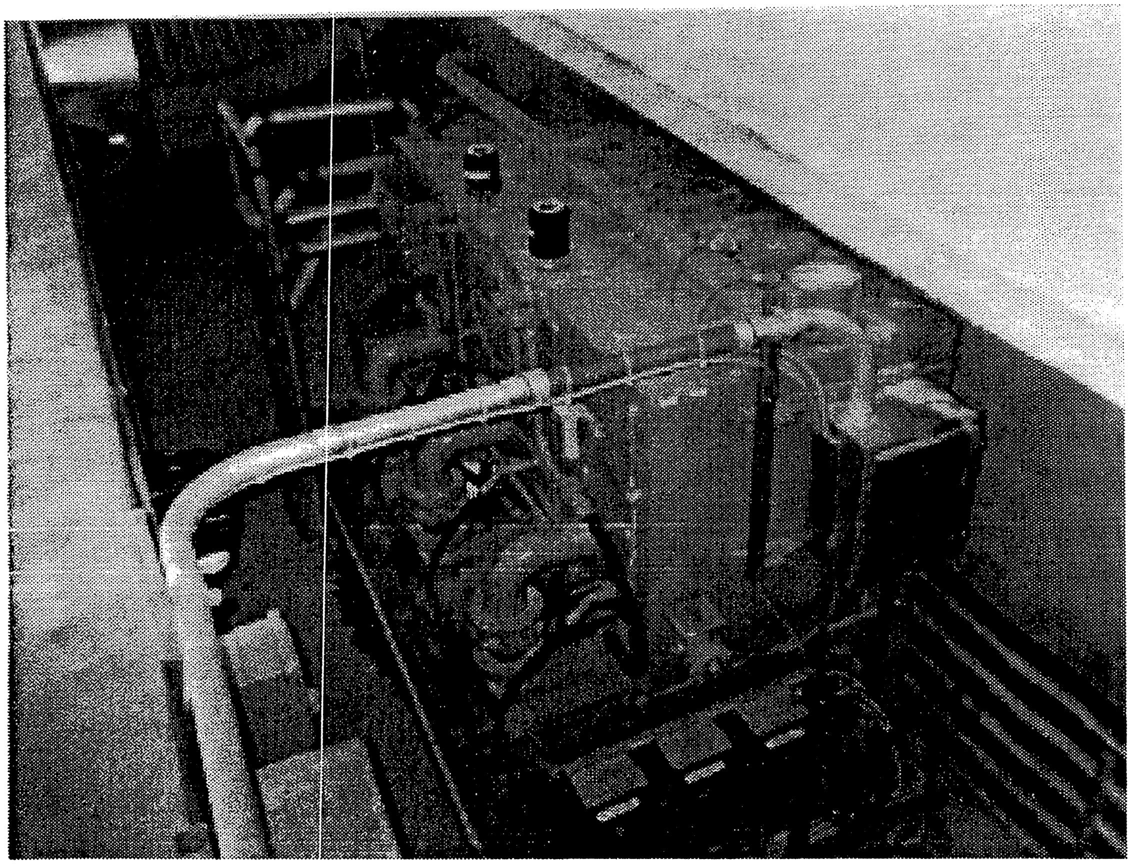

Figure 4

EFFICIENCY

The primary motivating factor in the hydraulic circuit design was the optimization of overall efficiency. In general, efficiency implies that the power introduced into the system is used for work and not dissipated as heat. With hydraulics, horsepower is directly proportional to the product of the flow rate and the system pressure. In this system, efficiency is increased with the use of electronically controlled variable displacement pumps and electronic counterbalancing.

ELECTRONICALLY CONTROLLED VARIABLE DISPLACEMENT PUMPS

The flow rate required to move the bridge is not constant . For example, due to the differential area of the cylinders, the flow needed to raise the bridge is about 20% less than the flow required for descent. Variance in the external operating conditions, such as wind speed and temperature, also change the flow requirements. Although, the pump is sized for the maximum flow, the actual flow is regulated by an electronically operated proportional directional valve which is mounted on the pump. For a given speed of the bridge, the software commands the pump to deliver the appropriate flow rate. The software is then able to automatically adjust the command signal to the pump to accommodate any changes in the external forces. By only providing the flow needed, little oil will be passed over the relief valve, and horsepower is conserved. Furthermore, with the use of electronically controlled variable pumps, pressure spikes are not created when the bridge first begins to open or close.

PROPORTIONAL FLOW CONTROL VALVES FOR COUNTERBALANCING

When raising or lowering the bridge it is imperative for the hydraulic system to maintain control and not be overridden by forces such as wind or gravity. Counterbalancing ensures this control. For example, when the bridge is lowered, oil from the pumps flows into the bore end of the cylinder and the oil in the rod end is diverted back to tank. If nothing existed in the hydraulic system to prevent the oil from freely flowing back to the reservoir, the bridge would "run-away " under its own weight. With counterbalancing, a minimum pressure is sustained on the tahk side of the actuator.

Although it is possible to use mechanical / hydraulic "traditional" counter-balance valves, a proportional flow control valve was selected to enhance efficiency. Like a standard counterbalance valve, an electronic flow control valve throttles the oil flowing back to tank. Due to the large flows necessary to move this bridge, the use of stnadard counter-balance valves would create high pressure drops. Control would be maintained, however horsepower would be wasted.

A proportional logic cartridge valve is used in combination with two pressure transmitters. Flow is controlled by a proportional solenoid which strokes the main spool to regulate the opening between ports A and B. The pressure transmitters sense the pressure of the oil both entering and leaving the cylinders. For example, when the bridge begins to open, oil flows to the rod end of the cylinder and pressure increases due to the load. Meanwhile, the flow control valve is open, allowing oil to exit the cylinder with minimum restriction. If during the cycle, wind creates a force which helps to push the bridge open, the load is decreased and the pressure of the oil flowing to the cylinder is reduced. A signal is then sent to the flow control valve to start to close in order to create a larger backpressure on the cylinder's bore end. The resulting force counteracts the wind load and prevents the bridge from accelerating. The software continually modulates the flow control valve during the entire cycle so that the bridge speed remains constant.

SAFETY FEATURES

The hydraulic system design for The Donald Ross Bridge incorporates various safety features.

1. Pilot operated check valves lock the bridge in position in the event of power loss during operation.
2. The bridge can be moved with only one of the three motor pump groups in operation.
3. The bridge can be moved with only one of the four hydraulic cylinders operational.
4. The bridge can be lowered in the absence of power.
5. Automatic closure of the proportional flow control valve in the event of power failure or cable breakage.

CONCLUSION

Because a hydraulic drive provides low initial cost, versatility, and various safety features, it was the chosen method to control bridge operation. Since The Donald Ross Bridge is one of the largest bridges on the east coast, its hydraulic system was the first opportunity to utilize large pumps and cylinders. Three axial piston pumps, AA10VSO500, each delivered 120 gpm to cylinders with a 12.5" dia bore, 8" dia rod and 20 foot stroke. Although the pumps are rated for a normal operating pressure of over 5000 psi, the hydraulic system's requirement of significantly lower operating pressures will result in extended life. The system's life is also extended with the use of Ceremax coating on the cylinder rod, and the fabrication of both the hydraulic reservoir and the piping of stainless steel. As an added precaution, environmentally friendly hydraulic fluid was specified. Furthermore, the normal maintenance is limited to visual inspection of the oil level and quality.