

STATE OF THE ART HYDRAULIC SYSTEMS

For Movable Bridges

BY

W. C. Adams, Vice President
ADAMS AIR & HYDRAULICS, INC.
7209 East Adamo Drive
Tampa, Florida 33619

&

John Ferguson, Sales Manager
HAGGLUNDS DENISON CORPORATION
12777 Jones Road, Suite 175
Houston, Texas 77070

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I. HISTORY OF HYDRAULICS:

Hydraulics date back to the pyramids and Egyptians. This means of power transmission became popular during World War II, when it was mass produced for the military. This paper deals with modern, state of the art hydraulics specifically for movable bridges.

II. EVERYDAY USE OF HYDRAULICS WE ARE ALL FAMILIAR WITH:

Hydraulic brakes on automobiles and other vehicles were at one time completely mechanical. These systems were changed over to hydraulics in the '30's. Hydraulics are more flexible and much more reliable. Then came hydraulic steering which is more popular today than anytime in history. It is safe to say that all in attendance here today have hydraulic steering and brakes on their automobiles. Every modern jetliner today depends on hydraulics, for their flight control, steering, brakes, and landing gear. The entire space program is dependent upon this technology of hydraulics, commonly referred to as fluid power.

III. MOVABLE BRIDGES:

When contemplating the very size of a movable bridge, one would note at the outset that there exists a requirement for smooth precise controllability. This as well as other parameters of their operation is very easily accomplished by fluid power systems. Most all engineering projects, that depend on extreme reliability, have specified hydraulic drives for the past fifty or so years.

The parameters for most movable bridges, easily accomplished with fluid power systems are:

- (a) Smooth and accurate acceleration and deceleration;
- (b) Positive locking in any position;
- (c) Driving endlocks or pins;
- (d) Capable of handling variable loading (wind, ice, etc.)

An inherent advantage in hydraulic systems, that can be advantageous to the design engineer, is that system components have an excellent power to weight ratio. Compared to electro mechanical components, they are smaller, lighter, easier to service, and in general are standard stock items available most anywhere.

Most common means of powering movable bridges with fluid power are:

- (a) Hydraulic cylinder(s) = linear motion;
- (b) Hydraulic motor(s) = rotary motion

Either means has its own unique features and both can be depended upon to deliver about the same degree of reliability and accuracy. The very function of the bridge itself will indicate which system you should select. Either system can be designed so that it is impervious to its environment.

The retrofit of aged bridges with mechanical drives to modern state of the art hydraulic operation is the shortest route to life extension of the installation, and the installed cost is much lower than purchasing replacements for older mechanical drives in most cases. Most retrofits become permanent installations, once the operator has experienced the controllability. As stated earlier, the high power to weight ratio of fluid power systems can, in some cases, allow the installation to be made along side existing mechanical systems, for increased serviceability or to add to the redundancy of the overall system.

IV. HYDRAULIC MOTORS:

If a drive is under consideration for a new or retrofit application, one must consider the drive shaft or pinion torque or horsepower. Here we are dealing primarily with shaft torque. Hydraulic motors that are available today fall into three basic categories:

- (a) High speed/low torque = 500 - 3600 R.P.M. (Will in most cases require a speed reducer.)
- (b) Low speed/high torque = 10 - 500 R.P.M. (Develops seven to nine power strokes per revolution and may require a speed reducer.)
- (c) Low speed/high torque = 0 - 50 R.P.M. (Develops up to one hundred twenty power strokes per revolution and will not require a speed reducer.)

It should be noted that on retrofit bridge applications a smaller motor may possibly be applied to existing gearing. If this is the option, in most cases it may be possible to reduce input horsepower by approximately 20% due to the high starting torque characteristic of high torque/low speed motors as mentioned in (c) above.

V. HYDRAULIC CYLINDERS:

The application of hydraulic cylinders to operate movable bridges has been the most widely acceptable to date. Be it lift, swing type, or bascule design, cylinders can easily be installed on both old and new bridges. Two cylinders per span are normally required; however, any number is possible.

There are basically two types of cylinders available for movable bridges, welded and tie rod design. There is a wide variety of mounting styles. Most common are spherical bearing clevis, both ends and intermediate trunnion. The tie rod designs are inexpensive and are used in many different industry applications because, regardless of manufacturer, they are all dimensionally interchangeable.

The welded type hydraulic cylinder is so constructed that it can be serviced in place even after years of exposure, and generally, stainless steel piston rods are standard whereas the tie rod design most often requires that you order stainless steel piston rods specifically as most manufacturers do not offer stainless steel rods as standard. For civil engineering projects stainless steel, chrome plated piston rods are the optimum.

VI. PROPORTIONAL VALVES:

Controlled acceleration and deceleration are extremely critical to the safety requirements in bridge operation since oil flow equals speed. This is accomplished by increasing or decreasing oil flow to the hydraulic cylinder(s). This is accomplished by using today's proportional directional control valves. These are extremely rugged and versatile valves that operate from a proportional force coil. The force controlled servo mechanism, an integral part of the directional control itself, provides an adjustable force output proportional to the amount of DC current being applied. Typical power supply is 0 - 9 volts DC/800 miliamps.

The adjustable force delivered from the servo is used to vary the travel of the valves main spool. This spool is so designed to offer excellent metering of the hydraulic fluid, both to and from the cylinder(s). Thus the cylinder(s) speed becomes infinitely variable.

Electronic amplifier cards are used to control current to the proportional servo. Cards are standard items and contain adjustable ramp circuits. The ramp feature gives an adjustable acceleration/deceleration no matter how abrupt the command. If applied with the "nearly open/nearly closed" limit switches, the bridge will automatically decelerate. This system could be applied with a programmable controller or very simple "raise/lower" push buttons at the control console.

VII. COUNTERBALANCE VALVES:

Since a movable bridge must be capable of handling varying loads, a hydraulic drive system is the best possible solution. Ice loading and high winds can contribute to a span becoming unbalanced and create a run-away condition. In open loop cylinder circuits, a component known as a counterbalance valve prevents this from occurring. Even without the use of a counter weight, a counterbalance valve will provide smooth control for lowering the span.

In addition the counterbalance valves will hold the bridge firmly in any position. The function of the valve is to lock oil in the cylinders until piloted open by pressure from the opposite direction. Should unexpected high winds occur greater than the holding force, integral relief valves will relieve the excessive load safely.

VIII. HYDRAULIC PUMPS:

Today's hydraulic pumps are available in a wide variety of types and sizes, enabling the designer to "tailor" a specific pump for a specific application to ensure proper performance and long life.

Most common varieties of pumps available today are:

- (a) Axial piston, variable & fixed volume, open or closed loop.
- (b) Vane pumps, variable & fixed volume, open loop.
- (c) Gear pumps, fixed volume, open loop.

Axial piston designed pumps are the most energy efficient of all pumps available today. Pressures range up to 6000 psi. There is really no limit to the control options available, especially in the hydrostatic closed loop versions which include manual, horsepower limiting, neutral brake & by-pass control, horsepower summation and electro-servo to name a few.

These pumps function extremely well with either high speed/low torque or high torque/low speed motors. In either case, all system valving is integral to the pump or motor which make system installation easy. In addition to this feature, closed loop pumps require far less oil reservoir capacity. With state of the art controls they lend themselves well suited to movable bridge applications in conjunction with high torque/low speed motors where failsafe brakes are required, their controls adapt well to process controllers.

Open loop pumps draw oil directly from the oil reservoir, and unlike closed loop pumps, they can pump oil in only one direction. They require directional control valves to port the hydraulic oil to and from the hydraulic cylinders. With this type of pump, external relief valves, and counter-balance valves, are also required. The above statement deals with fixed volume vane type pumps only. This type of pump can be obtained in single, double to triple pump configurations. It can also be configured to "piggyback" an open loop axial piston pump with various control options for special applications, pressures range up to 5000 psi.

Variable volume vane pumps are limited on both controls and pressure, 1000 psi generally being the highest pressure available. We could not recommend this type of pump for movable bridge applications.

Gear type pumps are the least efficient of all the pumps we have discussed. Their inherent design commits them to generating continuing amounts of metallic particles into the hydraulic system. Again we could not recommend this type of pump for movable bridge applications. Its main function is to power hydraulics for mobile and agricultural machinery.

IX. HYDRAULIC FLUIDS AND FILTRATION:

At this point, it is probably best to say a little about hydraulic fluids. We call them petroleum "fluids" rather than "oils" to emphasize that it is a special formulation with the additives to make it suitable as a hydraulic fluid. Primarily, these additives inhibit or prevent rust, oxidation, foam, and wear.

There are three common grades of "anti-wear" hydraulic fluids.

<u>ISO GRADE</u>	<u>GENERAL VISCOSITY</u>	<u>NORMAL OPERATING TEMP.</u>
AW32	LIGHT	10°-150°F
AW46	MEDIUM	30°-160°F
AW68	HEAVY	40°-170°F

Most bridge systems do not cycle enough to heat the fluid above about 110°F, obviously, the heaviest fluid provides the best lubricating ability; but it may require a tank heater for cold weather operation.

The proper filtration of the fluid is essential to the survival of a hydraulic system. A ten (10) micron filter is generally considered adequate for fluid used in piston pumps. The relative size of a particle this small is hard to comprehend since forty (40) microns is the lower limit of human visibility. A ten (10) micron particle is about the size of a red blood cell!

The standard, by which all hydraulic filter elements are rated, is the "Beta Ratio" system. This system classifies filter elements by their efficiency at removing a certain particle size. A simple test is performed by introducing particles of known quantity and size up stream of the element and recording the number that pass through downstream. By dividing the upstream particles by the number downstream, a Beta Ratio can be determined. Ten (10) micron filters with a Beta ratio of 50 are good cost effective filtration.

$$\text{BETA}_X = \frac{\text{UPSTREAM}}{\text{DOWNSTREAM}} = \frac{100}{2} = 50$$

BETA RATIO NUMBER

BETA RATIO VS. EFFICIENCY

<u>BETA</u>	<u>% EFFICIENCY</u>
1	0
2	50
4	75
5	80
10	90
20	95
25	96
50	98
70	98.5714
75	98.6667
85	98.9474
99	98.9899
100	99.0000
1,000	99.9
10,000	99.99

Many hydraulic component manufacturers offer hydraulic oil test kits, as well as some oil companies. This kit is simple to use and the owner/operator can make periodic analysis of his fluid to determine its condition.

X. SYSTEM INSTALLATION:

Now that we have taken a look at acceptable hydraulic fluids and filtration requirements, the next step is to consider the oil reservoir and interconnecting lines. To insure that you are getting a clean system to begin with, a good deal of care should be taken in the design and fabrication of the reservoir itself. After construction, it should be cleaned of all welding slag, blasted, and its interior coated to prevent rust. Once this important step is complete, the reservoir should be filled with clean oil filtered to at least ten micron.

All hydraulic lines should be cleaned and flushed using the same hydraulic fluid that will be used in the system. The flushing oil velocity should be the same as the system design parameters.

XI. PLUMBING:

The plumbing of the hydraulic system should be done by a professional, many of whom are in this type of business, rather than a local pipe fitter who is unfamiliar with hydraulic systems. The use of black iron pipe is discouraged as well as the use of galvanized fittings on the low pressure side of the system. Both types are known to rust quite easily and flake away material internally.

Stainless steel tubing specifically for hydraulic systems is the optimum solution with 37 degree flares or "o" ring seal SAE fittings at all pump, motor, valves, & cylinder ports.

Today's systems incorporate many modular valve systems and manifolds which accomplish two things at once, their use makes servicability simple and eliminates a good deal of plumbing. If hydraulic hose is being considered please refer to the SAE hose specifications which contain details on ratings, hose sizes, and bending radius. Again, as with stainless steel hydraulic tubing, 37 degree flares or "o" ring seal connections are considered the optimum solution to ensure a leak free system.

XII. CONCLUSION:

Considering all that we have discussed in this paper, one would be led to believe that hydraulic systems must be extremely complicated. On the contrary, there exists no black magic. Hydraulic systems of today are relatively easy to design, easy to install and come with many built-in features that reduce or eliminate the need for maintenance. They are quiet, energy efficient and provide superior life over that of electro mechanical drives.

Most of us have witnessed the pitiful spectacle of a noisy, leaking hydraulic system with at least one mile of poorly installed pipes that vibrate and leak. Those days are gone forever with tomorrow's hydraulics available today. As a final thought it is the prudent engineer, owner or operator who looks to the designer who can offer one source, one responsibility capability. This ensures that all componentry is guaranteed to work in harmony.