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Assessing Hydraulic Load Holding Solutions for Hydro Control Applications

Abstract:

Many dams and hydro-control systems have reached an age that is making replacement or refurbishment a necessity. These systems were built with older technologies that can be replaced with newer technologies and designs to provide higher safety and performance. One such design aspect is hydraulic load holding.

This paper begins with an overview of load holding solutions currently in use by the industry, in light of key safety and performance considerations. What factors should be considered for load-holding, especially for the massive scale of hydro control infrastructure? What options exist for reliable long-term load-holding? For water exposure applications? Or when locking or load-holding for remote unmanned equipment is required? Is there a faster, more reliable way to achieve safe lockout when maintenance or cleaning is needed?

This paper will explore design/engineering considerations in hydro control applications with a comparative view of traditional load-holding solutions, from basic to more advanced approaches.

What factors should be considered for long term load-holding? There are different options for supplemental mechanical locking and important parameters when choosing which to use: power needs; space available; operating pressure; operating environment; the need for locking in any location along the stroke, or only in fixed positions; and whether manual or automatic locking is best. These parameters determine the available options.

Safety First: Some Regulatory Considerations

Safety requirements vary according to business sector, application, and governing authorities. For example, OSHA recommends a safety factor of 2.0 for overhead load holding. The US Army Corps of Engineers in its *Mechanical and Electrical Design for Lock and Dam Operating Equipment* (USACE, June 2013) cites a safety factor of 5.0 for dams, locks and other hydro control applications.

USACE offers a succinct and relevant description of hydraulic systems and how they function: “Hydraulic fluid power systems generate, transmit, control, and apply hydraulic fluid to devices that perform work. Power is generated by a hydraulic power unit (HPU) consisting of one or more pumps, valves, and controls mounted on a fluid reservoir. Pipe, tubing, hose, and manifolds transmit the fluid to the output devices. Valves control the direction, pressure, and volume of the fluid flow. Actuators, such as hydraulic cylinders and hydraulic motors, are the typical output devices. Hydraulic fluid power output devices often are used to operate lock gates, spillway gates, and culvert valves.” Regarding safety, USACE adds, “The Unified Facilities Guide Specifications (UFGS) provide detailed assistance in the preparation of contract specifications of hydraulic fluid power systems, (Section 41 24 26 Hydraulic Fluid Power Systems and Section 41 24 27.00 10 Hydraulic Fluid Power Systems for Civil Works Structures). Other industry design standards covering hydraulic fluid power systems include NFPA and ISO. Many European-based companies primarily use the DIN (German) Standards.”

The Federal Energy Regulatory Commission (FERC) in its *Hydropower Primer* (FERC, Feb. 2017) classifies the hazard potential of 2,518 non-Federal US dams in its jurisdiction as High, Significant or Low, based on the potential losses should the dam fail. High represents probable loss of life and other high losses, Significant represents significant economic, environmental damage, disruption of lifeline facilities, or other concerns. Of the total, 815 are considered High and 185 as having Significant hazard potential: in total, 1,000, or about 40%. The point here is that safety is of the utmost priority for the owners and engineers responsible for hydropower projects in the communities they serve.

Option 1 For Basic Load Holding: Counterbalance Valves

Counterbalance valves (CBVs) help hold a load in place and are also referred to as load-holding valves (LHV). These valves are common safety components of load-carrying equipment offering a cost-effective, basic or first line of load holding safety. Understanding the pros and cons of these valves and knowing other supplemental options to combine with LHVs for safety will give you the ability to safely and productively use equipment that meets your load-holding requirements. In this section we will discuss what load-holding valves are, how they work, and their advantages and disadvantages.

What Are Counterbalance (Load-Holding) Valves?

A counterbalance, or load-holding, valve is a mechanism typically located near the actuator that uses hydraulic pressure to keep a load from moving. Generally, these valves have three related functions: support, control and safety.

When required for load support, these valves prevent a hydraulic actuator under load from drifting in position. When lowering loads, the counterbalance controls the rate or speed of motion of the load on the actuator.

How Do Counterbalance Valves Work?

Counterbalance valves are hydraulic devices that function using this basic principle: fluid can freely flow through a check valve into the actuator, and reverse flow will be blocked using a relief valve until a pre-set pressure is reached that is set based on the system pressure and load capability. This pressure is higher than the system pressure when the load is applied and allows the fluid to flow in the opposite direction and the actuator to function. When pressure is removed, the valve goes below this set value, closes, and the load holds its place.

The preset pressure to the pilot port will determine the direction the load can move. To lift a load, the valve allows free flow through the check valve, so the cylinder can extend. When fluid flows to the rod end of the cylinder, this pressure will pilot open the valve, so you can lower the load. This pressure will decrease if the load starts to run away, and the counterbalance valve will adjust to match the cylinder speed to the pump flow.

Advantages And Disadvantages Of Counterbalance Valves

Load-holding valves offer some advantages for systems that use them. These benefits of counterbalance valves have made them a popular component of hydraulic systems across numerous sectors and in a variety of hydro control applications. Their main advantages are:

1. *Safety Through Load Control*. The most well-known attribute of load-holding valves is the measure of safety they offer to devices equipped with them. By automatically regulating the descent of loads and holding equipment steady while lifted, these valves are meant to protect people and equipment in the area.

2. Simplified Design. The simple design of load-holding valves allows for multiple variations to accommodate individual needs. For systems with numerous hydraulic lifts, installing two-stage or restricting load-holding valves gives greater control over the entire system, while allowing for machinery that does more things.

Load-holding valves also come with some serious shortcomings. You may want to replace or supplement your valve with solutions to compensate for these disadvantages, which include:

1. *Not Fail-Safe, Limited Safety.* The main disadvantage of counterbalance valves is that they are not fail-safe. These valves contain parts that can stick or fail, at which point their level of protection is compromised or eliminated completely. If a valve opens too rapidly, you can experience instability. If a valve becomes stuck due to wear or contamination, loads may begin to drift. In the worst cases of failure or damage, the load holding could be lost entirely. Also, CBVs are dependent on other hydraulic circuit components. Using a CBV as the sole load holding device can mean that a failure in other points in the circuit could cause a load to come down, depending on the configuration of the circuit.

2. *Requires Checks and Adjustments*. Check valves require adjusting and checking the preset position. If the system loading changes it may necessitate the CBV to be adjusted. External pilot-operated load-holding valves don't need constant adjustments whenever you change loads, but other types of counterbalance valves do. Whenever manual settings or adjustments are required, the risk for error increases.

In critical or high-risk applications, you should consider additional fail-safe options to supplement counterbalance valves.

Option 2: An Intermediate Level of Safety With Manual Mechanical Locks

An intermediate level of safety is achieved by mechanical locks that press or clamp. Typically these are spring loaded or contain a second smaller hydraulic or pneumatic cylinder that is placed as a collar, or an installable "head," on top of the main actuator-rod end cap. The lock fits around the rod and clamps against it to prevent movement. In some designs, the load must be removed or the actuator moved in a specific direction to release the lock.

These off-the-shelf locks come in common rod sizes and can be hydraulic or pneumatic. They should be reliable and reusable and operate without too much maintenance or replacement requirements. They tend to be limited to cylinder pressures of 2,500 psi or less, so they cannot be used for high-load applications or with higher operating pressures.

Another manual approach is to use physical braces, support beams, or pins to fix a position for long-term load holding. This approach can be used to support very large loads, however, only pre-determined, fixed positions are available, and these physical supports can be difficult and dangerous to install.

The clear drawback of all manual systems is that they require human interaction to initiate locking and unlocking. This may be fine in applications that are consistently manned, however, there are times when instant, automatic locking is preferred.

Option 3: Automatic Locking

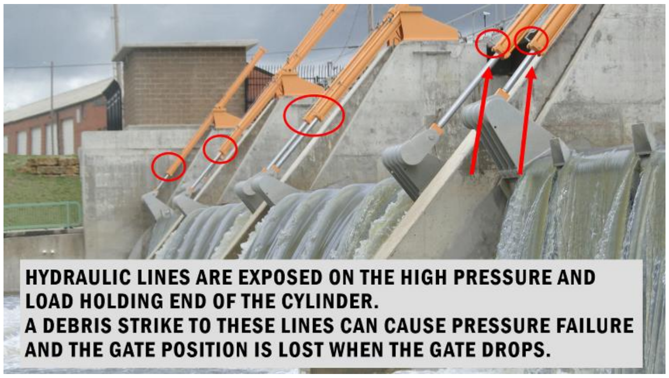
Automatic mechanical locks are load holding devices that can either lock at an operator's command or lock instantly if system pressure is lost. They offer the highest degree of safety as loads can be secured instantly in the event of a failure in the hydraulic system or other catastrophic event. These systems represent the most recent advances in technology and were often not available nor considered in many existing hydro control designs.

These systems typically function by incorporating a locking section into the actuator in which the unlocked position is maintained by positive hydraulic pressure. Thus, when pressure is lost for any reason, whether planned or unintentionally, the load will be secure.

While often the most expensive solution, these are widely considered the safest load-holding solution and can easily be paired with counterbalance valves. A challenge that can arise from these systems is that they add additional length to a stand-alone hydraulic actuator, which can make retrofitting these into existing applications difficult.

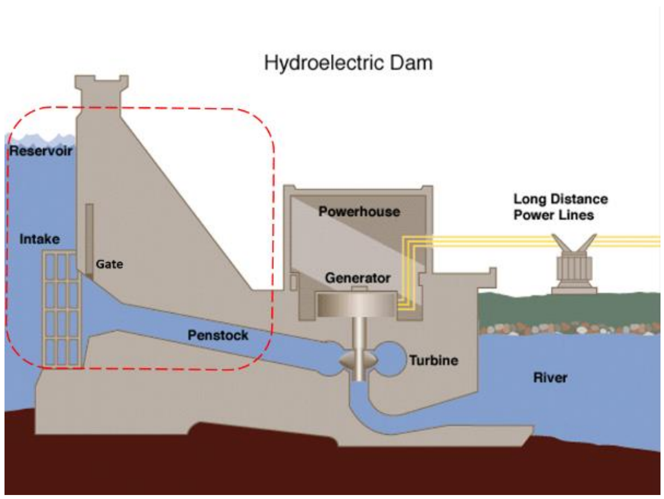
Whether a new design or a system overhaul, there are factors that will influence the load-holding solution. Here are a few scenarios in which a higher degree of load holding safety is critical:

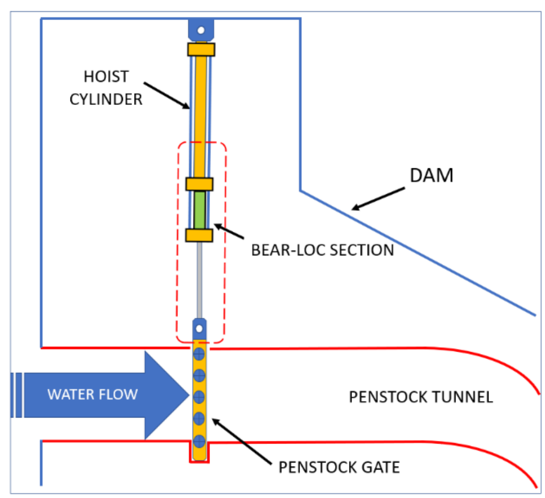
Example 1 – Safeguarding against component damage in Crest Gates: Crest Gates control water flow rates and have externally mounted actuators that control the water flow that passes through them. These exposed actuators are at risk of damage due to debris strikes from flooding, severe weather, or exposure to the elements. An unplanned or unexpected gate release or overflow can risk lives, cause property damage, and environmental damage. An automatic mechanical load-holding solution safeguards against these scenarios and prevents sudden and excess flow that can be caused by hydraulic pressure loss.



Example 2 – Preventing drift in Sluice Gates: Many sluice gates are powered by hydraulics and are required to hold a position for an extended period of time without drifting. These gates can be subject to very large load holding requirements, with sediment build-up as an additional challenge. A mechanical lock can ensure load holding for the gate at any needed point during operation. An automatic mechanical lock would be preferred in situations where manual locking is not possible or practical.

Example 3 – Enabling infinite-position locking in Penstock Gates: Penstock gates control water flow rates that determine the turbine speed and the dam's electrical output. They use actuators that control gates or large control valves. These actuators have mechanical locks installed to secure gates and prevent sudden flow rate changes that could damage equipment investments; or cause unscheduled maintenance and revenue loss. If mechanical locks are installed that only have several fixed or "step" locking positions, typically they can only lock at their fully open or closed position or a couple set locations along the cylinder rod travel. This means the gate must travel to these preset locking points to be secured. These locks limit the ability to provide precision control of gate position and the resulting power generation.





An automatic load-holding/locking solution has full locking power provided at any point in stroke. This means the gate or valve can be positioned at any point in stroke and not preset locations. This allows precision adjustment of single turbine flow rates or multiple turbine flow rates to meet exact power generation needs.

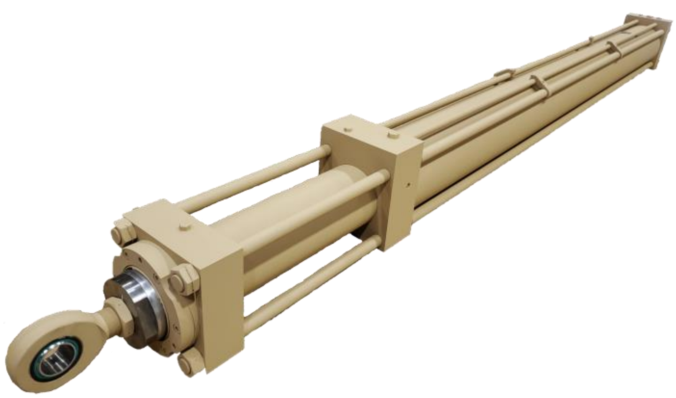
Example 4 – Ensuring worker safety during planned maintenance: Safe and speedy solutions are a must in accomplishing maintenance. Each hour of downtime comes with a significant financial cost, however, efforts to expedite a repair or overhaul process cannot come at the expense of safety. In fact, suspending loads or locking out hydraulic equipment can be quite time consuming. In writing or reviewing these maintenance processes, evaluate whether an automatic locking solution could replace a manual bracing or lock-out practice. For example, one customer proposed installing an automatically locking hydraulic actuator inside a turbine shaft to aid with disassembly. This saved several days of downtime from the existing manual, labor-intensive process, saving considerable labor dollars and preventing enormous loss of generation revenue.

Conclusion

When designing a hydro control system, think carefully about the safety and performance criteria required for the appropriate measure of safety and effectiveness in hydraulic load-holding and locking. Choose a solution that assures your requirements will be satisfied. We hope this overview has been helpful.

About Us:

Bear-Loc® Automatic Hydraulic Load Holding and Locking System
by York Precision Machining & Hydraulics



Cylinder Integrated Bear-Loc®

Stand Alone Bear-Loc® Unit

Bear-Loc® is a fail-safe, efficient, and dependable rod locking device consisting of liners encased in a sleeve that is mounted on a cylinder rod. The sleeve creates an interference fit with the hydraulic cylinder rod. The interference generates a positive mechanical connection. This positive mechanical connection is what enables Bear-Loc® to lock the rod in place. When the hydraulic pressure is removed, whether intentionally or not, the sleeve contracts and the Bear-Loc® instantly engages to hold the rod firmly in place, stopping its motion at once. All hydraulic fluid can be lost yet the Bear-Loc® will retain its position. When hydraulic pressure is present, the sleeve expands due to elastic expansion of the sleeve metal and removes the interference. The lack of interference allows the rod to move freely. These locks can be installed on cylinder rods or be installed as a stand-alone lock, to lock up to four million pounds, accommodate sleeves from one inch to seven feet, and fit rods from one inch to 27 inches across. The Bear-Loc® can work solo or in conjunction with existing equipment to keep people, equipment and projects safe and to optimize productivity. This patented design has proven itself through decades of continuous use through harsh sub-sea and above-sea environments such as oil-rig and US NAVY applications.

Author's Biographical Sketch: Daniel W. Baker

Dan Baker is President of York Precision Machining and Hydraulics. He holds a B.S. in Mechanical and Aerospace Engineering from Cornell University. The York, PA-headquartered company has a reputation for world-class quality and service, focusing on customers' mission- and safety-critical needs for custom precision fluid power components, including actuators, accumulators, cylinders and Bear-Loc® locking devices. The company provides services from design to production, assembly, and testing for a wide variety of commercial and US Military customers.