

LatchTool PowerCylinder™: fluid power in the palm of your hand...

By: Myron Tupper & Bob McPherson with commentary by Josh Hoyt, Ph.D. - The LatchTool Group

To some, the LatchTool *PowerCylinder™* is an off-the-wall, outside of the box, once in a lifetime happening. To others, it is a high force – fast closing actuator with its own internal pump. Whichever definition you choose, it is clearly a new paradigm for the 21st century; a closed multi-circuit hydraulic system that dynamically responds to loads. The *PowerCylinder™* requires no external reservoir, accumulator, hydraulic pump, manifold or fluid lines. A unit that rapidly extends the ram to the work and then progressively amplifies the hydraulic advantage. A 50 pound pull on the trigger of a 12 ounce 7/8"Ø x5" cylinder, for example, quickly delivers a ton and a half of force to the ram.

The genesis of the PowerCylinder is the proprietary FastFlow Valves™; small inexpensive digital valves capable of large unrestricted volumetric flows. They are a family of floating seal valves that range from unidirectional check valves to bi-directional poppet type valves. The LatchTool system stacks combinations of FastFlow valves together in a cylinder to produce three distinct, yet fully integrated hydraulic circuits.

The PowerCylinder was first developed as a boost for hand tools - miniaturized self-contained fluid power packages for shears, cutters, locking pliers and crimpers; tools that give a grandmother the grip of a gorilla. But the promises of small self-contained high-force actuators go beyond hand-strength, making bionic strength for prosthetics just a matter of time. And maybe too the LatchTool PowerCylinder is part of the solution in the never-ending quest for smaller and lighter aeronautical, automotive and heavy equipment components.



Figure 1 depicts the internal layout of a LatchTool PowerCylinder replete with FastFlow Valves™. A bulk-head separates the ram chamber from the pump chamber and houses a dart valve. A proprietary arrangement that provides overpressure relief and that is manually tripped by over retracting the pump piston to redistribute hydraulic fluid when the system is reset.

Figure 1: LatchTool *PowerCylinder™*

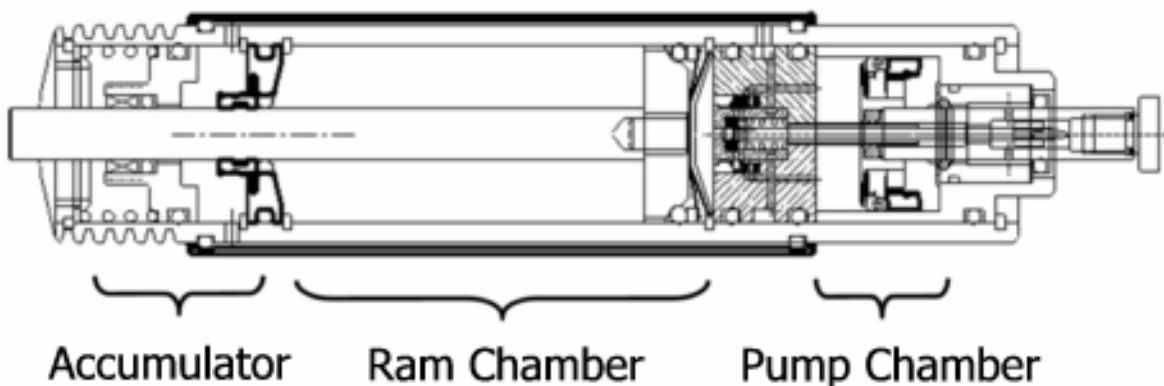
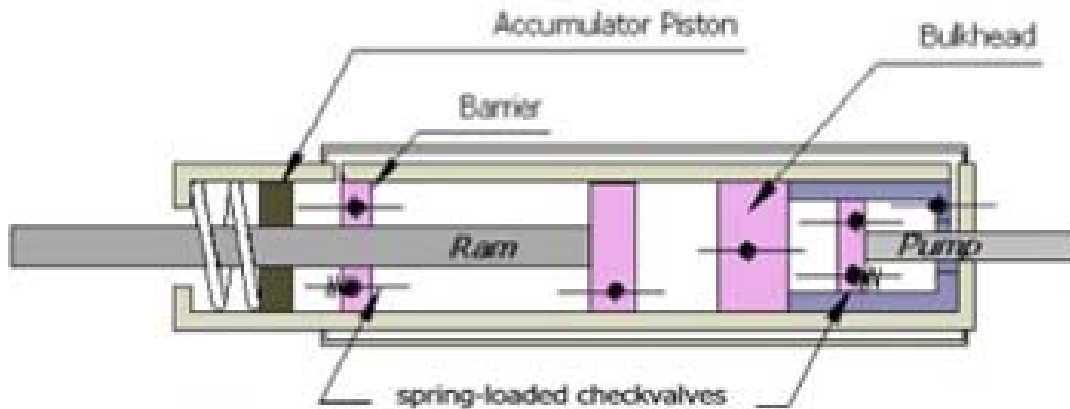


Figure 2 stylizes the PowerCylinder where the various FastFlow valves are depicted as either a check valve or as a combination of a check valve operating in one direction and spring-loaded check valve in the other.

Figure 2: Stylized *PowerCylinder* Internals



The rapid advance mode makes use of a regenerative circuit. Fluid expressed by the positive displacement of the pump enters the cap-side of the ram chamber through a check valve in the bulkhead. In the diagram, the ram moves to the left. The fluid on the rod-side of the ram correspondingly experiences incrementally higher pressure as the area of the backside of the ram piston is less than the cap-side's by the cross-sectional area of the ram rod. Consequently, fluid on the rod side is expressed back through the check valve in the ram piston to the cap-side further driving the ram to the left. The regenerative circuit prevails until the fluid's pressure on the rod side of the ram cracks open the spring-loaded check valve in the barrier. This transition happens when the external load on the ram causes the internal pressure to ramp past the cracking pressure. Fluid on the rod-side of the ram is now diverted into the accumulator rather than into the ram chamber. During regeneration, the pump piston is opposing the ram rod. Therefore, the output force is equal to the input force factored by the ratio of the areas of the ram rod to that of the pump piston. Speed is gained at the expense of force.

As mentioned, when internal pressures open the spring-loaded check valve in the barrier the PowerCylinder shifts into the expectant mode. This circuit has the ram piston opposing the pump piston. Fluid from the pump chamber is expressed into the ram chamber. Fluid on the rod-side of the ram is expressed into the accumulator. The resulting output force now equals the input force factored by the ratio of the areas of the two pistons.

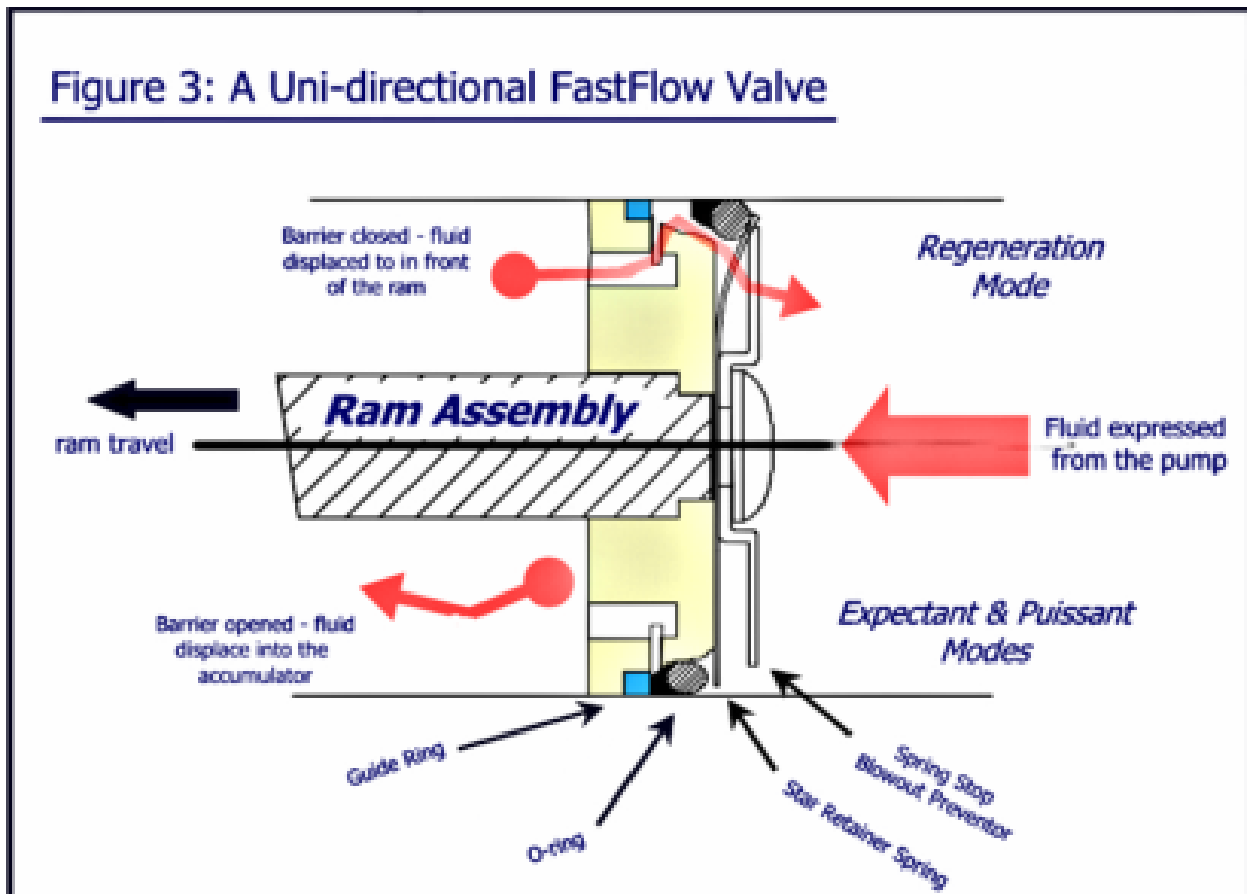
At another prescribed internal pressure the spring-loaded check valve on the pump piston opens to shift the system into the puissant mode. Pronounced *pwissant*; it is an adjective meaning powerful or might. In this circuit, the pump rod opposes the ram piston. Therefore, the output force now equals the input force factored by the area of the ram piston divided by the cross-sectional area of the pump rod maximizing the hydraulic leverage.

The relative spring loads of the spring-loaded check valves in the barrier and pump piston regulate the transitions between circuits. In our discussion, we've assumed the spring load in the barrier is less than that in the pump piston. However, if the spring loads were reversed such that the spring-loaded check valve in the pump piston opened first, then the ram rod would oppose the pump rod. This is a variant of the expectant mode. The first and last modes encountered remain the regenerative and puissant modes respectively. Deciding whether to use the expectant, its variant or both during the expectant phase is a design consideration in engineering a specific system.

When operating in either the expectant or puissant modes, keeping the spring-loaded check valves opened taxes the system with an energy penalty. In practice, FastFlow valves are available that once opened stay open until reset.

FastFlow Valves™: Quickly redistributing large volumes of fluid within the *PowerCylinder* system is critically important. The requirement of fast flow is further exacerbated with smaller systems. Consider the scalar effects on a traditionally configured check valve. Halving its diameter reduces the cross-sectional area of the fluid pathway by 75%. The increased constriction causes a correspondingly increased pressure drop requiring a greater driving force to deliver the same output. This natural consequence of miniaturization is particularly troublesome when the *PowerCylinder* is operating in the regenerative mode where the system demands a very large fraction of the fluid be quickly redistributed from the rod end to cap side of the ram. The pressure drop through traditional check valves makes the system unacceptably sluggish.

Figure 3 shows the operation of a FastFlow valve on the ram by noting the the different positions of the floating seal o-ring for the different circuits. The bottom half of the schematic depicts either the expectant or puissant modes where the o-ring forms a tight dynamic seal between the piston and the cylinder wall. The top half deals with the regenerative mode where the greater fluid pressure on the rod side unseats the o-ring permitting copious backflow. The valve orifice is effectively an annulus whose outer dimension is inscribed by the inter-diameter of the cylinder. FastFlow valves provide a significant fluid pathway compared to the largest check valve that can be accommodated in the piston's head.



As a new class of proprietary floating seal valves, FastFlow Valves™ circumvent the limitations of restricted flows and unacceptable pressure drops inherent with small check valves. And they greatly simplify and economize cylinder fabrication.

The LatchTool Group is in the business of manufacturing *PowerCylinders* and managing the intellectual property of its affiliates Latch-Tool Development Company, LLC and Fast Flow Technologies, LLC. Gener-

ally, the Company plans to market the *PowerCylinder™* as an open source technology, making them readily available as OEM components to manufacturers. However, LatchTool Group also envisions limiting sales of *PowerCylinders* for specific applications and then making these the subject of end-use or field of use licenses. The Company is also presently pursuing the manufacture of mass-produced and then mass-customized *PowerCylinders™* that are designed as throw-a-ways. Like an AA-battery, there are the super long-lasting alkaline kind and the less expensive regular ones. The design trick is to take robustness to prescribed levels and then differentiate *PowerCylinder* cartridges by their service life. It's all a matter of economic trade-offs. Then too, *PowerCylinders™* are differentiated by output ratings increasing in ¼ ton increments up to 1 ton and beyond. The *PowerCylinder* is just one manifestation of the LatchTool/FastFlow technologies, which together are a platform technology available for spin-off or joint venture.

Commentary by Josh Hoyt¹, Ph.D. - Not much can be done to contravene the fundamental law of physics: Work Out = Work In – Losses. Within the constraints of this law, however, are tremendous opportunities. One can minimize the losses. And one can tune the transmission for a given application to optimize the work being done. The *PowerCylinder™* does both. The *FastFlow Valves™* minimize the losses by eliminating the orifice constrictions typical of standard check valves. This also speeds up the actuation time. In addition, the fluid circuit shifts from work characterized by high displacement and low force to work characterized by high force at low displacement. Furthermore, this transformation from high displacement to high force takes place automatically with changes in load.

It is easy to understand the function of the high displacement—or regenerative—fluid circuit. Similarly, it is easy to understand the function of the high force—or puissant— circuit. More obscure is the function of the intermediate—or expectant—circuit. At this intermediate stage, the goal is to balance force and displacement in a useful manner. For many applications, such as locking pliers and clamps, this intermediate stage is of minor importance. In other applications such as cutting or crimping tools, where deformation is required, the spring loaded check valves can be tuned to make this middle stage able to output sufficient force with modest displacement.

Other key attributes of the *PowerCylinder™* are its scalability and relatively simple concentric architecture that make it well suited to a broad range of industrial and low-cost consumer applications. The one concern that has been expressed about this design is the unconventional use of o-rings. Recently concluded life tests have now put this concern to rest. As with any new technology design refinements will continue to improve efficacy and expand utility. As the *PowerCylinder™* cartridges become ubiquitous, an army of designers will find many uses for this truly unique device.

LatchTool Group
14760 Cherry Hills Place
Colorado Springs, CO 80921
719-488-8800

oo00oo

¹ Josh Hoyt is Senior Vice President overseeing engineering and technology for LatchTool Group. Previously, he managed strategic product development initiatives for Electronics Inc. the world's largest manufacturing services company. Prior to that, Josh was chief technologist for Ziba Design, a major industrial design firm serving Fortune 100 companies. Dr. Hoyt has held numerous research and development posts internationally focusing on the design of remote and portable sensing equipment, medical diagnostics and underwater robotics. He has led product development teams and formed collaborative development partnerships among major industrial players and fledging startups. Josh has a Ph.D. in underwater robotics engineering from Massachusetts Institute of Technology/Woods Hole Oceanographic Institution and his MS and BS in mechanical engineering from MIT. He has taught at the University level and holds patents in the field of fluid control. He can be reached at josh.hoyt@latchtool.com.