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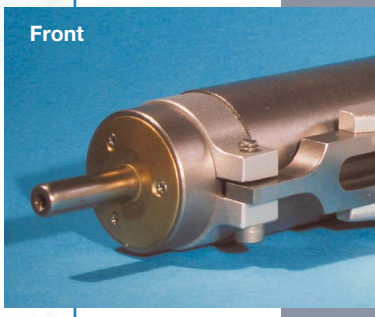
Edited by **Alan L. Hitchcox**

Special valves help downsize force amplifier

Engineers at the LatchTool Group, Colorado Springs, set out to develop a hydraulically powered force amplifier small enough to fit into hand tools such as locking pliers. They wanted a product that would literally put fluid power in the palm of the user's hand . . . giving Grandma the grip of a Godzilla. But they got much more in the bargain: A tiny hydraulic system that can be run from the end of a wire, Figure 1.



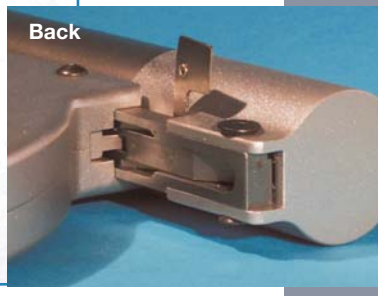


Fig. 1. Demonstration PowerCylinder™ set up with squeeze handles to mechanically drive internal pump. This unit has a ¼-in. ram rod and ⅜-in. bore; it can extend for 1¼ in.

Of course they faced the problem of every designer trying to shrink hydraulic components: each time the size of a flow passage is reduced, it becomes exponentially more difficult to force fluid through it. A greater driving force is necessary to overcome the increased pressure drop just to distribute fluid throughout the system. This situation is particularly exacerbated in the configuration of a typical check valve — the type of valve that would play an important role in the miniature amplifier circuits.

Valves and seals

LatchTool resolved this difficulty with a proprietary class of digital floating-seal valves. This FastFlow™ family of valves — in uni-directional check and bi-directional poppet configurations — is capable of relatively large volumetric flows. The seal technology offers the desired economies in weight and space and simplifies cylinder construction.

The designers stacked combinations of FastFlow valves in a resistance-regulated, fast-closing, high-force hydraulic actuator —

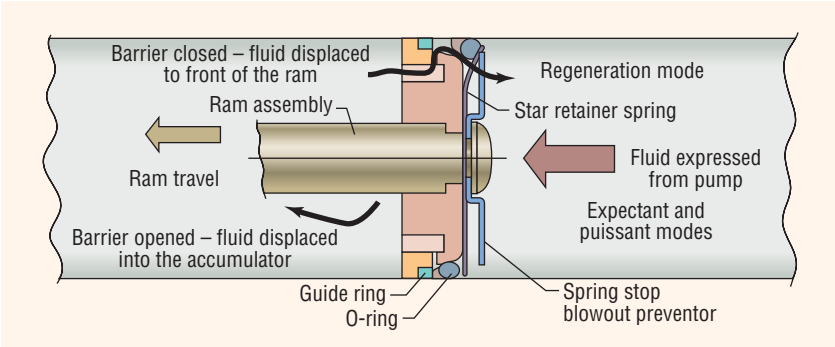


Fig. 2. Two views of operation of unidirectional FastFlow™ valve's floating-seal O-ring. In bottom half of drawing, the O-ring forms a tight seal dynamic seal between the piston and the cylinder wall. In the top half, greater pressure on the rod side unseats the O-ring, and the valve orifice effectively is an annulus whose OD is the cylinder's bore.

equipped with its own internal pump — that they named the *PowerCylinder™*. This configuration automatically shifts between three distinct, yet fully integrated hydraulic circuits in response to the encountered load. The three circuits are tuned to trade speed for force — from rapid advance, through an intermediate expectant mode, to an intensified most-powerful puissant mode. The package eliminates the need for external reservoirs, accumulators, and valve manifolds. The PowerCylinder is designed as an off-the-shelf force amplifier to be installed as a component in larger assemblies for either mechanical or electromechanical actuation.

In the *rapid-advance mode*, fluid expressed by displacement of the pump to the left, Figure 3, enters the cap side of the ram chamber through a FastFlow valve in the fixed bulkhead. Fluid on the annular side of the ram piston undergoes higher pressure because the area of the annular side is smaller than that of the full piston. Consequently, fluid from the rod side is pushed back through a check FastFlow valve in the piston to the cap side in a regenerative circuit that drives the ram farther to the left. Speed is gained at the expense of force.

The rapid advance of the regenerative circuit prevails until the external load on the ram raises fluid pressure past the cracking pressure of the FastFlow check valves in the fixed barrier. Fluid on the rod side of the ram piston now is diverted into the accumulator chamber and the PowerCylinder is in its expectant mode. The output force equals the input force factored by the ratio of the areas of the two full piston faces. The moderate force, moderate speed of the expectant mode can be tuned to the application.

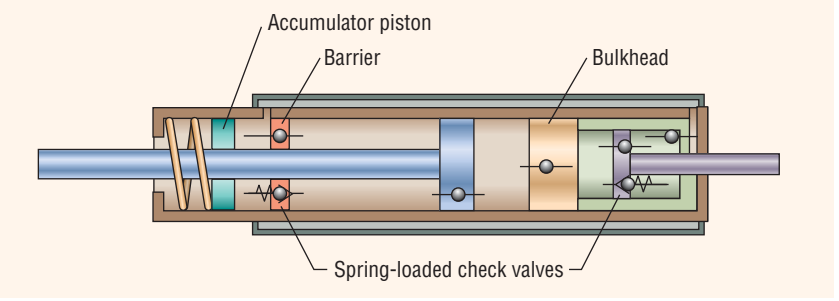


Fig. 3. This stylized cross-sectional drawing reveals the simple architecture of the PowerCylinder™ package. By changing dimensions, the location of the bulkhead and barrier, and the cracking pressure of the valves, the unit can be customized to the user's specifications.

At another prescribed higher internal pressure, the check FastFlow valves in the pump piston opens and the unit becomes an intensifier, shifting into its most powerful mode. Output force now equals the input force factored by the ratio of the area of the full ram piston to the cross-sectional area of the pump rod — thus providing maximum hydraulic leverage.

When work is complete, the pump direction is fully retracted in reverse, mechanically tripping a proprietary dart valve to redistribute fluids and and reset the FastFlow valves again respond to pressure conditions to allow fluid to flow between the chambers. At the end of the pump's return stroke, it mechanically resets the dart valve for the next cycle. This dart valve also serves as an overpressure relief valve, which sets the maximum force the PowerCylinder will deliver. Without the over retraction of the pump rod, the reset mechanisms are not activated and the system continues to deliver its maximum rated force.

The PowerCylinder's unit construction, Figure 3, enables plug-and-play simplicity in both product assembly and field maintenance — replacing complete hydraulic subassemblies with self-contained cartridges. Gone is the need to flush and purge hydraulic circuits and to contend with accidental fluid spills. Gone too are the catastrophic implications of a ruptured or severed hydraulic line; as well as ancillary fluid handling, control, and distribution systems and their complicated umbilical connections.

The PowerCylinder has gone through robust testing for 40,000 cycles with no measurable wear or degradation in the FastFlow seals. It is deliverable as a sealed unit to user specifications — from pre-set force amplification to the stroke of the ram. And it is scalable, beginning with an OD of less than an inch. The PowerCylinder brings the features of hydraulic power to a range of smaller applications, particularly crimping, clamping, and cutting. LatchTool has successfully begun modulating the PowerCylinder and sees a future with applications in prosthetics, and aeronautical, automotive, and mobile equipment application fields.