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Paper

HISTORICAL ADVANCES IN WATERBLASTING PUMPS

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The focus of the present paper will be on reciprocating power pumps, specifically plunger pumps used in waterblasting. While acknowledgement may be given to the progress in developing UHP Intensifier pumps, as well as high volume Hydraulic fracturing pumps, the concentration here is specific to the development of pumps used in industrial cleaning and surface preparation applications.

WJTA has made recommendations on color coding to visually identify pressure plateaus as part of their *Industry Best Practices for use of High-Pressure Waterjetting Equipment* publication. See Table 1 An effort has been made to identify some of the technical advancements which made these pressure plateaus possible.

PSI	BAR	Color
10,000	690	Yellow
15,000	1,034	Green
20,000	1,379	Blue
40,000	2,758	Orange
55,000	3,792	Red

Table 1 - WJTA Color Code Scheme

Many of the high-pressure pumps used in waterblasting were initially driven by the needs of the oil industry. Early models were used for crude oil gathering, artificial lift, pipeline applications, drilling fluid circulation, and others. The close ties between high pressure pumps and the needs of the oil industry led to an early adoption of waterblasting as a technique used in refinery cleaning. Arguably, industrial cleaning with waterblasting started in earnest with two entrepreneurs, John Goss and Dick Paseman. These two gentlemen had enough experience to develop and copyright a pumping unit called a “Water Blaster” which was marketed by their company, American Powerstage, during the early 1960’s. (Gracey,

2006) The reciprocating power pumps used for industrial cleaning during these early times were grossly unreliable with pressures above 5000psi. One weakness in maintaining the 5000psi + (plus) pressure consistently was the big block style fluid ends. As pressures increased higher loads were placed on all internal components of the pump and advancements in one area highlighted weaknesses in others.

By the 1970's, enlightened cleaning contractors realized that downtime for waterblast equipment maintenance was rather costly for asset owners. Valve components and packing elements are particularly vulnerable to wear. (Summers, 1995) As a result, Fluid Ends became the focus of many high-pressure pump developers. Initial improvements incorporated the use of cartridge style valves, use of newer alloys and stainless steels, and reducing the size of pressure chambers. Several waterblast equipment specialists started developing their own fluid end designs capable of sustaining the higher pressures, while relying on long established pump manufacturers for the powerend. John Bean, Union, and Wheatly were some of the long established powerends adaptable for Fluid End improvements by high pressure waterblasting equipment suppliers & specialists. The focus of these reciprocating power pump manufacturers was not necessarily on the needs of the waterblasting industry because their customer base was far more varied and diverse than the specific needs of a small industry.

In the late 70's and early 80's, Hydro-Services was one of the first high pressure innovators to have a resonating effect in the waterblasting industry. By adapting a Wheatly powerend to their own in-house fluid end, they were able to establish a more reliable, maintenance friendly pump for their waterblasting services. A key development in their new fluid end was their Dura-Pak, cartridge style valve. See Figure 1. (Gracey, 2006) This new valve with the corresponding fluid end enhanced the company's ability to maintain pressures of up to 10,000psi.

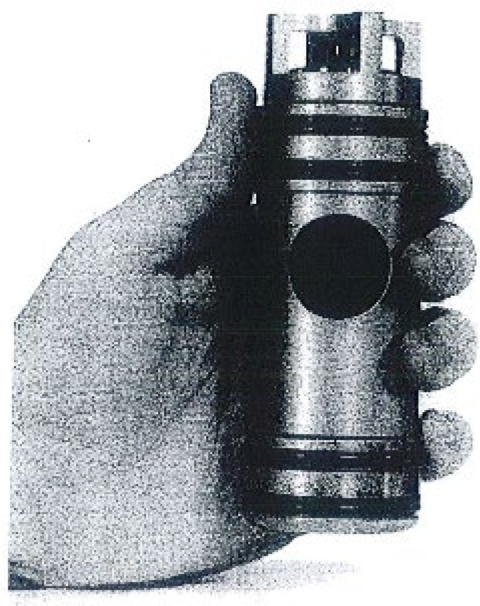

Figure 1 - Valve cartridge design developed by Hydro-Services

Perhaps the largest contribution to waterblasting pumps being able to reach even higher pressures of 15,000 and then 20,000psi consistently was the development of the inline valve. (Gracey, 2006) Aero-Dyne and Reliable were both leaders in developing valves that took advantage of material advancements and coaxial valve/plunger configurations. This design aligned the plungers with the valves, eliminating the need for the customary pressure cylinder. Further, the inline valve withstood higher pressures with greater consistently because the bore of the valve was no longer at a right angle to the bore of the plunger, thus eliminating the stress concentrations at the apex between the right-angle bores. This coaxial arrangement was significantly less costly to manufacture, and greatly simplified Fluid End configurations.

American Aero developed a fluid end using what was called a “racetrack” valve cartridge. The design was very similar to the in-line valve arrangement and placed the suction and discharge valve between the manifold and the stuffing box. This moved the area of fluctuating high pressure from the manifold and extended its life tremendously. The suction and discharge seats were both located on a single oval piece of metal. Though not a true self-contained cartridge, this arrangement made valve replacement easier than other designs. Another innovation was to recess the packing completely inside the gland nut instead of in the stuffing box bore. This meant that the packing came out with the gland nut instead of needing to be forced out of the stuffing box manually.

Jetstream was another company that took advantage of an existing powerend and adapted the UNx fluid end to accommodate their customer’s needs. The introduction of the UNx Fluid End with the Union powerend took advantage of previously mentioned fluid end innovations. The use of a valve cartridge was used in conjunction with the inline valve arrangement but went further in incorporating both the suction valve and the discharge valve into a single cartridge, called the Univalve. See Item 57/58 in Figure 2. The design also allowed quick access to both the packing elements (Item 42) and the valve by allowing the manifold to pivot at the bottom of the rod box. Having quick access to both high maintenance items in the fluid end was instrumental in the commercial success of the Jetstream design. (USA Patent No. 4878815, 1989)

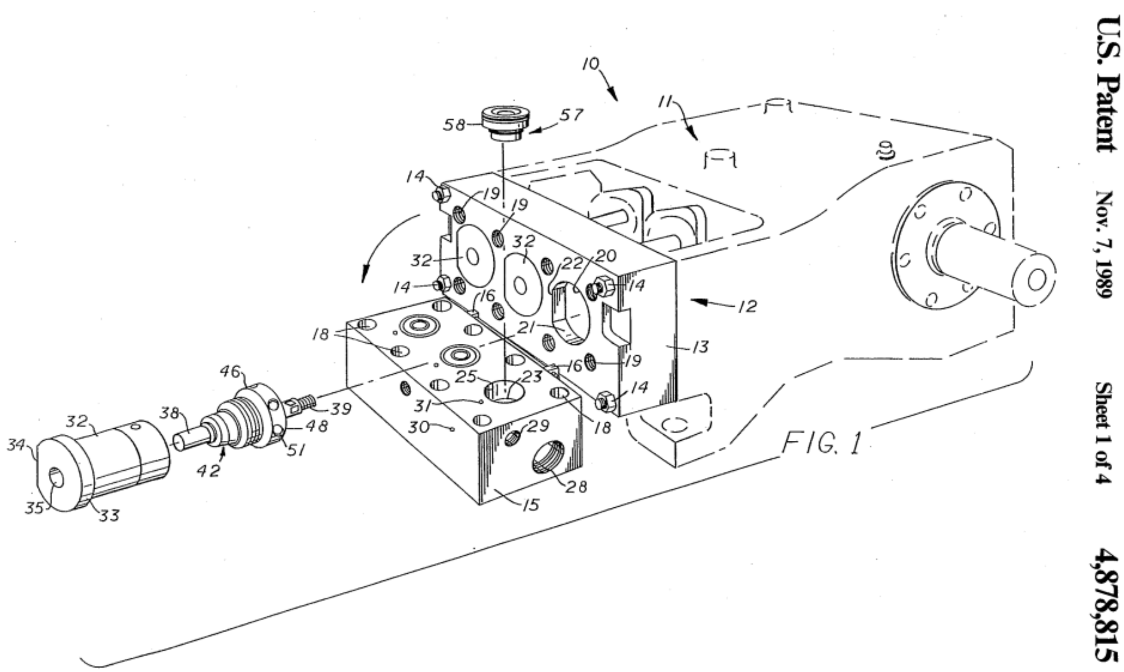

Figure 2 - UNx Fluid End

While valve improvements were continuing to advance, simultaneous advances were being made with packing seals. Of all the expendable wear items that construct a reciprocating power pump, the packing elements are the most prone to damage and replacement. Initial designs for reciprocating pumps were of the form of braided cotton rope, then interlocking square braiding with more advanced materials, such as Nylon fabric. The square cross section was formed into a ring and during operation, the sharp 90-degree corners deformed into the inner and outer diameter gaps between the plunger and the stuffing box, respectively.

Universal Packing & Gasket, now called UTEX, was instrumental in the early development of high-pressure reciprocating pump packing seals. By the mid-1960's, the benefits of stacked "V" ring seals were understood, but the use of a back-up ring made of harder material to prevent extrusion was first starting to become known. (USA Patent No. 3094337, 1963) In addition, the company developed some of the first lip seals for use with reciprocating power pumps, called the J-Design 838. (Anonymous, 2023) At the time, these seals were classified as noncrushable or nonadjustable packing. The design was unique because it was a molded ring of a Nylon impregnated with a nitrile elastomer that extended radially, both inward and outward. This configuration took advantage of the sealing characteristic known about the V-ring even further. See Figure 3(USA Patent No. 3120960, 1964) The design allowed an axial force imposed on the sealing ring to have minimal effect on the two sealing lips. The sealing ring could be clamped tightly without effecting the sealing force between inner lip and the plunger. This allowed the stuffing box gland nut to stay tight at all times without adjustment. (Henshaw, 1987) UTEX continues to develop reciprocating pump packing seals with some of the latest advancements continuing to build on the original J-Design 838.

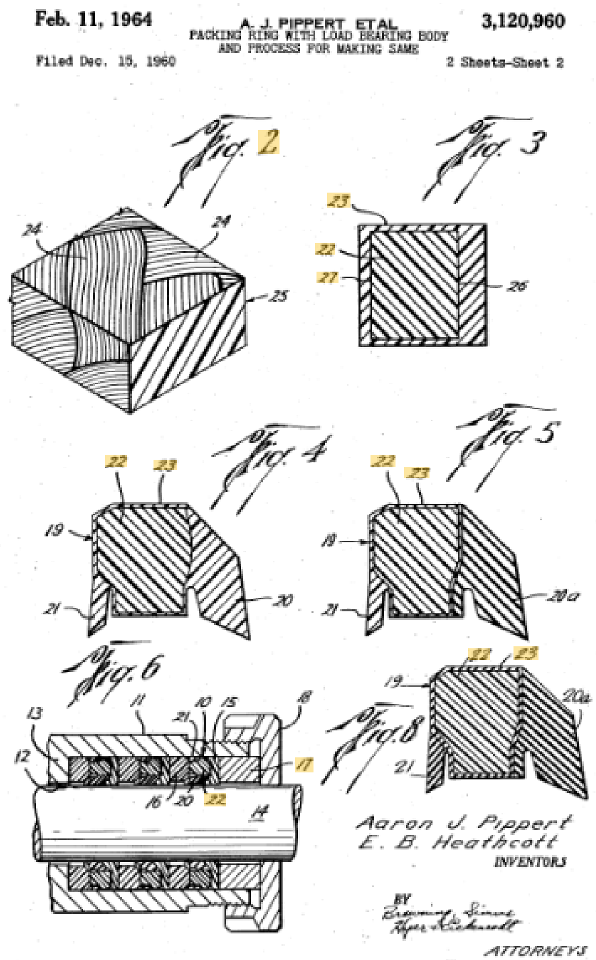

Figure 3 - UTEX Lip Seal

Plungers are yet another high wear item due to the sealing friction of the packing. Plungers can be made of ceramic, tungsten carbide, or a litany of other base materials and coatings that provide a smooth, hard surface for the packing to seal against. Ceramics have the greater performance advantage for use as plungers because they are corrosion resistant, have high hardness and can be polished very smooth. However, ceramics are brittle and costly, therefore many operators prefer tougher, lower range performance at a lower price.

Similar to plungers, many powerend advancements for reciprocating pumps were more adaptive than developmental. As the demands grew for delivering greater volume at plateau pressures, so changed the metallurgy of the rods and crankshafts to take the higher loads. Earlier metallurgical advancements, particularly in internal combustion engines, allowed pump manufacturers to adapt existing technologies such as higher strength alloy steels, forgings, and advanced heat treatments rather than having to develop the technologies themselves. However, there are certainly unique features about reciprocating pumps, such as the variable speed of the crossheads, pony rods, and plungers. Their speed at mid-stroke is greater than their speed at the ends of the stroke and this phenomenon causes pressure pulsations in the fluid called acceleration head. (Henshaw, 1987) The severity of pressure pulsations is dependent upon system variables, such as flow friction, which itself is dependent upon several factors. Perhaps this is one reason waterblasting equipment suppliers generally provide complete units to their customers.

Pumps paired with engines offer specific drive ratios, sufficient suction pressure, and take full advantage of a complete system design to optimize pump performance. Other challenges, such as lubrication constraints, pump over-speeding, and crankshaft side loading are constant reminders that pump applications in waterblasting are unique and allowed for specialization. A good example of this trend in specialization was the first 40,000psi pumping unit, offered by NLB in 1985. (NLB Corp, 2023) The launch of NLB's 40K unit set a new pressure plateau for others to follow.

New Jet Technologies shadowed NLB using a Hughes powerend. They were able to design a fluid end in the 125hp range that developed 4.2gpm at 40K in 1995-1996. (Gracey, 2006) Flow continued to increase as the company focused on increasing the speed of the pump to 750rpm. New Jet's design was unique by developing a reduction drive that allowed the capability to bolt directly on to an engine. The new drive allowed a smaller unit footprint with fixed alignment. Further, they used a pressurized and filtered lubrication system that extended the life of bearings.

In 1999, Jetstream also developed 40K fluid end adaptable to the original UNx technology. The most significant change was the reconfiguration of the valve cartridge, which put the suction valve outside the discharge valve. Similar to New Jet, Jetstream initially developed several fluid end conversions with existing brands of powerends. The success of these fluid end conversions provided a segue for Jetstream's own internally developed powerend. The first offered a three-inch stroke, the 3000, quickly followed by the 4200, with a 4.2-inch stroke. Both pumps are still offered, along with three addition pumps ranging from 75-700hp, in plateau pressures of 15,000, 20,000, and 40,000psi.

Hammelmann was the first company to offer a reciprocating plunger pump capable of sustained pressures of 3,800 bar. (55,000psi) The first Hammelmann pump to offer this pressure was well over a decade ago. Today, many of their pumps in the HAMPRO series offer operating pressures of up to 4500 bar (65,267psi). (Hammelmann, 2023)

While there has been continuous growth in waterblasting applications, many equipment suppliers do not encounter enough commercial opportunity to continue developing pumps into the 55K pressure realm. In fact, most equipment today is sold between 15K and 20K, so even the 40K pressures have limited applications. Still, higher pressures have always been at the forefront of new equipment offerings. Applications always develop after the advancements in technology that provides an ability for pumps to function at higher pressure with greater flow. Market growth for 55K plus pressure applications will continue in the future, most likely in ways unforeseen.

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