The MAXINOZ rehabilitation tool from Etschel Brunnenservice is prepared for an outside test run.

High-Pressure Impulses for Well Development and Rehabilitation

A fast way of getting things done effectively without the use of chemicals.

By Don Baron and Leonard R. Etschel

High-pressure water jetting since the early 1960s meant $^{3}/_{16}$-inch up to ½-inch-diameter drilled holes into a coupling with a smaller hole in the bottom, with the design later including prefabricated nozzles, normally four per single row.

At a maximum output of 100 GPM and 250 PSI discharge pressure, each nozzle had a jetting velocity in the range of 200 feet per second (fps). Attached to drill rod, these tools rotated 10-50 RPM while traveling slowly up or down selected well screen intervals.

The secret to a successful well cleaning was to simultaneously jet and pump the well, thus removing solids and drilling fluids from the initial drilling process.

If one injects water into the well, the well's static water level (SWL) rises, creating a positive hydraulic head or mound effect which tends to push water away from the well screen assembly and out into the formation. When a depression pump is installed above the jet and is pumped at a rate greater than the injection rate, those well screen flows will go in reverse whereby bentonite and solids will be drawn out of the formation and filter pack and into the wellbore pump. With that pumping water level below that original SWL, more water is being discharged than injected.

The problem that may arise with this is the competition for space within that borehole. In some cases, a drill rod inside a well casing may not allow enough space for the submersible pump, cable wire, or even a 1-inch-diameter airline pipe.

In other cases, a 1-inch or 2-inch airline pipe may be the only solution for that confined space. Depending upon static water level and anticipated pumping rate, the airlift method may not be practical.

Many times, the water jetting operation did not have any

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water withdrawal method, so solids returning into the well would be removed after the jetting tool was extracted. This jetting method may be adequate but is not ideal. Without a means to extract solids, that jetting device with sediment-filled water in the screen area may have acted like a liquid sand blaster to the metal screens and casings, causing slot erosion and continued sand pumping problems due to well screen and pipe damage.

Subtle Changes Come

Within the last 15 years, a subtle change has been made in industry terminology. The former high-pressure water jetting term is being relegated to jetting with water and "high-pressure water jetting now means pressures up to 10,000 PSI and sometimes more with velocities up to 1000 fps." (*Groundwater & Wells*, Third Edition)

This jetting method may now have the power to penetrate the filter pack, break down the skin layer (barrier or mud wall) on the face of the borehole, and penetrate the mud-invaded zone (invaded into aquifer before the mud cake was formed) beyond the borehole.

That high-pressure water jetting beam may also now be from a self-rotating nozzle for continuous horizontal water jetting into the well screen or a stationary jetting nozzle. The 10,000 PSI pressure value is gauge pressure and represents pressure inside the jetting tool assembly and piping equipment. The pressure at the nozzles may be less than this gauge pressure due to differential head pressure from submergence and friction losses, depending on the hose or pipe diameter and length.

In water jetting and high-pressure gas impulse wave generation, both are being used in initial well development, redevelopment, or well rehabilitation. Due to the nature of these new development and rehabilitation tools, they are now being designed for more specific screen variations, diameters, slots, materials, and aquifer types.

It develops quicker for better efficiency. It completes the well development or rehabilitation process within hours rather than days.

This approach thus maximizes and focuses that energy where it is needed most. Both jetting and gas impulse methods may be effective removers of bentonite and solids in the screen area and most of the filter pack when penetrating from a single plane. Depending upon filter thickness, mud wall or skin barrier, and invaded zone, some methods may have serious energy loss penetrating within that filter media material and beyond.

High-pressure gas impulse and percussion methods are used in well rehabilitation. The gas impulse uses compressed gases to discharge up to 4000 PSI with an impulse every three to five seconds. It generates an ultrasonic wave with a frequency in the 20-25 kHz range.

The percussion method, used primarily in rehabilitation,

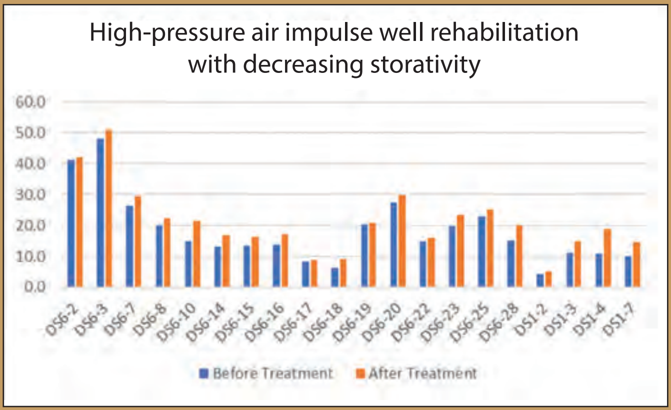

Figure 1. The average increase in specific capacity is about 22% in 20 wells, using the high-pressure gas impulse rehabilitation method.

detonates a frequency wave in the 20-40 Hz range, and it may generate supersonic type waves. The percussion needs a detonating cord which gives a mild harmonic frequency shock wave by a series of three or more explosions at about 100-millisecond intervals.

One limiting factor with the sonic wave motion is its effective depth of penetration. This depth of penetration may be in the 25-35 cm (10-14 inches) range. Therefore, it is recommended to surge this well with a tightly fitted dual-swab surge block afterwards to help draw the dislodged material out of the filter pack and into the bottom of the well where it can be removed by airlift, bailer method, or other means.

Studying Completed Projects

All treatment types have certain projects with exceptional specific capacity results after completion, but Figure 1 (and later Figure 2) is an example of various specific capacity summary changes before and after 20-well and 10-well rehabilitation project completions.

The October 2019 article, "High-Pressure Air Impulse Technique for Rehabilitating Well and Its Application to a Riverbank Filtration Site in Korea" (*Journal of Environmental Science International*) is an interesting report reviewing high-pressure gas impulse results.

Before and after treatment results for transmissivity, storativity, and specific capacity were recorded. Select before and after results for specific capacity values are plotted in Figure 1. Two-thirds of the 33 wells had storativity data values decrease after high-pressure gas impulse treatments and one-third of the wells had storativity data increase after treatment completion.

The increased storativity or specific yield in an unconfined aquifer cannot be greater than its porosity. Therefore, one-third of the wells with increased storativity or specific yields close to or greater than porosity were not plotted in Figure 1.

In the wells where the storativity or specific yield (SY) decreases, it should indicate that the specific retention (SR) should then increase if porosity (P) has a near constant value (SY + SR = P).

When high-pressure air impulse occurs and it decreases storativity or specific yield, some fines may not be removed during and after treatment but may become lodged farther

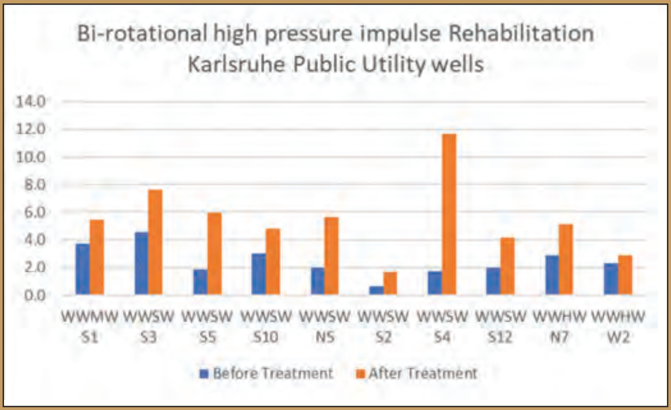

Figure 2. Before and after treatments using bi-rotational high-pressure impulse water jetting.

Figure 3. The rotational unit has two rotation heads with two nozzles each.

into the aquifer where specific retention is increasing. With an increase of fines into those pore spaces, capillary attraction from fines should then attract more water to cling to the sand grains, thereby increasing that specific retention.

Even with an increase in specific capacity immediately after treatment, those high specific retention areas may then become sites for future rehabilitation efforts. This then means that the next rehabilitation event may occur as a more frequent event than originally anticipated.

As with the high-pressure gas impulse, water jetting methods should rely on pumping, airlift assist, or double disk surge blocks to remove bentonite and solids from the system after water jetting is completed.

For whatever rotating high-pressure jetting system is used, careful consideration for the rotational bearing assembly is important for long-term continued success. Personal communication with the user of both a single beam and bi-rotational double beam high-pressure water jetting system, it appears that the bi-rotational, two-tier type system appears to have superior bearing assembly as compared to conventional high-pressure jetting systems.

In Germany, a bi-rotational movement in two planes rather than one was developed in the 1990s. The German Technical and Scientific Association for Gas and Water (DVGW), a similar organization to the National Ground Water Association, invited companies at that time to a test site at the German Groundwater Research Center in Dresden, Germany.

A test stand was built incorporating well screen, gravel pack, and aquifer. Sensitive transducers were added to screens, the middle of the gravel pack, the borehole wall, and another three in the aquifer. The penetration depths were measured to determine effectiveness through all these barriers into the aquifer. Any velocity variables were also measured.

The results were published in a huge study called “DVGW W 55/99” in 2003. The results showed a clear difference between the efficiency of all the methods available and led to a new publication (“DVGW W 130”) in 2007. In a comparison of all available methods, the high-pressure impulse process achieved outstanding results in terms of efficiency.

This technological advantage had already been confirmed several times by independent authorities, making it the market-leading technology in Europe for almost three decades.

In comparison to the high-pressure gas impulse model, Figure 2 shows the results of a bi-rotational high-pressure impulse process project. The wells were in the Rhine River Valley and had heavy biofouling problems. Their average depth was 120 feet and diameters ranged from 16 inches to 32 inches. The average specific capacity increased about 152% using this jetmastering process with the high-pressure impulse bi-rotational movement.

Using Impulse Waves

In a bi-rotational, high-pressure impulse water jet (Figure 3), there are two bi-rotational (or oppositely driven) heads rather than one rotational head. Each nozzle uses up to 12 GPM of water at 590 fps exit velocity. This 8000 PSI pressure system has counter rotation up to 7000 RPM.

Each nozzle pair travels in the opposite direction due to a recoil effect. At 7000 RPM, the nozzles do not create a water beam but generate a high-pressure impulse wave similar but stronger than the gas impulse and percussive methods.

The high-pressure impulses penetrate farther than the gas. Horizontal penetration occurs up to 6.5 feet laterally, through the filter pack, into the invaded zone, aquifer, and beyond.

When jetting wells with the high-pressure impulse process, it loosens drilling deposits, breaks down solidified deposits, has power to reach the entire filter pack and beyond, and cleans the whole area during the same pass. With all four nozzles working in two planes, a 24-inch section is simultaneously treated whereas a much smaller section is treated using the high-velocity jetting beam.

It develops quicker for better efficiency. It completes the well development or rehabilitation process within hours rather than days, saving money and suitable for all filter medias.

With the bi-rotational direction of each nozzle pair, its high-pressure impulse is more than four times greater acceleration than the ordinary high-velocity water jetting units. This is the case even with those higher-pressure advertised (10.000-20,000 PSI) output.

This high-pressure impulse method creates continuous im-

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Figure 4. The upper half of this low open area bridge slotted pipe was rehabilitated with the high-pressure impulse process.

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pulses superior to ordinary gas impulse units to remove debris in less time than the other units. It is also safe to be used on PVC slotted screens without the damage other water jetting can do.

These high-pressure impulses cause the filter pack to vibrate. Soft and hard deposits break down and are pulverized by its abrasion (Figure 4). Therefore, chemicals may not be necessary to rehabilitate that old well.

Many people are reluctant to allow the use of harsh chemicals into their wells, and they also do not like the hazardous bi-products and costs associated with their removal.

"That's why customers are asking for this new green technology to be used in their wells," says Roger Russell of Russell Drilling Co. Inc. in Nacogdoches, Texas. "We intend to set a new standard here in Texas with this very advanced technology."

Between the two rows, above and below the two-counter rotational elements, a low-pressure area or suction zone draws loosened deposits, debris, or other solids back into the well. These low-pressure areas are unique to this type of high-pressure impulse process. The suction zones occur due to this counter rotational design. A submersible pump is recommended to simultaneously remove solid matter from the wellbore as the suction zone pulls debris into the well.

The percentage of solids versus total water discharge can easily measure whether that interval needs more work or if it is fully developed. When taking samples at regular intervals, one knows immediately when the well is fully developed or rehabilitated. Substituting an airline makes the analysis of this operation more difficult but it still can be accomplished by measuring output in gallons per minute with a difference in differential line pressure to achieve a comparison specific capacity.

What Users Think

Each unit can be individually adjusted for any well diameter and material. The rotary heads are always at the ideal distance from the filter. This is critical to achieve maximum depth effectiveness for each well.

"The pressure, size of nozzle, nozzle exit velocity, and angle, moving speed, and withdrawal speed are widely adjustable to allow use in a wide range of well intake types. This includes wooden stave and glued or sintered pre-packed screens, slotted pipe, PVC, louvered and wire-wound screen," says Stuart A. Smith, MS, CGWP, a consulting hydrogeologist with Ground Water Science in Poland, Ohio. "Based upon available background information, rapid results are possible with the high-pressure impulse water jetting process."

Dwayne Graff of Well Initiatives Ltd. in Ontario, Canada, says, "I have had my eye on this technology for several years and always felt it was the right tool for the job. We understand the value of jetting in difficult formations and will often utilize our drilling rigs to assist in new development and existing well rehabilitation. Once I understood the science behind this high-pressure impulse water jetting technology, I knew immediately it has distinct advantages over other existing similar technologies."

Graff adds that the main advantages of this technology are: "Rapid results, scientifically documented case studies, no hazardous chemicals needed; it can be used on any well construction, and patented and license-protected technology.

"As an added benefit, this tool excels at cleaning casing scale from older wells, facilitating the ability to properly inspect the well casing for deterioration/failure."

A development project, re-development project, a rehabilitation project, or chemical treatment project is now much more efficient. The chemical rehabilitation project taking many days now takes a fraction of the time without the chemicals and typically with better results.

In the 40-gallon reservoir tank, either chlorine or bentonite thinning chemical can be easily added and injected under high pressures with remarkable end results, says Don Smith of Donald Smith Co. Inc. in Headland, Alabama.

"This has saved weeks of work for my crew on one job alone," Smith says, compared to the older method of swabbing in deep, difficult-to-develop wells.

Using the high-pressure water impulse has significantly increased Smith's employees' efficiency in the field when jetting wells. Not only are his customers happier with the results of higher specific capacities, but he can sell his service at a premium. WWJ

Don Baron is the managing director for JET-Master in the United States and Canada. His responsibility is to promote and sell the JET-Master brand of high efficiency after well completion equipment. Previously, he spent more than 43 years with Johnson Screens.

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