# Well development with newly developed nozzle rotation unit MAXINOZ® shows significant increase in efficiency


*Figure 1: Construction site Donauried*

**Practical test for well development on 6 renovated wells using the HPI-process with high water pressure delivers trend-setting results**

Donauried in Württemberg is one of the most important groundwater reservoirs in the state. It holds about one billion cubic meters. The water reservoir, which is filled in the winter half of the year, is available during the hot summer months to cope with high water demand.

The groundwater from the Donauried represents the most important pillar for the supply of drinking water to the members of the association of the state water supply of Baden-Württemberg. The central distribution and treatment in case of need is carried out by the Langenau waterworks. The groundwater in Donauried in Württemberg has its catchment area on the plateau of the Schwäbisch Alb northwest of Ried. The precipitation seeping into the Schwäbische Alb flows into Donauried in widely ramified underground crevices and fissures. The mean age of the limestone groundwater aquifer in the Donauried is about 12 years [1].

The state water supply of Baden Württemberg operates 204 wells in the local catchment area of Niederstotzingen near Ulm. The wells are divided into six catchment zones. The 49 wells of the first catchment were drilled in the years 1912 - 1913 and were already in operation since 1916. The dimensioning (1000/500) probably stems from the earlier view that wells with a relatively small aquifer must have a large bore diameter - as a "storage volume", so to speak. For more than 100

For over 100 years these wells have been supplying up to 800 l/s of water, using the energy-saving siphon principle. This siphoning principle does not require well pumps once the water has been sucked in, thus saving enormous operating costs. Preliminary investigations on these wells of the 1st catchment resulted in severe corrosion damage to the screens and casings (Fig. 2).

*Figure 2: corrosion damage*

**National water supply is a major well operator**

There was therefore a need for action to prevent the production wells from collapsing. After weighing up the two restructuring options a) cost-effective restructuring by means of insertion so called inliners and b) complete restructuring by means of over-drilling and new construction, the state water supply authority decided to implement option b for these already proven century-old structures [2].

**Tender**

After a nationwide invitation to tender, the most favorable bidder, Eder Brunnenbau GmbH, Hebertsfelden, was awarded the contract for the general sanitation of 23 wells in zone 1. The method used for the well development was the high pressure impulse process with high water pressure, combined with subsequent sectional surge plugging according to DVGW W 119. The company Etschel Brunnenservice was commissioned as subcontractor by the company Eder to carry out the well development with the HPI-Process® and the final CCTV acceptance tests. The execution period was fixed for the years 2012/2013.

**Preliminary remarks:**

During the development and rehabilitation of wells it has been observed that the methods commonly used up to now, such as brushing, swabbing, shock pumping and/or surge plugging according to DVGW W 119 (2002) and common jetting processes are often not sufficient to optimally develop a newly constructed well or to optimally rehabilitate an older well. However, in the case of pure rehabilitation, it is not always necessary to reach deep into the aquifer, but only in the case of deep-seated ochre formation or silting up, and only with the effect of the equipment components used. In many cases, penetration depths of a few centimeters are sufficient to remove the solids that reduce the inflow. In contrast, in the case of well development, and where a well is redeveloped, a few centimeters of penetration depth are not sufficient to optimally develop or redevelop the well. In practice, this has also been demonstrated by combinations of different processes and equipment components.

This insight prompted the ETSCHEL development team to think about how to optimize development effects.

According to DVGW W 119, the nozzle rotation unit (called "UNINOZ®" at ETSCHEL Brunnenservice GmbH), which has been generally standard up to now, in combination with the JET Master®, is a well development device with "generation of high pressure impulses by means of high water pressure" (Fig. 2).


*Figure 3: The ETSCHEL **JET Master®** in action on a construction site.*

It is well known that between the nozzle arms, which rotate in opposite directions at high speed due to the backstroke, an underpressure is created in relation to the water space above and below the pairs of nozzles. It is also known that cavitation occurs between the two nozzle bodies at very high pressures. This was made visible in tests, proven and documented on video by a neutral body under the supervision of a DVGW certifier [3]. Each of the above-mentioned phenomena is individually or jointly capable of hydraulically separating the area above and below the nozzle pairs.

Our development team's considerations were aimed at the new development of a nozzle rotation unit which is able to penetrate the space between the nozzle pairs in such a way that a larger negative pressure area is inevitably created and at the same time a deeper penetration of the impulses into the gravel pack and the aquifer close to the well is made possible. Therefore, the angle of the nozzles should be adjustable so that it can be individually adapted to the geometry of the screen material in order to generate deeper penetration depths of the high pressure impulses.

The result of this innovation is the newly developed and meanwhile patented nozzle rotation unit brand name MAXINOZ® [4].

This new nozzle configuration was now to be tested in a series of experiments for well developments in order to prove its significantly increased efficiency in practice.

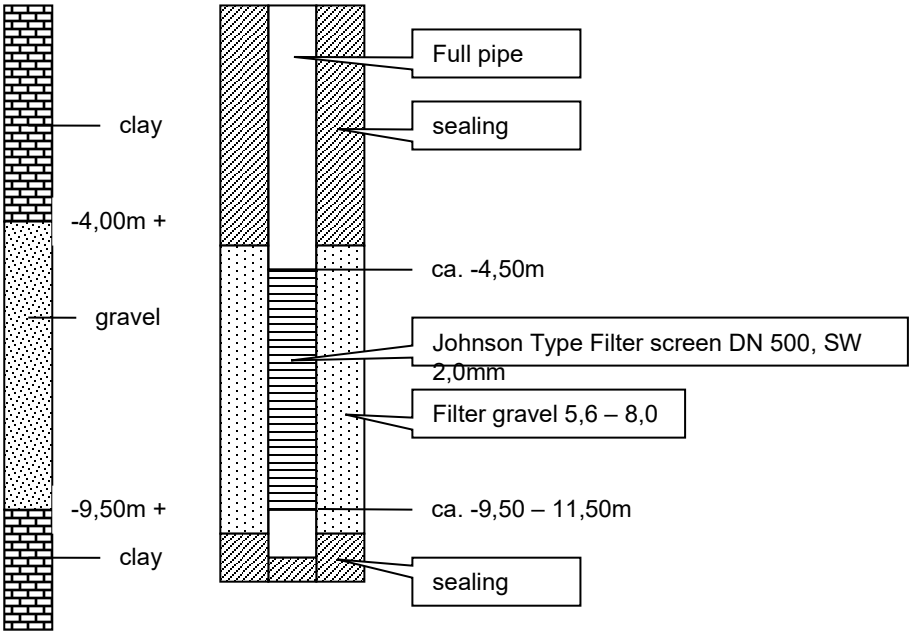
The purpose of the tests described below is to compare the differences in efficiency of the standard nozzle rotation unit UNINOZ®, which has been used for more than 20 years to carry out the HPI-Process with high pressure water, and the newly developed nozzle rotation unit MAXINOZ®. The results of this practical comparison test are described below.

**Comparative field test at six wells...**

The practical comparison test was carried out on six wells lying in a row with the numbers 1814 to 1819. For the best possible comparability, the wells 1816, 1818 and 1819 were developed with the previously standard HPI-Process UNINOZ® and the wells 1814, 1815 and 1817 with the newly developed HPI-Process MAXINOZ®.

The treatment of the wells with the JET Master® (Fig. 3) was carried out directly after the well sanitation, before any kind of pumping took place. Afterwards, the company Eder carried out surge plugging with variable pumping quantities.

As there are no absolutely identical wells in terms of their layer structure, the geological conditions are nevertheless comparable. The six wells No. 1814 to 1819 selected for comparison have almost the same layer structure. All wells were equipped with V4A Johnson Type filter screens DN 500 with a slot width of 2.0 mm and gravel packs of 5.6 - 8 mm (Fig. 4).




In the following, the well numbers treated with the conventional rotary nozzle configuration UNINOZ® are marked with the suffix "U" and those treated with the new rotary nozzle configuration **MAXINOZ®** are marked with the suffix "M". Both configurations work with the **High Pressure Impulse-Process®** with high water pressure.

First of all, the old wells, which had been removed and were equipped with steel slotted bridge filters, were overdrilled and rebuilt by the EDER company, Herbertsfelden with excavator and piling machine, DN 1000 piles.

**Overdimensioning of the filter gravel pack makes development difficult**

It should be mentioned that the dimensioning of the wells (1000 mm bore diameter to 500 mm filter screen diameter) significantly impedes any development. To be able to treat the extremely thick (250 mm) layer of filter gravel (see W 123) sufficiently effectively even into the aquifer is a challenge for equipment and procedures. When using the JET Master®, all six wells were pumped out simultaneously at 25 l/s.

## Effective well development with new nozzle rotation unit MAXINOZ®

### 1. Developing with HPI-Process using high pressure water

| Well Nr. | System | Sand in ltr. | Time to termination criterion |
|---|---|---|---|
| 1816 U | UNINOZ | 16 | 90 min. |
| 1818 U | UNINOZ | 16 | 90 min. |
| 1819 U | UNINOZ | 9 | 90 min. |
| average | | 14 | 90 min |
| | | | |
| 1814 M | MAXINOZ | 207 | 75 min |
| 1815 M | MAXINOZ | 103 | 120 min |
| 1817 M | MAXINOZ | 99 | 120 min |
| average | | 136 | 105 min |

*Table 1: Desanding with different methods*

Table 1 clearly shows that with the newly developed MAXINOZ® rotary nozzle configuration, in average, 10 times as much sand and undersize particles could be removed from the wells as with the conventional UNINOZ® configuration.

The reason for this is the significantly greater depth effectiveness of the "MAXINOZ® rotary nozzle configuration through the gravel pack into the aquifer.

It can be seen: The rotary nozzle configuration "M" surpasses the previous variant "U" and desands much deeper into the aquifer. It is therefore better suited - especially under the given well dimensions - to develop an extended, natural filter gravel grain structure at the transition from the borehole wall to the existing aquifer.

When using the **HPI-Process®** with high water pressure, the new rotary nozzle configuration "M" should preferably be used for future desanding and development work on similarly dimensioned wells, based on above findings.

The evaluation of removed sludge parts was waived, since these are very probably not of natural

origin, but rather result from removed skin (filter cake, clay carry-over during piping). This skin is formed when clay particles are carried away by oscillating the auxiliary piping during drilling, once downwards and then again upwards when it is pulled. However, the high sludge content shows the strong destructive effect of MAXINOZ® on the skin.

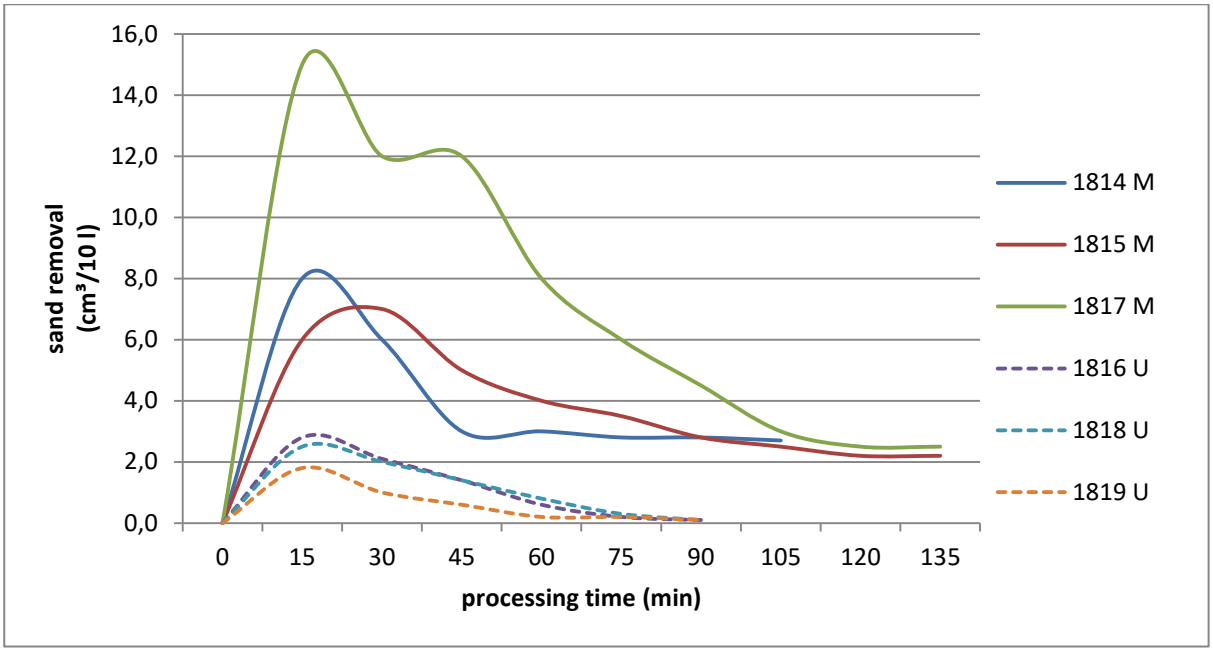



*Table 2: Sand removal in the different wells through the treatments MAXINOZ®=M and UNINOZ®=U*

The low and almost congruent values of the dashed curves (Fig. 6) for the 1816 U, 1818 U and 1819 U wells also show the much lower depth effectiveness of the conventional UNINOZ® rotary nozzle configuration. Only "apparently" is a termination criteria according to W 119 reached after about 75 minutes. This is because desanding deeper into the aquifer does not occur with this conventional standard configuration.

**New MAXINOZ® rotational unit achieves far greater depth effectiveness**

In reality, with the much greater depth effectiveness of the MAXINOZ® rotary nozzle configuration, sand can be removed far deeper into the aquifer, thus developing a "natural filter". If you had continued to jetmaster for more than 135 minutes, you could have removed much more sand - already during jetting. It may be assumed that the subsequent "partial desanding" would then have been unnecessary.

It is noticeable that the brown and blue M-curve are almost congruent, while the green M-curve shows much higher sand values. Apparently this is due to higher sand content in the geology near Brunnen 1817 M. Also the dent in the curve at about 30 minutes suggests a spontaneous improvement of the path after the first 30 minutes. This is probably the reason for the increased development and is probably due to the breaking of the skin.

**Conclusion Development by HPI-Process®**

In the development of wells that are as extremely dimensioned in terms of filter gravel bulk density as in Niederstotzingen, treatment using only the conventional - previously generally used - UNINOZ® rotary nozzle configuration is no longer as effective. In any case, under these circumstances - if technically possible - a secondary desanding with a greatly increased pumping quantity is recommended (see later under "Partial desanding").

With the newly developed **MAXINOZ®** rotary nozzle system, jetmastering should be applied longer in the future. However, it is certainly possible to do without "partial desanding" like surge plugging in many cases. In this case, it will no longer result in a significant (measurable) improvement of the well performance in relation to the benefit to cost ratio.

**2. Re-development through sectional surge plugging**

Due to the similarity, only two randomly selected depth steps from the lower filter string segment are used for evaluation here, namely between 8 to 7m (Fig. 7) and 9 to 8m (Fig. 8).

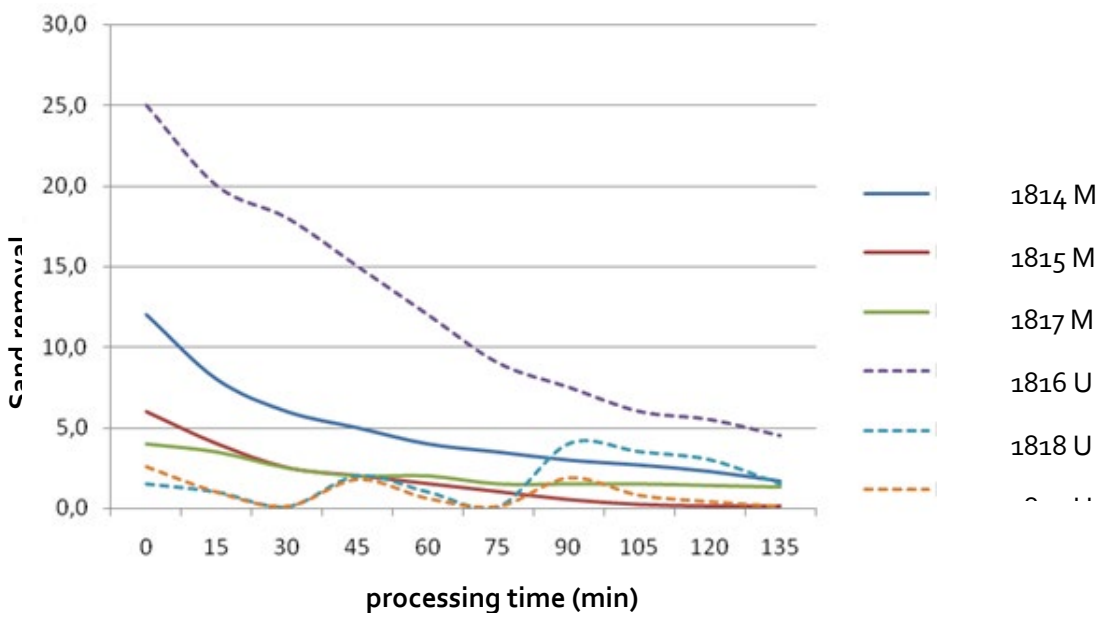



*Table 3: partial desanding by surge plugging, 8-7m*

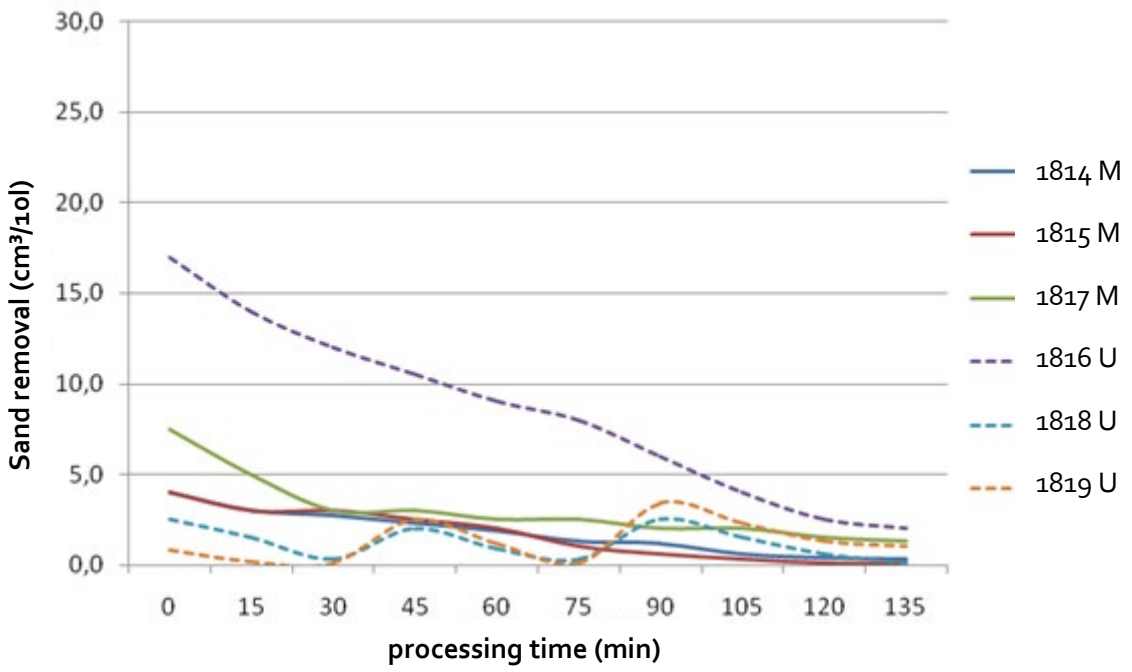



*Table 4: partial desanding by surge plugging 9 - 8m*

At well 1818 U, the partial desanding was carried out with first 10, then with 25 and then with 40 l/s, at 1819 U at first with 15, 30 and then with 50 l/s. As this procedure proved to be unsuccessful, wells 1815 M and 1817 M were desanded with 40 l/s (according to the calculated specifications of W 119).

At well 1814 M the desanding was carried out with 50 l/s (i.e. 25% more than W 119 proposes!), at well 1816 M U - due to favorable hydraulic conditions at the well - even with 60 l/s (50% more than W 119).

Due to the different treatment quantities, a direct comparison of all curves is now unfortunately not possible.

Nevertheless, the curves from the diagrams shown above can be evaluated individually:

**Curve 1818 U and 1819 U:**

A gradual treatment with too small quantities (10 / 15 and 25 / 30 l/s) is generally not useful. Even with 40 / 50 l/s no reasonable desanding result can be achieved.

**Curve 1816 U:**

This curve also clearly shows that the standard rotary nozzle configuration "U" is not able to penetrate deep enough into the aquifer at the given well dimensions.

Furthermore it clearly shows the much more favorable depth effect at 60 l/s (pumping rate increased by +50% compared to W 119).

**Curves 1814 M, 1815 M and 1817 M:**

The curves show that - after the "pre-development with the JET Master® and the new MAXINOZ® rotary nozzle configuration - only a small additional development effect can be achieved in "partial desanding" by the use of surge plugging with the pumping quantity provided for in W 119, or increased by only 25%.

Also, with "Partial Desanding", the termination criterion (0.1 cm³/10 liters) according to W 119 can only "apparently" be reached after about 60 minutes. The other curves were not drawn further after 135 minutes, because here finally the comparison to jetmastering had priority. The partial desanding was in fact carried out at all depth levels up to the termination criteria of 0.1 cm³/10 litres, which took several hours.

**Resume**

The treatment of wells which are as extremely dimensioned as in Niederstotzingen, a "partial desanding" by the use of surge plugging only with the pumping quantities provided in W 119 (2002 edition) is not reasonable.

If the well hydraulics (draw down / pumping quantity) allows it, however, a "Partial Desanding" with at least 50% more than the quantity required in W 119 (2002 edition) – applied after jetmastering with the Maxinoz® rotary nozzle configuration - can be useful.

It would be even better to use a pump with at least 50% above W 119 (2002) during carrying out the HPI-Process®. However, this will often not be technically possible because the well hydraulics do not allow for that.

The "remarkable fine grain discharge (...) (desanding effect)" [5], which the **JET Master®** was already certified by the DVGW in the research project W55/99 as the only rehabilitation system, could also be more than confirmed here. All in all, the new **MAXINOZ®** rotational unit is a forward-looking innovation that leads to significantly better well development results for loose rock wells.

**Thank you**

At this point we would like to thank all participants for giving us the opportunity to test our newly developed **MAXINOZ®** rotary nozzle configuration in practice. A special thanks goes to the state water supply of Baden-Württemberg represented by Mr. Dipl. Ing. Rainer Scheck for his innovative spirit. We would also like to thank the well construction company EDER for their professional cooperation during the tests and for providing us with the reports on partial desanding.