

Newly constructed nozzle rotation unit MAXINOZ® shows significant performance increase at mechanical well rehabilitations



Figure 1: Etschel JET Master® (r) and TV Master (l) in Action

Practical test on ten wells with different screen materials of the city of Karlsruhe shows way above average rehabilitation results

Public utility Karlsruhe is a water supplier with responsibility

With the Karlsruhe public utility company pumping up to 23 million m³ of water per year, high standards are set for perfect groundwater pumping and treatment. Divided into four waterworks with a total of 64 wells, between 70,000 m³ and 90,000 m³ a daily consumption is ensured. Much technical effort, to ensure the protection of groundwater within the five water protection areas, which cover an area of 183 km², is a basic requirement (Fig. 2).

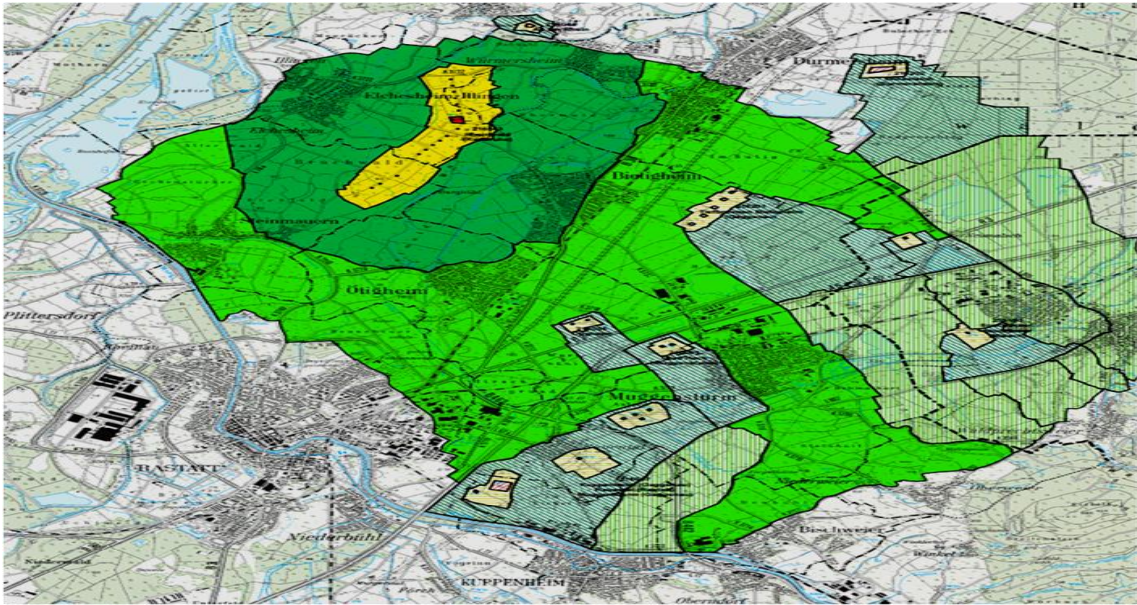


Figure 2: water protection areas near Karlsruhe

Nowadays, the complete control of the waterworks and thus also the operation of the wells is operated from a central point in a highly modernized way. Precise monitoring and documentation also provide information about wells that are losing their performance over the years and need to be promptly rehabilitated. However, a detailed examination of the processes that reduce the performance of the wells themselves is essential. For this reason, and also because of the large number of wells, Stadtwerke Karlsruhe has put together its own camera equipment and technology for carrying out geophysical measurements in order to document the ongoing process of well ageing and ochre formation in the filter area and to be able to intervene at an early stage.

The Rhine plain, a very special challenge

The "Oberrheingraben" is covered with very young sediments. The sand and gravel that make up the aquifer date from the Pleistocene ice age and from the present-day Holocene. In the area between Basel and Rastatt, groundwater covers three quarters of the population's drinking water needs and more than half of the demand for industrial water. Even irrigation by agriculture is almost entirely provided by groundwater. In the area around Karlsruhe, the Rhine plain is bordered directly by the Vogesen mountain range to the west and the Black Forest to the east. Like into a hopper, the raining precipitation from the

plateaus flows underground and over numerous streams and smaller rivers into the Rhine plain and feeds a huge groundwater aquifer.

The flow direction of the groundwater tends to be from west to east from the direction of the Vorgesien mountains and from east to west from the Black Forest. In the immediate vicinity of the Rhine river, the flow paths drop off to the north, thus following the natural gradient out of the low mountain range. The aquifer is made up of several layers of sand and gravel of different thickness and grain size. The trench filling is about 70 m (210 ft.) thick on average, in some areas up to 260 m (780ft.). It is therefore not uncommon for wells in the Rhine plain to be extended to a depth of up to 300 m (900 ft.). The changing layer sequences from coarse and fine sand to clay lenses have the effect that the wells are equipped with several filter sections. These sections optimally cut the water-bearing layers without introducing ultra-fine particles from less productive layers into the well. These wells require a high degree of preparation and technical equipment in order to be able to carry out the rehabilitation measure professionally.

Wells with history

The 8 wells rehabilitated here at the Mörscher Wald waterworks are constructed with stoneware and Johnson type filters from DN 400 to DN 600 with a maximum depth of 40 m (120 ft.) and filter sections of up to 25 m (75 ft.). The other two rehabilitated wells at the Hardtwald waterworks are constructed with stoneware DN 600 and coated bridge slotted filters DN 800 at a maximum depth of 37 m and filter sections up to 27 m (51 ft.). These wells are also quite old; the well with bridge slotted filter screens was already drilled in 1951, the stoneware well in 1966. With this pretty big well diameter of casing and filter screen, the wells of the Stadtwerke Karlsruhe are already among the heavyweights in well construction (Table 1).

A special feature that had to be included in the planning of this rehabilitation is the double gravel pack. Between the existing geology and the coarse filter gravel there is a finer filter packing, which is intended to create an improved connection to the aquifer.

well	WWMW S 1	WWMW S3	WWMW S4	WWMW S10	WWW W N5	WWW W S2	WWMW S4	WWMW S12	WWHW N7	WWHW W2
material	Johnson type	Johnson type	Johnson type	Johnson type	Stein-zeug	Stein-zeug	Johnson typ	Johnson type	Stein-zeug	Schlitz-brücke
Slot width	3,0 mm	3,0 mm	3,0 mm	3,0 mm	n.b.	n.b.	3,0 mm	3,0 mm	n.b.	n.b.
diameter	DN 600	DN 600	DN 500	DN 500	DN 500	DN 400	DN 500	DN 600	DN 600	DN 800
filter section	15+8 m	15+8 m	25 m	15+8m	6+5m	5+5 m	25 m	15+8m	27 m	7,5 m

A surface treatment of the gravel ring space is indispensable

The construction method was of decisive importance for the planning of a rehabilitation. It had to be handled with the greatest possible experience. As a performance-reducing process, an ochre formation by iron and manganese bacteria in the form of bushy growths was identified along the entire filter sections. Due to the high performance of 100 to 300 m³/h pumping capacity there is an increased mixing of near-surface oxygenated and deep oxygen-free groundwater in the upper area. The result is a microbiology that makes use of a conversion of iron²⁺ to iron³⁺ as a nutrient basis. Depending on the construction, well operation and groundwater quality, this process can be either faster or slower.

Newly designed MAXINOZ® nozzle rotation system

Over a period of four weeks at the end of 2015, these ten drinking water wells were optimized for the public utility Karlsruhe in terms of their specific yield. For the rehabilitation campaign, the High Pressure Impulse-Process with high water pressure according to DVGW W 130 was selected. With this method, a part of these wells was rehabilitated for the last time in 2005. At that time, these wells were still being rehabilitated with the conventional UNINOZ® nozzle rotation system. With UNINOZ®, the generation of the pressure wave impulses takes place at an angle of 90° to the filter screen material. In 2015 the new guideline "Saving costs and energy in drinking water supply" was published by the Bavarian State Office for the Environment in cooperation with the University of the Federal Armed Forces in Munich. The annex includes "case studies and best practice solutions". The "Best Practice" example "Introduction of a well management system to increase the energy efficiency of submersible pumps and to extend the lifetime of existing wells through rehabilitation" also deals with the topic of well rehabilitation.

An average performance increase of about 69 % was determined for the examined well rehabilitations using the High Pressure Impulse-Process with high water pressure [2].

The investigations were based on the UNINOZ® rotation system previously used for rehabilitation when applying the High Pressure Impulse-Process with high water pressure.

During the rehabilitation now carried out in 2015, the **MAXINOZ®** nozzle rotation system (Fig. 3), which has now been redesigned and patented, was tested in action.



Figure 3: MAXINOZ is ready for rehabilitation

The new design is a nozzle rotation unit with adjustable angles. The preset angle is no longer necessarily 90° to the vertical, but depends on the geometry of the filter screen material. The aim of the **MAXINOZ®** invention is to bring the pressure wave impulses into the gravel pack up to the borehole wall in a more targeted manner by adapting them to the screen material. The simultaneous pumping volumes (Fig. 3) were determined in advance in coordination with the operator between 130 m³/hr and 300 m³/hr and were oriented to the production capacity of the wells.

The pressures used varied between 280 and 400 bar (3.500-5.800 psi), depending on the screen material. Immediately after the installation of the new **MAXINOZ®** nozzle rotation unit and the effect of the High Pressure Impulses on the filter gravel pack, a rise in the operating water level was observed. If the operating water level rises while groundwater extraction remains constant, this is an indication of improved permeability in the filter area. In the course of the immediate increase in capacity, the discharge capacity was increased and resulted in a higher discharge of solids (Fig. 4 & 5).



Figure 4: Measurements can be taken at any time during the rehabilitation

Function of the JET Master® System

The purely mechanically rehabilitation process **JET Master®** is based on the generation of High Pressure Impulses by means of high water pressure. The high rotational speed of the two pairs of nozzles generates negative pressure below the lower and above the upper pair of nozzles. This causes that the solids in the gravel pack which are loosened by the High Pressure Impulses are simultaneously sucked into the well. The energy is thus distributed over the whole hole area evenly during the treatment, which is achieved by using 2 counter-rotating rotation unit with a total of 4 nozzles. The combination of High Pressure Impulses, vacuum generation, continuous up and down movement in the filter area and simultaneous pumping of the loosened solids ensures an optimum rehabilitation process. The new **MAXINOZ®** nozzle



Figure 5: Comparison of two measurements.

rotation unit worked during pre-cleaning without pumping at a low pressure of up to 200 bar (2.900 psi) and cleaned the entire casings from external deposits. In many rehabilitation processes (e.g. high-pressure jetting) the technical limits have already been reached at this point. However, the High Pressure Impulses are only reached at a pressure of at least 270 bar. These pressures (and higher) were generated during the subsequent rehabilitation process. The natural inflow paths are activated by the pressure. The drag forces generated above and below the rotation unit by generating a negative pressure transport the deposits, dissolved by the High Pressure Impulses, into the interior of the well. When the working pressure is built up between 270 and 550 bar (3.900 – 8.000 psi), the **JET-Master®** (Fig. 6) unfolds its depth-effective High Pressure Impulses.



Figure 6: The JET Master

These impulses have an effect even in areas of the geology beyond the borehole wall. In some cases, colmation effects from the time of new drilling more than 60 years ago have even been observed. By means of simultaneous groundwater pumping, through the submersible pump positioned just above the filter, the entire filter section remains in an active state and supports the discharge of inflow-reducing particles. The criteria of the

DVGW W 130 " regulations Separation - Discharge - Measurement" are simultaneously fulfilled by the **JET Master®** process in an excellent way. The process is finished as soon

as the termination criteria is met. It can be verified by continuous solids measurements on top of the well in regular intervals. This enables, that the shut down time of the well is as short as possible and the process as effective as possible. The well is now rehabilitated in the best possible way.

Results - Rehabilitation success

The rehabilitation results were recorded and documented in detail. The specific yield of the wells was determined by pumping tests before and after the rehabilitation. In some cases, the pumping tests were determined by measurements with the operating pump or by measurements with the rehabilitation pump under the leadership of the public utility Karlsruhe. The evaluation of the Stadtwerke Karlsruhe (Table 2) proves that at the ten treated wells an extremely high-performance increase of 152.5% on average could be achieved by using the **JET Master® HPI-Process®** with high water pressure when using the newly designed nozzle rotation unit **MAXINOZ®**.

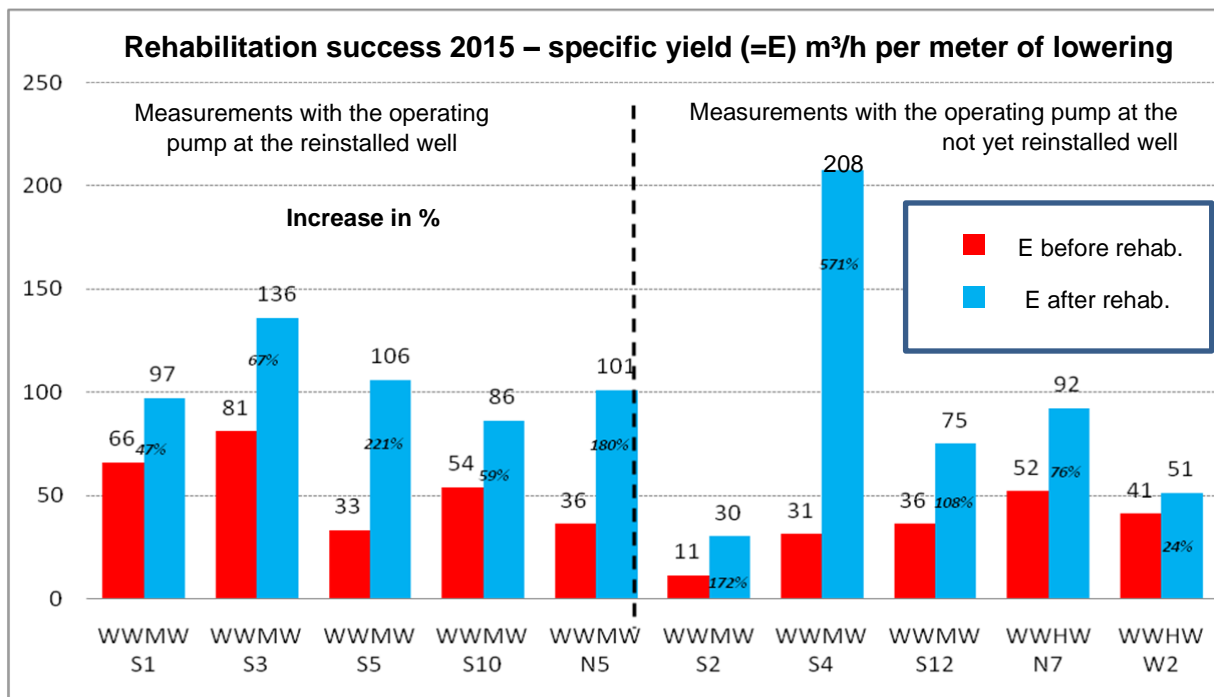


Table 2: The rehabilitation results are amazing.

The rehabilitation success at the 10 wells treated was way above average. A differentiated consideration according to the screen material shows an average performance increase of 143% for the wells equipped with stoneware screens and of remarkable 179% for the wells equipped with Johnson Type filters.

MAXINOZ® causes above-average increase in performance

Bottom line

For the operator, the results mean a significant saving of electricity during pump operation due to the overall lower pump head (approx. 500 m³/hr) after rehabilitation. The results of the **JET Master®** shown here when using the newly developed nozzle rotation system **MAXINOZ®** are clearly above the results of the above-mentioned study of the Bavarian State Office for the Environment and furthermore excellent rehabilitation results with the nozzle rotation system **UNINOZ®** used so far for more than 20 years. The author is therefore converting his **JET Master®** fleet to the new **MAXINOZ®** system.

Acknowledgement

We would like to take this opportunity to thank the municipal utility Karlsruhe for the trust it has placed in us and for its open-mindedness towards innovation. In particular, we would like to thank Dipl.-Chem.-Ing. Joachim, who planned and managed the project with his extensive experience in dealing with wells and plant engineering in the field of groundwater extraction.