sonic umwelttechnik

Well Rehabilitation with high-energetic Ultrasound

A highly efficient, economical, environmental friendly and material-preserving method of rehabilitation of water wells.

SONIC Information No. E1-09

Contents

1 Preface:

Ultrasonic well rehabilitation is an essential contribution to the preservation of our environment: Neither soil nor underground water have to be charged with additives when rehabilitating a well.

Ultrasonic well rehabilitation also contributes to preserve the value of a well, as it does not stress the structure of wells.

Ultrasonic well rehabilitation is not only ecologically worthwhile but also has economical advantages

The SONIC ultrasound unit for well rehabilitation is the result of long experience in ultrasonic techniques for industrial and scientific purposes.

The function of the system has been proved in many hundreds of well rehabilitations and in a large scale scientific research program

Ultrasound – an innovative method of well rehabilitation

2 Decline of flow-rate through ageing

Water wells often show a decline of flow-rate over the time of its use. This process is termed “well ageing”.

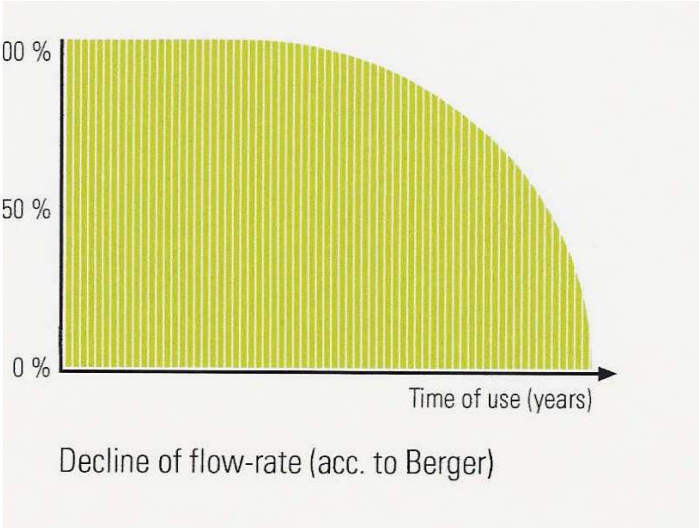
Well ageing is caused by physical, chemical and bacteriological action. These lead to

- clogging the well with sand
- silicifying
- Sintering
- Mucuous tissue
- Sedimentation of metallic reactions or
- Corrosion.

The most typical cause of ageing is the biological ageing. In practical reality very often there are combinations of different causes of ageing.

The result of ageing is a deposition or sedimentation of substances, which were caused by chemical precipitation, mechanical alluvion or products of biological metabolism and can be found in following places:

- In the inner area of the filter tube
- In the filter slots
- In the hollow space of the gravel filling
- In the aquifer



Decline of flow-rate (acc. to Berger)

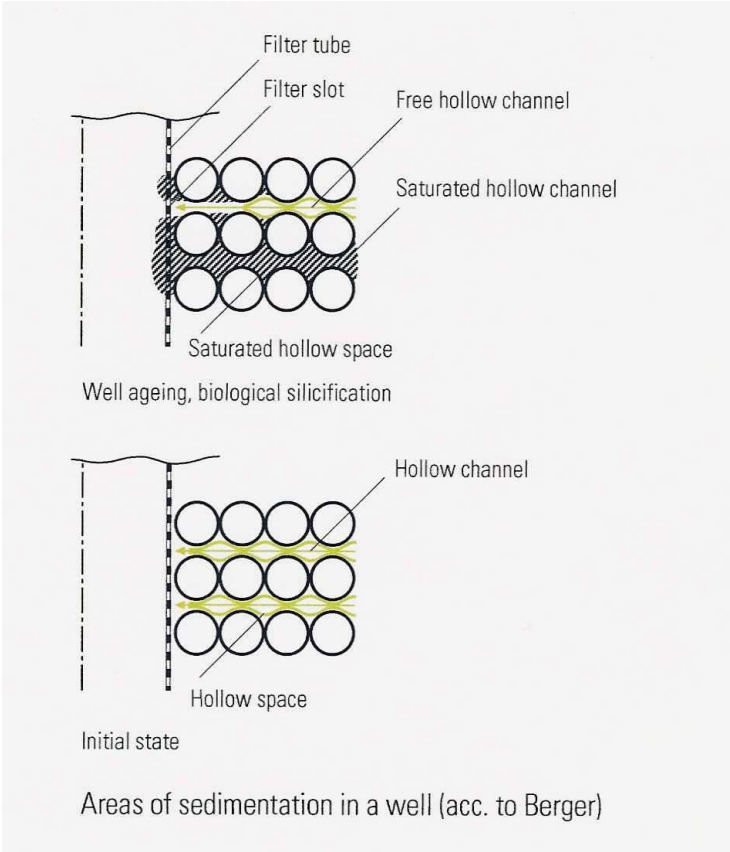
Very important for all rehabilitation procedures is a correct timing. The measures already should have been taken, before a significant decline of flow-rate is stated. The more preventive a rehabilitation measure is carried out, the more secure it is, the less measures which have the character of sanitation have to be applied.

3 Conventional measures of well rehabilitation

Different measures have been developed to reduce the effects of well ageing, i.e. to reconstitute the initial flow-rate of wells. The productivity of the alternatives is to a large degree dependent from the nature of causes of well ageing and from the material of a well.

The numerous measures offered can be divided into the following categories:

- mechanical cleaning using valve pistons and high pressure pumps, as well as so-called rinsing lances
- chemical rehabilitation, partly applying organic and inorganic substances, harmonized to the kind of sedimentation and its components.
- Creating energy-loaded pressure waves by explosions within the filter tube
- combination of mechanical and chemical measures



Areas of sedimentation in a well (acc. to Berger)

Not all methods are able to clean the well within the gravel.

High energetic ultrasound has a range of at least 35 cm into the gravel.

4 Criteria for well rehabilitation

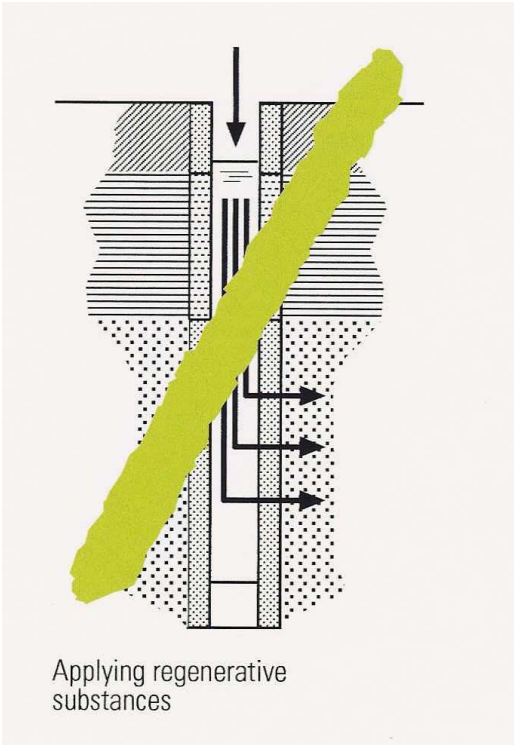
The following quality features have to be respected for well rehabilitation:

- increase of productivity
- equal results of rehabilitation on the entire filter surface
- long lasting result of the measure
- avoiding stress of the environment
- human beings should not be endangered
- avoiding mechanical damages of the well structure
- proper optical appearance of the filter tube
- efficiency
- duration of the measure, resp. time of disuse of the well

The first principle of all measures of well cleaning is a minimum chemical stress of the underground water, a minimum chemical and mechanical stress of the well structure and to avoid any danger for human beings and the environment.

Some mechanical cleaning measures implicate the danger to have a negative effect to the structure of the well, the gravel infill and the filter tube, especially to the existing seals and barrier layers, caused by applied enormous forces which are vehemently changing direction.

Chemical rehabilitation processes may cause a bacteriological impairment of the water drawn subsequent to the cleaning of the well. Furthermore it leaves undesirable chemical reaction products, which require separate and special preventive measures.
(see DVGW-rules W130, April 1992 and DVGW Water information 38)



Applying regenerative substances

An additional potential of colmation could initiate a re-crystallisation of carbonate-compounds in the gravel infill.

The estimated number of undetected cases, where regenerates of chemical well cleaning are simply pressed into the filter pack , might be considerable.

This method leaves big amounts of the regenerate to intrude into soil and underground water.

5 The alternative – Ultrasonic well rehabilitation

For obvious reasons a method was searched for, which would not have the mentioned disadvantages, nevertheless had a good rehabilitation effect, independent from the cause of pollution and independent from the well structure.

Ultrasonic action, which has been successfully used in industrial cleaning processes for several decades, repeatedly appeared as a possible alternative. Even strongly cohesive layers in locations that could not be approached otherwise can be removed easily and with a preservative character, in a so-called sonic bath.

5.1 Basic principles of ultrasound technologies

The term ultrasound refers to oscillations of frequency above the audible range of an adult human being, which means it ranges above 16 kHz.

Ultrasound has a multiple effect. It is therefore used in many fields of technical applications, chemical applications, in medicine and science:

- ultrasonic diagnostics
- ultrasonic massage
- material testing
- destroying of cells
- emulsion of water and oil
- de-gasification of metallic smelting processes and liquids
- medical treatments
- measuring technique
- ultrasonic soldering of aluminium
- ultrasonic drilling
- ultrasonic welding
- ultrasonic cleaning

In the following areas, related to well rehabilitation, ultrasonic methods are already common:

- Soil analysing showed that colloids which are in the ground disperse into liquids within a few minutes, when ultra-sound is applied. When the same colloids are treated by shaking and centrifuging, the effect is far from the effect of ultrasonic treatment.
- Developing ore showed that raw material, which was encapsulated by ferromanganese ore, when treated with ultra-sound for five minutes could immediately be developed, whereas other treatment did not show success.
- Rock containing clay was exposed to ultra sound in order to extract the clay. The ultrasonic method had a 100 to 1000 times bigger efficiency than conventional mechanical measures.

Sound is a continuous series of overpressure and underpressure in a medium. As everybody knows from experience, sound creates a mechanical movement due to the (changing) sound pressure. Even from audible sound levels, which are no health-hazard yet, we know the clinking of windows, the dropping off of plaster a.s.o.

Contrary to an expansion wave created by an explosion, sound creates a “standing wave”. No substance is transported which could, due to its kinetic energy, cause any damages.

Oscillation rather takes place in the micro-zone, where it is nonetheless energetic. ”Damages” caused by sound energy materialize in dirt-removal.

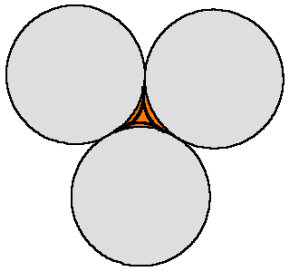
The sound energy of ultra-sound waves can be a great deal higher than the energy of audible sound. Sound sources with a corresponding energy in the audible level are not produced due to the health-hazard to the human ear.

Different applications of ultra sound require different kinds of ultra sound. Frequencies vary for example between 20kHz and 500 kHz and more (seldom MHz or GHz).

The sound power varies between a few watt in medical applications and several kilowatt in technical applications. Accordingly the sound intensity differs between some tenths of a Watt/cm^2 up to 20 Watt/cm^2. Also the kind of modulation of the emitted ultra sound influences this mechanism.

Depending on the configuration of the ultra sound thermal, mechanical or chemical effects can be achieved.

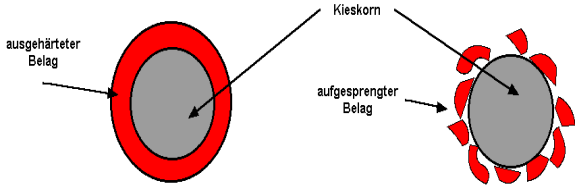
5.2 The effects of ultrasound in the well



There are several reasons why ultrasound is effective in well treatment:.

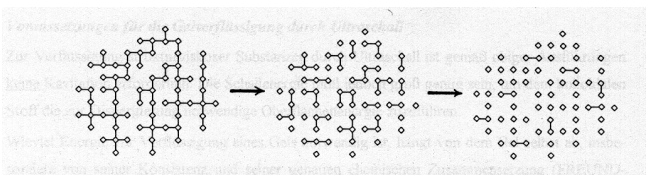
1. Ultrasound oscillations periodically compress and attenuate the medium which is passed through by the sound. As the sound energy of the SONIC system is very high, even the gravel oscillates. By that, the gravel gets smaller and bigger (20.000 times per second!), the size difference is app. 1 micrometer. By that you have a “rubbing effect” between the gravel which removes dirt from the gravel.

   Everybody knows this oscillation: e.g. clinking of windows or droning of walls



2. The above mentioned size difference depends on the material. In cases when the dirt on the gravel is petrified, you can’t remove the coating by rubbing. But as there are high tensions on the boundary surface, the coating will chip off from the gravel. That is the same effect when pieces are falling from the ceiling by noise.

3. Clogging of wells is often a result of biological reasons. The substances consist of macro-molecules which break in smaller molecules by ultrasonic treatment. The substances get liquid.



5.3 Advantages of well rehabilitation by ultrasound

Long standing experience in well rehabilitation by ultrasound proved that this method fulfilled all hopes set in it:

- Well rehabilitation by ultrasound is highly efficient.
- Well rehabilitation by ultrasound works in various kinds of conditions.
- Well rehabilitation by ultrasound does not require the application of chemical substances. It saves the environment from unfavourable effects.
- Well rehabilitation by ultrasound requires little time per meter of the filter surface. Therefore it is very economical.
- Well rehabilitation by ultrasound does not stress the well structure. It therefore leads
- to an extended period of use.
- Well rehabilitation by ultrasound does not cause any chemical reactions. No secondary chemical products are created, which strengthen colmation and thus would cause a weakening of the well.
- Well rehabilitation by ultrasound does not require the negotiation of approvals with water authorities.

5.3.1 economical efficiency

The Sonic ultrasound procedure considerably reduces the rehabilitation time.

Comparative rehabilitation measures for the same well showed that rehabilitation, including preparation and refinishing, by using chemical measures took thirty days, rehabilitation by shock pump took ten days, while rehabilitation by ultrasound only took five days.

The cost advantages of the rehabilitation method by ultrasound are made up by the following factors:

- Little rehabilitation time per meter of the filter screen.
- No waste of water
- No cost for chemical substances
- No costs for rinsing the soil, neutralization and disposal.
- No costs for chemical monitoring
- No negotiations for approval with water authorities.
- The short rehabilitation time permits a high frequency in the use of the unit. Costs of financing can be reduced.

For the user of the well a further cost reduction results from the increase of the period of productivity, because of short rehabilitation times.

The cost saving is considerable, especially in cases where the well suffers from various kinds of ageing problems, which would require several different standard measures.

5.3.2 Environmental aspects

Rehabilitation by ultrasound does not implicate any environmental pollution. The unit works completely without chemical substances. Therefore it is absolutely friendly to the environment. Underground water is not stressed. In the course of rehabilitation no harmful substances or radiation is released. There is no deposit problem regarding remaining liquids.

From an expert opinion:

"The ultrasound rehabilitation method is absolutely preserving and economical. Especially environmental aspects as to protection and preservation are observed."

5.3.3 Preservation of the well structure

When a well is rehabilitated by ultrasound, neither strong forces effecting large parts of the well surface have to be applied, which would stress the entire construction, nor would water jets with a high pressure affect the filter screen. The mechanical force of ultrasound arises decentrally in many different places, especially in border surfaces.

Accordingly, also wells having a filter tube manufactured from ceramics, wood or PVC can be cleaned without the risk of damages.

From an expert opinion

"Damages to the well structure by using ultra-sound cleaning methods can be completely excluded".

5.4 Questions and Answers

Which kind of deposits within the gravel infill are removed by ultrasound?

Generally with ultrasound, as with other methods too, deposits with a low or medium degree of solidifying are removed. Also deposits with a high degree of solidifying can be removed.

Where in the well the ultrasound is effective?

The rehabilitation efficiency of ultrasound preferably works within the filter slots and in the circular area behind the filter.

Which is the efficient distance of ultrasound (horizontally)?

Test in laboratories and geophysical measurements showed that ultrasound is **effective very far into the gravel pack** behind the filter tube. The high range of ultrasound is based on the fact that sound waves are only slightly attenuated when passing the gravel infill.

Up to which depth the ultrasound is efficient?

Practical applications and tests in laboratories showed that there is no limitation regarding depth. Independent measurements of an Institute for water research and technology showed that the efficiency of ultrasound considerably increases with increasing pressure, i.e. increasing depth.

Does ultrasound change the structure of a well?

Independent geophysical investigations showed that within the gravel infill of a well the following features are influenced in a positive sense:

- density of the material
- porosity
- water content
- perviousness

This indicates a sustainable removal of deposits.

How does ultrasound affect the different kinds of deposits in a well?

In practical applications no influence of the kind of well ageing on the efficiency of ultrasound could be observed up to now.

Does the filter material have any influence on the efficiency of the ultrasound in the well?

In practical applications there was no influence onto the efficiency of ultrasound coming from the material of the filter. Wells with

- PVC filters
- Obo-filters (wooden filters)
- Ceramic filters

- Steel slot bridge filters
- Copper slot bridge filters
- Wound wire filters as well as
- Resin bonded gravel screen

have been cleaned. The removal of dissolved particles in resin bonded gravel screen filters with very small pore diameters can create problems.

What is the period of use of a well after cleaning with ultrasound?

Regular resp. repeated treatment of a well with ultrasound does not shorten the period of use between two rehabilitation measures. It probably even prolongs the period of use, due to the germicidal effect of ultrasound in cases of biological silicification.

How is the procedure of well rehabilitation by ultrasound?

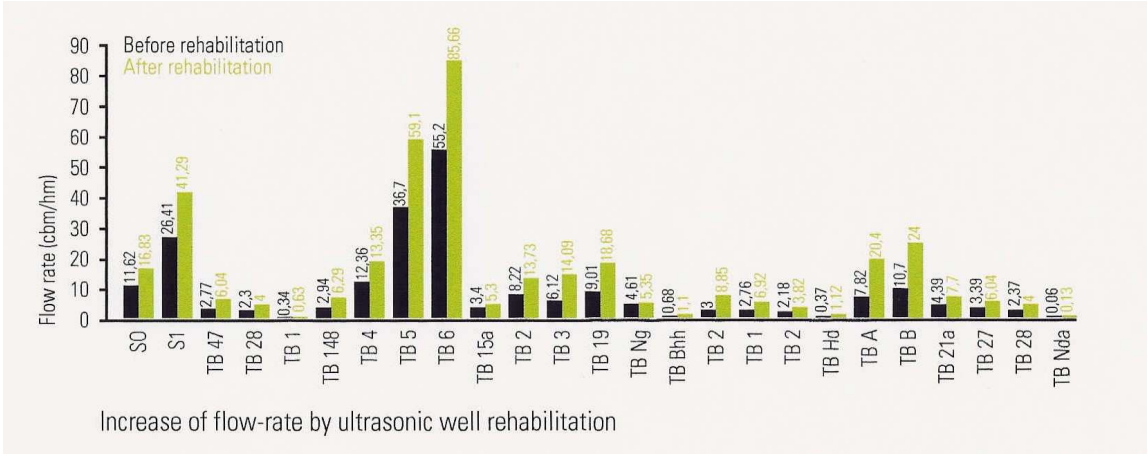
Under normal circumstances well rehabilitation is carried out as follows:

- Cleaning the whole filter tube with a brush to remove overgrowth and to make the filter slots visible. The ultrasound probe must be able to move in the well without friction.
- Exposing sections of the well to ultrasound, and after that pumping out the dirty water of this section. Each section is exposed to ultrasound for approx. 5 – 10 minutes. Repeating this procedure for the same section is only required in exceptional cases.
- All other procedures are identical with conventional measures.

6 Results of practical well rehabilitation

During the last years approximately 1000 of well rehabilitations with SONIC ultra-sound have been carried out successfully.

The following diagram shows a random average of the results of one user during a certain period of time.



To monitor the rehabilitation measure usual procedures like monitoring with a television camera, tests by pumping and flow meter measurements are available. The most reliable method however is a geophysical examination. Especially changes in the gravel filling, e.g. , perviousness, hydraulic resistance, share of sand in the gravel etc. can be detected.

The effects of rehabilitation by ultrasound energy are astonishing and brought up remarkable results. Due to the big number of practical applications no incidents
are possible.

Below there mentioned only a few examples:

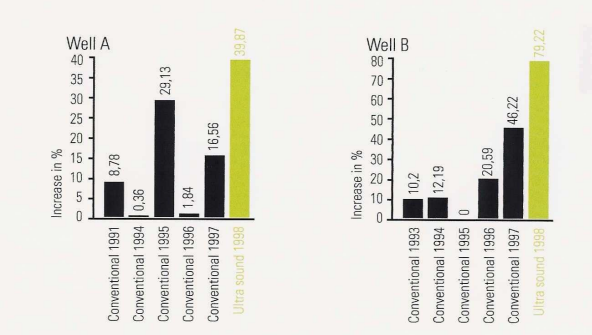
6.1 Rehabilitation of a mineral well

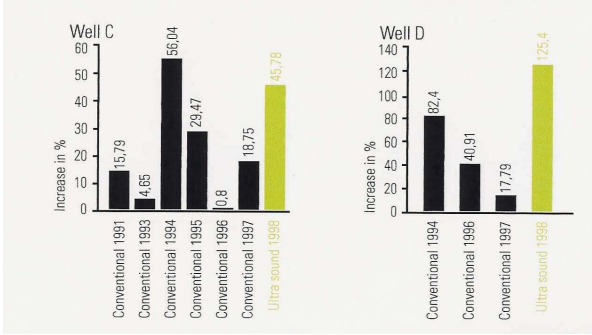
From a report of a mineral spring society:

" In April 99 the filter tubes have been cleaned by ultrasound. The result of this measure was a rise of the water level in the well (with identical drawing-rate before and after the treatment) from –10m to –6.5m below the upper edge of the well head. The water contained 25 % more minerals. This rise of the water level and content of minerals in the water corresponds a "re-juvenation" of the well of about 10 years."

6.2 Well gallery on the lower part of the river Rhine

A well gallery, which previously was mechanically rehabilitated once a year, was rehabilitated with ultrasound for the first time in 1998. The results of the ultra-sound rehabilitation are clearly better than the results of conventional treatments.





6.3 Rehabilitation with SONIC ultrasound after high pressure cleaning and chemical treatment

In this case the well first had been treated with a high pressure cleaning procedure and then with a chemical rehabilitation medium.

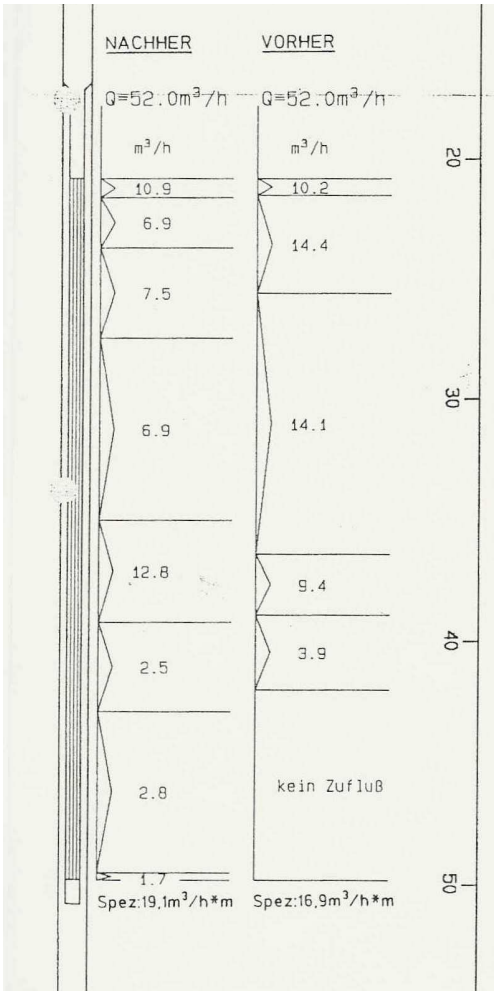
The flow meter recording after the high pressure and the chemical treatment is shown in the following graph. („before the ultrasound treatment on 15.02.1999“).

Some days after these two treatments the well was rehabilitated with ultra-sound. The flow meter recorded thereafter is shown by the upper curve („after the ultrasound treatment on 23.02.1999“)

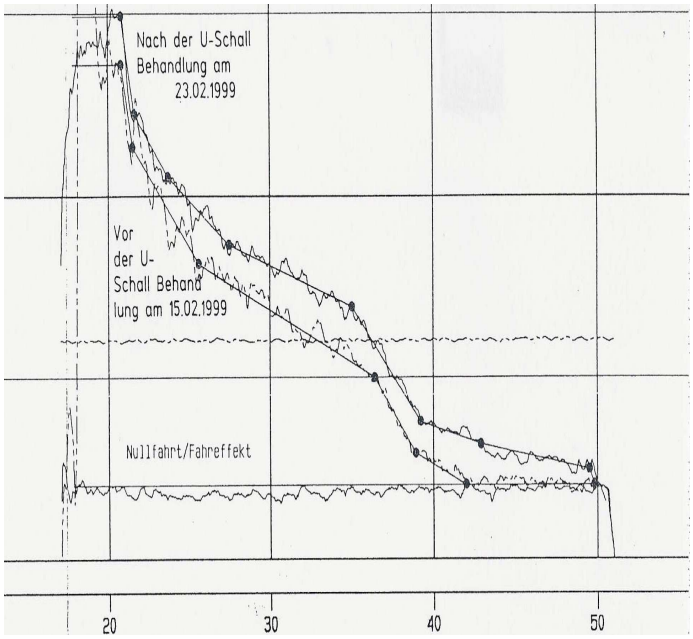
A further improvement of the specific efficiency from 16,9 m³/h*m to 19,1 m³/h*m is recognized.

In addition the evaluation of the flow meter curve shows , that the ultrasound treatment opened filter areas, which before have not been opened by either of the two conventional treatments.

Technical data of the well:
Total depth: 49 m
Lining: stoneware
Rock type : sands
Filter surface: 29 m
Diameter: DN 250 mm

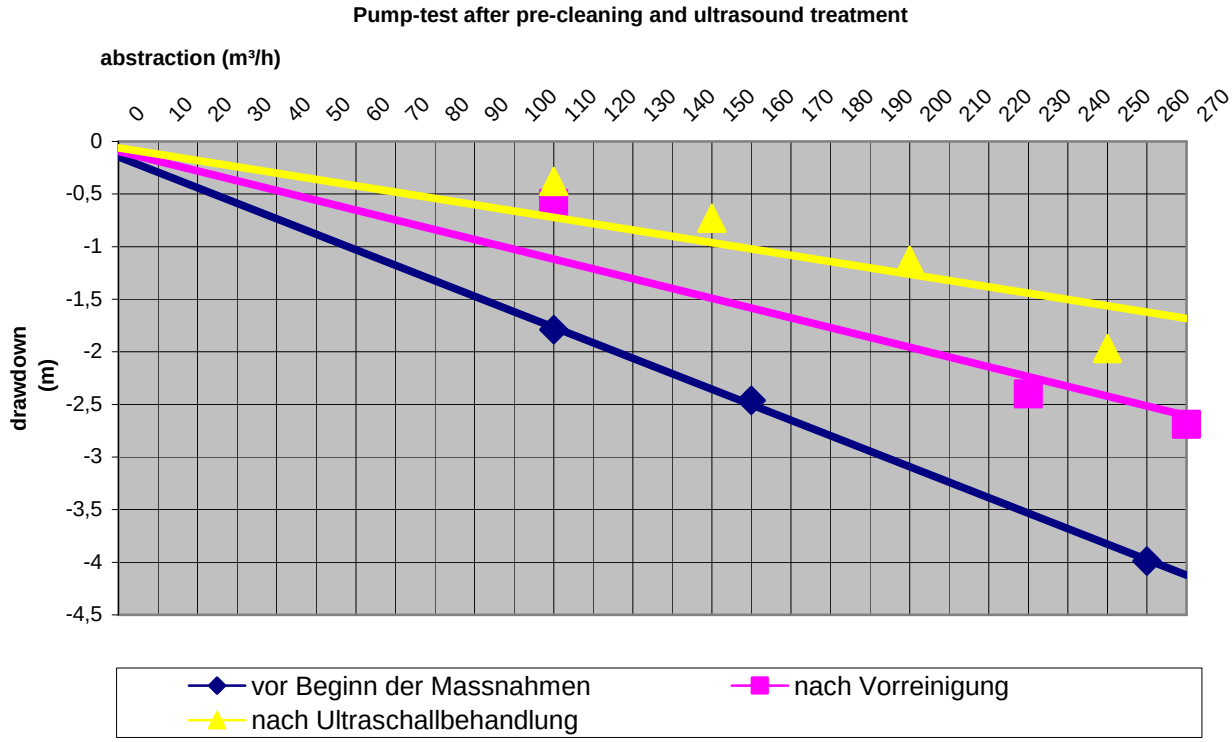


6.3.1.1.1 Flow meter diagram and evaluation after test cleaning



6.4 Well in France

To measure the results of precleaning and ultrasound treatment pumping tests were made before treatment, after brushing and after ultrasound treatment.



7 Scientific Results

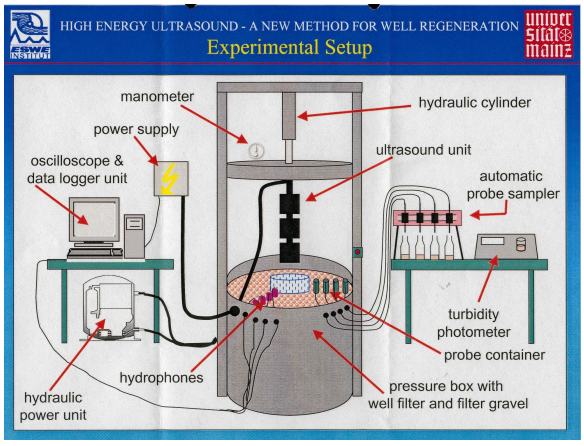
At University of Mayence a large scale scientific research project was made. The project was supported by the Deutsche Bundesstiftung Umwelt (DBU) in Osnabrück for two and a half years (05/ 2001 – 10/ 2003).

Here a report:

"This project was divided into two main parts. The first part included primarily laboratory work at a specially designed model well (outline and foto below), named URSEL (Ultrasound – Rehabilitation – System in ESWE-Institute's – Lab). The heart of this model well is a hydraulic closable pressure vessel, stable up to 20 bar to simulate the hydrostatic pressure of a water column of up to 200 metres.

With its construction and implementing there is a worldwide unique experimental equipment available to simulate conditions of a vertical filter well. In laboratory tests all parameters of wells and the ultrasound device which could effect the rate of success of the rehabilitation were simulated, including:

- period of exposure to sonic waves
- temperature
- hydrostatic pressure up to a simulated water column of 200 m
- sound propagation at different postions in the annular space
- different types of filter screens and filter gravels



All laboratory tests showed sound propagation far behind the filter screen in the annular space. The rate of success was closely connected to hydrostatic pressure. The optimal duration of exposure was found.
The effects of the sound waves to the coatings was simulated using different materials, including e.g.

- original coatings from wells, containing iron-oxides
- original coatings from wells, containing manganese-oxides
- gelatine-like substances to model biofilms

All materials showed clear effects. Ultrasound is able to remove iron- and manganese-oxide-coatings and biofilms from the filter gravel.
Brought forward to well rehabilitation this means that ultrasound has the ability to cause a cleaning of the annular space.

The second part of the project in conclusion should bring evidence of laboratory results in field tests at real drinking water wells. For this three wells were chosen with different characteristics regarding depth, filter screen materials and aquifer qualities. They were rehabilitated closely followed by scientific measurements.
This included videotaping of condition of the filter screen, pumping tests and geophysical applications before rehabilitation, after pre-cleaning and after exposure to ultrasound.

Again the ultrasound method proofed to be successful in rehabilitating aged wells.

8 Technical description

Rehabilitation of a well by ultrasound requires several units.

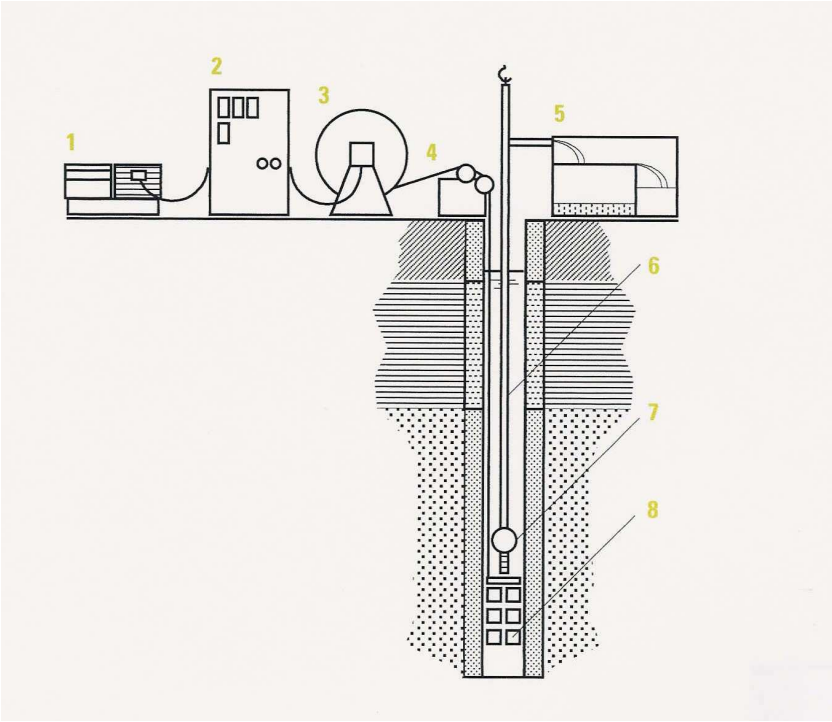
An ultrasound device, lifted down into the well, is the essential part of the ultrasound rehabilitation system.

The ultrasound generators, transforming the current of the mains supply into alternating current of a high frequency, are installed in a switching cabinet.

The ultrasound transducers are stimulated by this high frequency current.

All required control- and supervising devices are installed in the same switching cabinet.

A special cable on a motor driven cable drum is required to transfer the high energy.

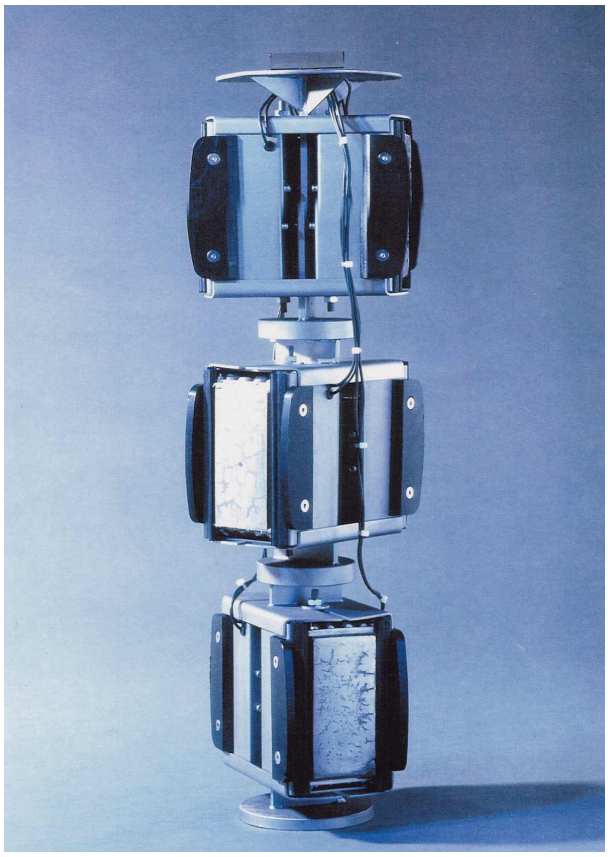


The main units required are:

1. Power generator
2. Switching cabinet*
3. Cable drum*
4. Cable*
5. Container
6. Tubes
7. Dirty water pump
8. Ultrasonic device*
9. crane
10. transport vehicle

*Delivered by SONIC

The ultrasonic unit consists of several ultrasonic transducers. The ultrasonic transducers emit ultrasonic waves radially outwards. The diameter of the probe is 140 mm. The filter tube of the well to clean therefore has to have a minimum diameter of 150 mm.



8.1 The Ultrasonic Probe

The Ultrasonic cleaning device is available in two versions:

The standard unit B20/6 is equipped with 6 transducers. It can be used for well diameters from 150 mm to 1000 mm.

Technical data of a transducer	
Operating frequency	20 kHz
Rated power	2000 Watt
Peak power	4000 Watt
Weight	app. 18 kg
Sound radiating surface	85x185 mm
Sound energy (rated/peak energy)	12/25 W/cm^2
Modulation	Double half wave
Ultrasound technology	magnetostrictive

Technical data of the ultrasound device	
Type	B 20/6
Number of ultrasonic units	6
Total power (Watt)	12.000
Weight (kg)	120
Length (cm)	160
Outer diameter (mm)	140
Usable for well diameters of (mm)	150-1000
Maximal depth (techn. limitation)*(m)	250

* The limitation of depth has technical/economical reasons. Bigger depths available on request.

8.2 Special mains cable

Transferring the required high electrical energy from the surface to the ultrasonic probe and to the dirty water pump requires a screened cable. The cable cross section is selected big enough so that transmission losses can be ignored.

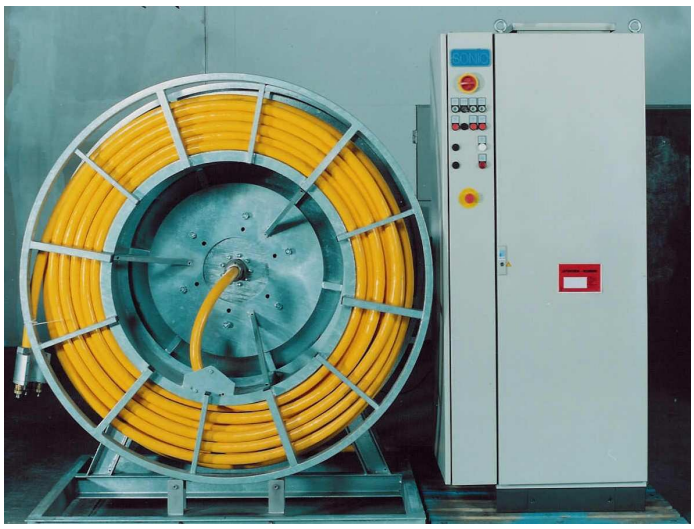
The cable can be ordered in standard lengths of up to 250 m. The cable is highly resistant against mechanical stress and abrasion, weather proof and moisture-proof.

8.3 Cable drum

The mains cable is coiled on a motor driven cable drum. The cable drum is equipped with collecting rings.

8.4 Switching cabinet

The ultrasound generators needed to operate the ultrasonic probe are installed in a switching cabinet, together with extensive security and protection devices.



Cable and cable drum with switching cabinet

Technical data of the complete unit

Type	B 20/6
Power supply	15 kVA
Mains voltage	230/400/50Hz
Weight switching cabinet (kg)	app. 200
Weight cable (kg/m)	2
Weight cable drum without cable (kg)	app. 150
Outer dimensions of switching cabinet, WxHxD (mm)	800x1800x600

Special equipment: Cooling aggregate for use in countries with higher average temperatures (extra cost).

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