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# Two Year Results of a Breakthrough Physical Water Treating System for the Control of Scale in Oilfield Applications

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## Abstract

The presence of scale in a well is arguably one of the most difficult and expensive problems facing the production function of the oil industry today and despite many years of concentrated effort to effectively combat it, the problem still exists in a widespread manner. Much of the effort to mitigate the scale problem and render it less of a threat to production has been centered on methods of inhibiting its formation with chemicals or by mechanically removing it, but in many cases the action taken has not met the overall effectiveness sought by industry. A new approach to the problem is indicated but what form might it take? If a method were to exist that would prevent the deposition of scale rather than treating it when it appears, then this would represent a quantum leap forward in production operations.

This paper presents a unique and non-chemical method for the control of oilfield scales using a physical water treating device that was originally developed for industrial water treatment. This patented technology presents an alternative for oilfield scale treatment and control when it is installed at the surface of the well. It functions by inducing a randomly pulsed high frequency signal into the piping system which causes the scale crystals to form in the produced fluid rather than on the walls or surfaces of down hole and topside equipment. Prior to field testing this mechanism was evaluated under laboratory conditions using a dynamic tube-blocking test with concentrated brines that produced calcium carbonate, barium sulfate and combinations thereof. Subsequent field studies encompassed the treatment of oil and gas wells with various forms of lift in four different regions in North America with over ten different companies. The system was designed to overcome the wide range of variables that exists from well to well and specific results from several wells will be reviewed to illustrate the value that this approach is bringing to well management.

The conclusion to be drawn from this work is that physical water treating technology can be effective in controlling oilfield scale deposition and there are many benefits to be enjoyed by an operator including increased production, significant cost savings and a positive impact on the environment. It is these benefits that make continued work in this field of science a worthy endeavor to pursue for the oil industry.

## Introduction

"Few production problems strike fear into the hearts of engineers the way scale can", so began an article on fighting scale that was published in 1999, and it is true to say that little has happened to change that perception (Ref. 1). Scale can be deposited on a gradual basis, slowly building up to where it becomes a problem, or it can happen literally overnight as happened in a well in the Miller Field in the UK North Sea where production dropped from 30,000 bpd to zero in a period of 24 hours. Typically scale will deposit on the walls of the production conduit and even in the perforations clogging the bore causing production losses, but it will also deposit on downhole safety valves and surface production controls rendering them inoperable and thus creating a major safety hazard. Most oilfield scale precipitates from production water occurring when the pressure and temperature reach a supersaturation condition. Depending on reservoir conditions the presence of scaling ions can have its origins in the produced water or from a mixing of it with injected fresh or sea water from enhanced recovery operations – in either case the costs associated with combating this problem can be substantial. The methods of combating scale have generally been chemical or mechanical in nature but in many cases are undertaken after the fact. While inhibition efforts are becoming more effective, all these methods have one thing in common in that they are continuing, recurring and expensive processes and do not usually comprise a permanent “fix” for the problem.

Carbonate scales are highly soluble in hydrochloric acid and a simple acid wash can usually be very effective in its removal, however continued scale precipitation on the piping walls cannot be avoided and so the operation must be repeated on a regular basis reducing production and increasing damage to the well. Hard scales, such as barium sulfate, are not soluble in acid; however, they can be treated with chelating agents even though their effectiveness is perhaps questionable. Chemical inhibition can be employed on a continuous basis but, as in the case of a scale squeeze where slow dissolving chemicals can be injected in the near wellbore area, scale deposition increases as the chemical concentration level declines over time only delaying costly well workovers. This process is repeated each time with chemical monitoring, almost a science in itself Ref. 2, to gauge their effectiveness. Scale inhibition can also be achieved by filtration prior to injection, as in the case of desulphation of seawater or by dilution of the produced water prior to re-injection using very soft water containing minimal amounts of scaling ions. Filtration and dilution are capital intensive and generally only make sense under high production scenarios. In addition to chemically based methods, much of the effort to remove hard scales is centered on mechanical methods such as scrapers, rotating mills, motor driven under reamers or abrasive jetting tools. All of these can be effective in the short term, but can shorten well hardware life and require expensive well tubing replacement and disposal. The cost of scale control and remediation worldwide far exceeds two billion dollars annually, and this does not take into account diminished or lost production which could easily triple the damage incurred by the industry, providing more than enough incentive to find better alternatives to a widespread and longstanding problem.

## An Alternative Approach

Against this backdrop of traditional methods, Weatherford became interested in evaluating a completely different approach to treating scale using unique physical water treating (PWT) technology. The physical water treatment system developed by Hydropath Holdings fit that description. The system is attractive from the standpoint that it is easy to use, has a proven track record, could treat the well bore from the wellhead and it is environmentally acceptable.

The device is designed to extend an electric field in and around the tubing. In simple terms the electric field creates seed crystals held in suspension in the aqueous phase. These crystallites act as sites for other crystallites and ions to attach and grow rather than seeking nucleation sites on the tubing walls and creating a severe operating issue. In an oil or gas well using the PWT device, the scale is carried out with the produced fluids.

Non-chemical water treatment systems (NCWTS) have existed in many forms, including simple magnets, for over fifty years and their history is long, controversial and marked by many claims for and against their effectiveness (Ref. 2). More recent studies confirm the notion that an alternating electric field can have a profound effect on decreasing the energy necessary to allow small nucleation sites to form in a supersaturated liquid and to grow into crystals (Ref. 4,5). It has been shown that crystal growth in a fluid becomes energetically favorable only when clusters of seed crystals have achieved a critical size for nucleation. Once this occurrs, all available clusters during supersaturation integrate onto the homogeneous seed crystals rather than on heterogeneous sites on the wall.

In an oilfield fluid filled with a high concentration of hydrated cations and anions the lack of crystallization sites forces the crystal formation on to the well pipe (heterogeneous crystallization). The patented ClearWELL™ technology applies an alternating electric field along the pipe (see Figure 1) creating an environment for the cations and anions to move together forming clusters. The produced water is turbulent and pressure is reducing so, the water moves in and out of a state of supersaturation with the result being the release of more ions and increased cluster size. Eventually the attractive forces within the large clusters cause the remaining charged particles join to form a seed crystal. Nucleation is a dynamic process. If enough of the tiny seed crystals are available they attract any available ions and clusters until growing rapidly to the critical size. As long as a supersaturation condition exists all the available ions and clusters support the growth of the crystal. Ultimately all are consumed and a state of saturation is reached.

One of the most important features of the device is how efficiently it orients and delivers the electric field across the length of the piping system. The PWT device is attached at the surface of the well without breaking into the flowing high-pressure system, and induces the alternating current (AC) signal into the pipe and transmits it down the full length of the well or pipe. From an oilfield standpoint this is important because it doesn't interrupt production and it is entirely safe. The effect of this device is not local or directional or dependent on flow. In order to understand how the waveform is transmitted the well bore should first be considered as an open circuit from an electrical point of view. Using transformer principles and an AC source, a high frequency signal is induced within the casing and well bore. See Figure 2. This causes a flow of electrons and a propagating electromagnetic field. It is in this way that the PWT device protects the complete well bore.

In practice the ClearWELL™ device can be powered by 110 or 220 volt 60Hz source or run by alternate sources of power such as a generator or solar panels. Depending on the well configuration, as in the case of an electric submersible pump, the device can be attached along the production flow line.

**Laboratory Testing**

Prior to field studies a series of laboratory testing was conducted to observe and validate the scaling mechanism under controlled conditions using standard oilfield test procedures. The testing program was comprised of a traditional tube blocking test and a subsequent series of flow line tests using simulated anion and cation fluids from a known producing well with severe barium scaling issues. Paraffin and asphaltene studies were also conducted and the results of these tests will be reported upon separately. These tests were contracted at Hycal Energy Research Laboratories in Calgary, Canada starting in February of 2005. The laboratory objectives were:

- To verify the basic mechanism of the PWT device
- To determine the impact on calcium carbonate, barium sulfate and combinations thereof
- To gauge the scaling effects as the velocity increases while using the PWT device
- To determine the effect of the PWT device in the presence of scale inhibitors

The tube blocking test procedure is a well developed method for determining scaling rates. It incorporates the mixing of two fluids. One is a source of anionic scaling ions and the other is a source containing cationic ions. With adjusted ion concentrations and known salinities both fluids are pumped through a heated flow line at a constant rate. Multiple flow rates can be run to examine the effects of flow velocity. The duration of the test is based upon the amount of time it takes for the test tube to block or become plugged. Because the PWT device generates an electrical output to control scale special consideration was given to the test configuration to insure that that the PWT signal was properly directed. See Figure 3 for a schematic of the test apparatus with the PWT in line. These tests were conducted at 50 C. The injection pumps and apparatus for the initial blocking tests were capable of flow rates up to 3000 mL/hr and maximum pressure of 4000 psi. The laboratory test results and the conclusions from them were as follows:

- The blocking test was performed using 1/8" stainless steel tubing and 50 mL/hr of each brine for a combined flow rate of 100 mL/hr. The brine flow rate is equivalent to 2 bpd in 2" pipe (i.e. a very low rate). The brine was circulated without the ClearWELL device being in operation and a pressure build up was observed after 7 minutes as the system plugged with scale. Pressure continued to build until the test was stopped. The test was then repeated with the ClearWELL system installed and a pressure build up was observed beginning after 45 minutes. This continued for 90 minutes until the plug broke free at 100 psi differential and the process of build up and break down continued for several hours. See pressure curve in Figure 4. The unit was eventually switched off to see if scale would form but none did. The system was then shut off for 36 hours and restarted without the ClearWELL device whereupon it plugged completely. Several conclusions were drawn the first being that the PWT system was creating seed crystals and they were growing rapidly in suspension before they were sheared. Also, due to lingering effects within the whole systems including the brine tanks, when the ClearWELL was disconnected, seed crystals continued to form. Only after 36 hours with the device turned off did scale form as the seed crystals were no longer present.
- These tests were repeated with different conditions. A larger 1/4" tube was used along with a higher flow rate to determine if settling in the tube was a result of scaling or low flow rate. The flow rate was

increased to 300 mL/hr for each brine plus 3000 mL/hr of distilled water. This is roughly equivalent to 70 bbl/day of flow through a 2" diameter pipe. The brines were adjusted to include a calcium carbonate component in addition to the barium sulfate in order to reduce the bulk weight of the scale. A visual window was inserted into the tubing being machined using EDM techniques in order to be able to observe any scaling, or lack of it, during the tests. In the untreated test there was little pressure build up indicating there was no plugging due to settling but, by observations made through the visual window it was obvious that scaling was occurring. After 3 hours the system was dismantled and it was observed there was severe scale build up on the walls of the tubing and at the injection end and, once the scale dried it required mechanical scrapping to remove it. The test was then repeated with the ClearWELL unit in operation and discontinued after 3 hours with no sign of pressure build up. During the trial run one could see through the visual window that the flow was different and the scale crystals that had grown large enough could be seen flowing down the tube. On dismantling the test assembly the difference was dramatic. With the tubing still wet there did not appear to be any residue but once dried there was a thin film of precipitate which was easily brushed off indicating that crystals were settling out of the brine film rather than scaling. A comparison of the treated and untreated tubes is shown in Figure 5 and 6.

- A subsequent test was performed in 2007 to determine if the PWT system was compatible with chemical strategies. In this trial, fluids simulating offshore brines and sea water were used with a blocking chemical used in squeeze applications. The inhibitor was injected at rates corresponding to treatment concentrations of 50 ppm, 15 ppm and 5 ppm and the PWT device was on during this experiment. The results showed that as the inhibitor concentration decreased the mass of the precipitate collected from the effluent increased. At high concentrations there were more crystallites consistent with the idea the inhibitor was blocking most of the nucleation sites created by the ClearWELL device. At the lower concentration of inhibitor more of the nucleation sites were not blocked and they grew proportionately. Figure 7 shows this relationship. The behavior in this experiment of the chemical and device was consistent with the function of each methodology and indicated that they are compatible.

The results of these tests established that the ClearWELL system enhanced nucleation in suspension rather than on the surface of the pipe walls and that it was compatible with current forms of treatment. Overall, our conclusion was that further validation of these concepts with field testing was warranted.

**Field Tests**

In August of 2005 following laboratory testing, operators across North America were contacted with a view to arranging field tests for the PWT system in order to establish its viability in oilfield applications with the following objectives:

- To include a minimum of 25 oilfield installations
- To involve as many companies as possible
- To evaluate the device in several oil producing regions
- To test the device under as many well conditions as possible

With these objectives the device would be scrutinized under a broad array of users and test conditions and a better measure of its capability could be obtained. In order to achieve meaningful results data was requested on historical well production and maintenance along with well construction and completion information. Standard water analyses were to be performed at the time of installation of the devices and plans were made for periodic water testing thereafter. Operators were asked to monitor production volumes, pressures and flow rates, if possible. Because the wells were producing wells with known scale problems, the operators were asked to conduct caliper runs when the opportunity presented itself and despite lost production, at the time of installation.

The initial evaluation group consisted of 26 applications with 11 companies in 4 geographical regions. See Figure 8. Currently there are over 120 units in the field. Of the 26 units the longest running devices have reached 747 and 717 days with the first units installed on October 17, 2005. Coincidentally both of these wells are lifted with an electric submersible pump (ESP). The 26 units have amassed a total of 14,931 days run time for an average duration of 574 days. Encouraging results have been obtained from this field experience and several illustrations are given below describing the well parameters, any issues encountered and the visual evidence noted. A typical wellhead installation is illustrated in Figure 9.

- A natural gas well LST#1 in South Texas was plagued with severe calcium carbonate and minor amounts of barium sulfate scale. The well depth is 12,790 ft and it produces approximately 1,000 Mcf of gas and 400 bbls of water per day at a well surface temperature of 185ºF. In 2005 prior to the ClearWELL device installation the operator spent over $400,000 on scale removal with bi-weekly acid jobs and mechanical workovers. The scaling was so aggressive there were periods of extended down time resulting in significant production losses. The ClearWELL device was installed on the well on 5/23/06 after an acid clean up and the well has been producing trouble free since. Figure 10 illustrates the value this operator has obtained. There has only been one well intervention for scheduled maintenance since the installation and with the elimination of unplanned workovers the well produces more and a safer environment is provided.
- Well #1959 is an oil well in West Texas with an electric submersible pump (ESP) plagued with severe calcium carbonate scale. The ClearWELL device was installed on January 9, 2006 and as of January 2, 2008 it has been operating 713 days trouble free. The well was pulled in January of 2007 to examine the condition of the well and pump. Figure 11.0 and 12.0 show virtually no scale present. The system was reconnected and the well continues to operate as of this day. Typical of the wells under study efforts were made to determine if there was any surface accumulation of loose scale. None was found. It was concluded that because minute amounts of scale were formed at any moment in time, the tiny particles were adequately being carried out of the system without a trace. There was no measurable increase in BS&W and more frequent cleaning of surface equipment than in the past has not been needed.
- Two ESP wells in the same lease in West Texas were installed with ClearWELL on the same day to guard against calcium carbonate. The maintenance history of these two wells showed that both the ESP pumps were failing on average about every 12 to 14 months primarily due to scale. With the ClearWELL installations monthly acid treatments were suspended but corrosion inhibitor was continued as before. One of the wells stopped pumping after 3 ½ months, it was pulled, the tubing and pump were analyzed and it was determined that the pump had failed due to an electrical short. It had been installed about 14 months which was the normal mean time to failure for ESP in the field. Loose scale was observed at the discharge of the pump attributed to the fact there was pre-existing scale and the ClearWELL device had begun to remove it. Because the operator was uncomfortable with the presence of the loose scale, the device was not reinstalled. However, the ClearWELL device was left on the companion well. The device on the companion well continues to operate to this date without chemical and minimal maintenance far exceeding the expected mean time to failure for the well and pump. The operator has since developed a better understanding of how the device functions and has rationalized the early observations seen with these two wells.
- Two gas wells in shallow water in the Gulf of Mexico, both approximately 13,000 feet deep, have a strong propensity to form calcium, barium and lead scales. They required continuous chemical, periodic acid treatments and mechanical workovers while the surface separation equipment normally required clean out every 3-4 months. A ClearWELL system was installed on each well on 12/7/05 and the wells were taken off chemical treatment. In June 2006 a 1.7” gauge run was made to bottom and surface equipment was examined. No scale was measured with the caliper and surface piping was free of scale as evidenced by the check valve shown in Figure 13. Because of the enormous expense to conduct treatment and workover on water the operator has realized annual savings of over $170,000 by using ClearWELL technology and due to reduced downtime a note worthy production increase has been seen.
- One operator chose to put one device on a heater treater to prevent calcium carbonate scaling. And a second device on a well. After six months the heater treater was examined and found to be clean of any scale as seen in Figure 14. This prompted the operator to pull the well to examine it and no scale or any paraffin was found. At the urging of the operator the device was move from well 8404 to a more aggressive well that had both scale and paraffin issues. This well was installed with the PWT device on January 5, 2006 and pulled on August 16, 2007 to evaluate its condition and again no scale virtually no paraffin were found. See Figure 15. There were no chemical treatments for scale or paraffin over this time period and the well continues to operate with the ClearWELL device.
- The PWT device was installed in a well with hard scales in New Mexico on April 4, 2006. This well suffered from a combination of calcium and magnesium scales and had been treated with continuous

chemical. According to the operator the well would scale in a matter of weeks if not treated. All chemical treatments were suspended and the well operated trouble free maintaining production over a 5 month period. It was decided to pull the well and examine its condition in August of 2006 following a well test 3 days earlier which indicated production was stable. When the well was pulled there were loose scale particles in the rod pump and 1/16 inch scale around the collars where two formation waters were commingling. The scale particles were believed to be pre-existing scale loosened by the ClearWELL device, however; the operator decided not to reinstall the device. It became evident that better communication about the behavior of the ClearWELL device was necessary.

- ClearWELL systems were installed in two rod pump wells (52-26 and 52-27) in a field under water flood in Canada in April and May of 2006, both of which had a history of going down due to scale problems every few months. One well was worked over and some scale was seen in the pump although it was not the reason for the workover and according to the operator it did not bring the well down. Nevertheless, the well operated for 19 months before intervention was needed far in excess of its historical frequency for workover and the device was re-attached after the workover. The second well with a history of scale and asphaltene problems continues in operation to date, since installation in May of 2006.

## Summary

As a result of this testing several lessons were learned that can be applied in the future, among them being:

- *Demonstrated the PWT device Capability* - Both in the laboratory and in oilfield runs the system worked. When used properly the device was shown to effectively control all types of scale that form from a state of supersaturation. The ClearWELL PWT device performed under a wide variety of well conditions i.e., depth, T, P, etc.
- *Education and Expectations* - It became obvious that it is extremely important to properly educate potential users on the ClearWELL technology to avoid any misunderstanding as to how the device performs and the significance of loose scale. It is equally important to clarify the differences between a physical water treating device that causes “nucleation in suspension” as opposed to more traditional control strategies.
- *Positioning* - The PWT device is an electronic device and it was learned that to correctly apply it in an oilfield environment proper positioning was necessary. In cases where the device was incorrectly positioned the output was damped. Better signal measuring techniques were learned and employed.
- *Monitoring* - It became readily apparent that traditional chemical monitoring was of little value with this device. Scaling ion concentrations were measured at the surface and there was no change with or without the PWT device. Because the PWT device causes the ions to form in suspension rather than on the walls of the piping system, there was no effective change in ionic concentrations. Different monitoring methods need to be tried. One such method would be to examine the fluid filtrate (Ref. 5).

## Conclusions

As scale continues to present massive and expensive problems for operators worldwide it is perhaps time for the oil industry to start viewing things from a different perspective, to ignore conventional thinking and to consider unconventional methods to combat scaling problems. It has been shown that a physical water treating device can be an effective alternative method. It was also shown that the patented technology described herein offers clear benefits and savings as a result of fewer well workovers, chemical savings, improved safety and, perhaps most importantly, as a result of increased production from an asset.

## Acknowledgements

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## References


Ref. 1 - *Fighting Scale – Removal and Prevention by Mike Crabtree, David Eslinger, Phil Fletcher, Ashley Johnson and George King, published in the Oilfield Review Autumn 1999.*

Ref. 2 - *Non chemical water treatment systems: histories, principles and literature review, by Loraine A. Huchler, P.E. presented at the International Water Conference, Pittsburgh PA., 22nd October 2002.*

Ref. 3 – *In Situ Observation of Colloidal Monolayer Nucleation driven by an Alternating Electric Field, by Ke-Qin Zhang and Xiang Y. Liu published in Nature, June 2004*

Ref. 4 - *Reducing the Viscosity of Crude Oil by Pulsed Electric or Magnetic Field, by R. Tao and X. Xu published in Energy and Fuels, 2006.*

Ref. 5 – *Direct Monitoring of the performance of Scale Control Programs across the produced Water life cycle via suspended solids analysis. By M.M. Jordan, J. Buckman and C. Johnston, presented at the European Formation Damage Conference, Scheveningen, The Netherlands May 2005.*


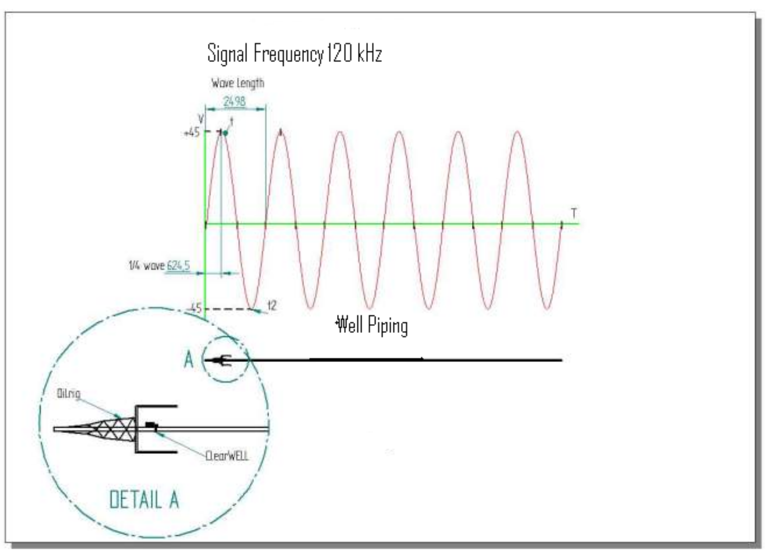


**Figure 1 PWT alternating signal**

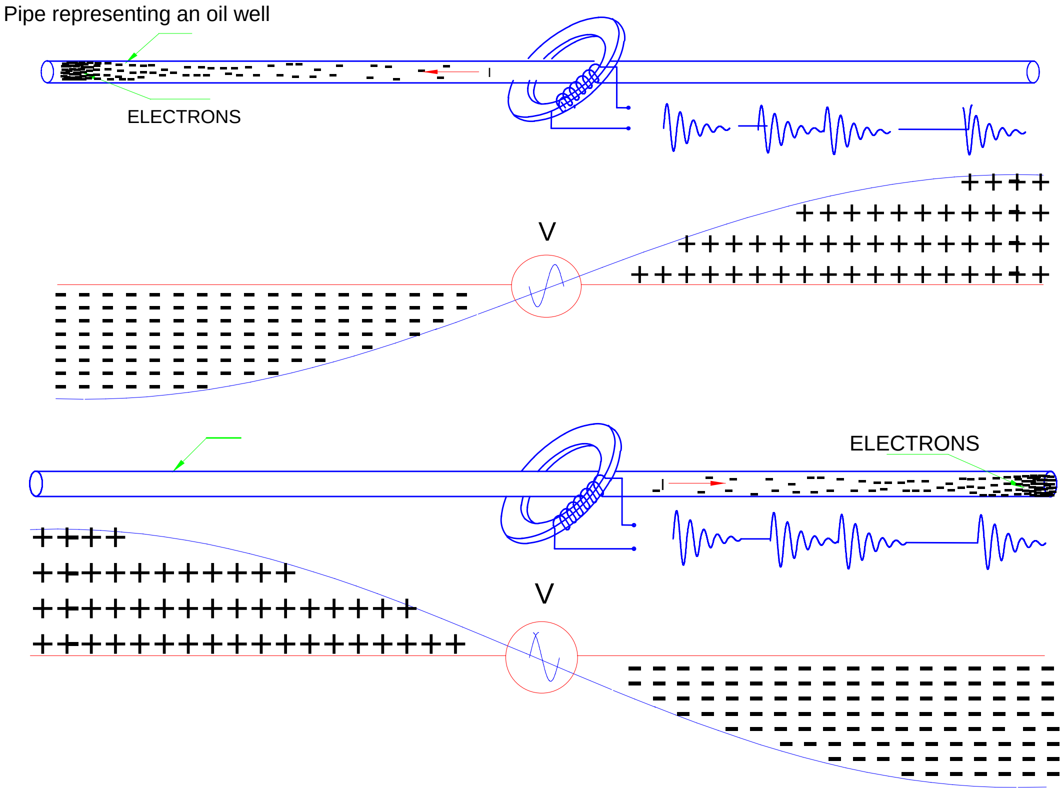


**Figure 2 High frequency transformer**

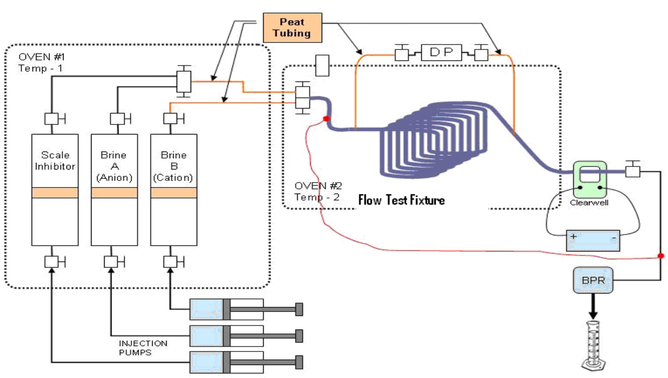


**Figure 3 Laboratory test schematic**

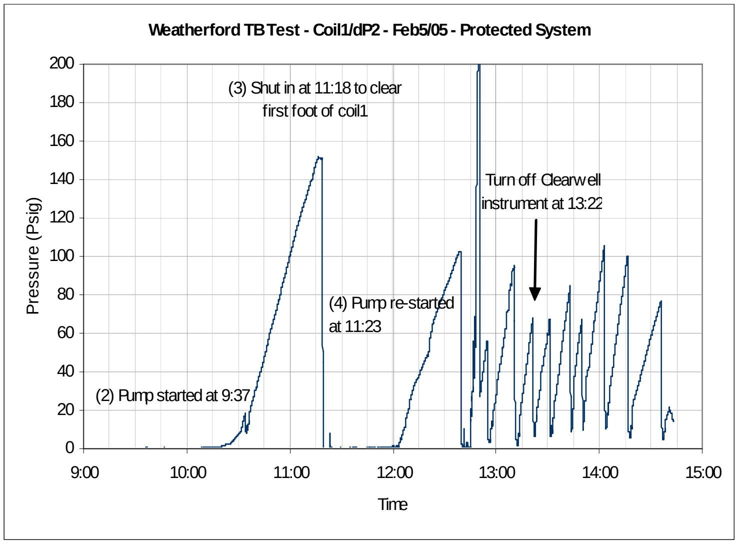


**Figure 4 Blocking test w/PWT**

**Figure 5**
**Comparison of untreated (right) to PWT treated tube (left)**

**Figure 6**
**Untreated tube (left) and PWT treated tube (right)**

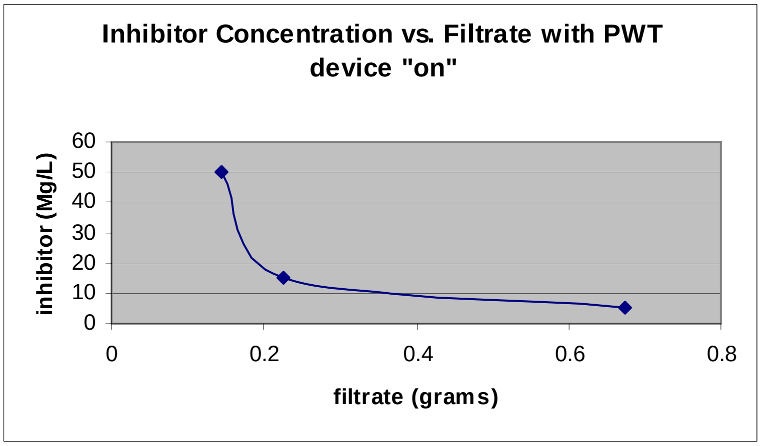


**Figure 7 Compatibility curve**

| | Method of Lift | # Applications | Depth (Range in feet) |
|---|---|---|---|
| **OIL** | Rod Pump<br>ESP<br>Free Flowing<br>Plunger Lift | 15<br>3<br>2<br>1 | 4,316 - 9,162<br>5,599 – 8,110<br>12,800 – 13,100<br>3,825 |
| **GAS** | Compression | 3 | 12,970 – 13,010 |
| **WATER** | Disposal | 1 | 2,200 |
| **SURFACE** | Heater Treater | 1 | NA |

**Figure 8 Field population**


**Figure 9.0 Typical installation**

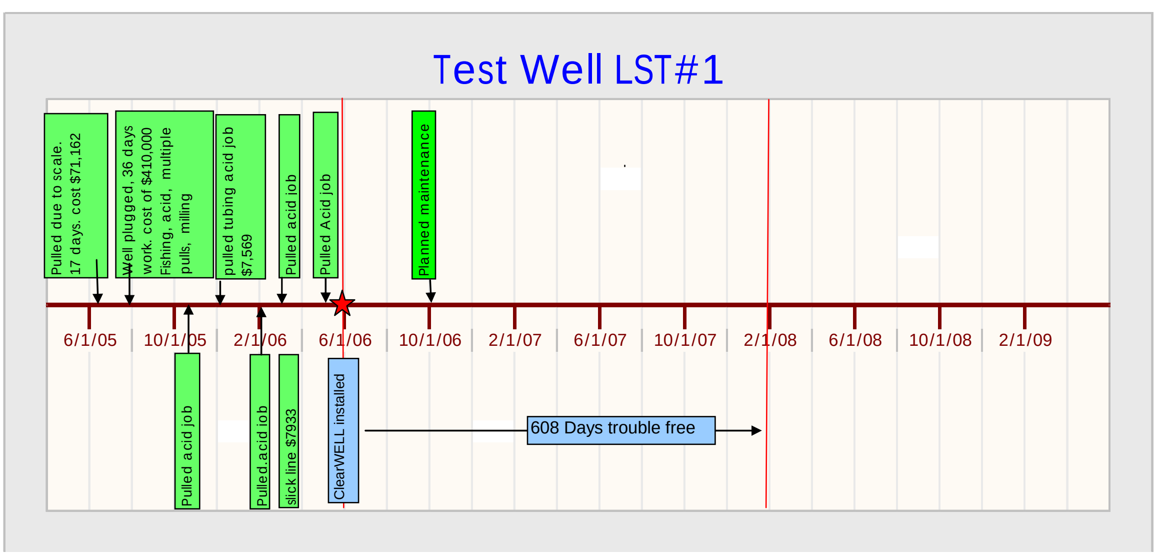


**Figure 10 Reduced maintenance**

**Figure 11 ESP has no scale**

**Figure 12 Clean tubing**

**Figure 13 Inlet and discharge of check valve clear of scale after 8 months**

**Figure 14 No scale on fire tube**

**Figure 15 No scale after 20 months**