# ADVANCEMENTS IN THE USE OF MAGNETICS FOR CONTROLLING DEPOSITS AND BS&W IN OIL WELLS

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## ABSTRACT

Deposits of paraffin wax, asphaltene, mineral scale and the water component of BS&W (basic sediments and water) in oil wells have cost producers millions of dollars in chemical, thermal and mechanical treatments, and in lost production. In some cases, traditional treatment methods have reduced the ability of the wells to produce to their potential.

Previous treatment methods such as biological, galvanic, and magnetic devices were minimal and were limited to a few geographical areas. Ceramic or alnico magnets used in the past have been replaced by the introduction of new high energy product magnetic material, which is eight to thirty times more powerful.

This new magnetic material has allowed more effective circuit design in magnetic fluid conditioners (MFCs). Performance of properly designed MFCs has greatly increased, resulting in more effective control of the deposition of solids in oil wells and associated equipment.

## INTRODUCTION

Magnetic fluid conditioners (MFCs) that require no external power source to treat fluids in oil wells have been classified as miracle gadgets by many well-meaning skeptics in the past. Some producers have used MFCs with great success, documenting great cost savings and, in some cases, increased production. If the success ratio were 75% or better, magnetic fluid conditioners would be an integral part of production equipment. A study of past attempts to market MFCs indicates a success ratio of less than 25% for the following reasons:

1. As the need for more effective treatment of oil wells is ever present, the opportunity for ruthless peddlers to make a quick buck with high profit gadgets could not be resisted.
2. A lack of understanding of basic magnetics has resulted in a lack of funding for research and development for the few true inventors who have dared to oppose traditional treatment methods. For example, it is not in a chemical company's best interest to use R & D dollars to promote a non-chemical treating device.
3. Promoters not having practical field experience with oil production problems or producers not knowing the true nature of the problem or problems in a specific well have led to mis-application and failures.

After twelve years of developing MFCs, a company was formed to develop and manufacture magnetic fluid conditioners where the overall success ratio is greater than 75%, and in pumping wells, better than 90%.

By directing crude oil and water through strong, permanent magnetic fields within a tool, the growth pattern of paraffin and scale crystals is altered, inhibiting the build up of solids in the well and production equipment. The MFC does not require any external power and does not need to regenerate the internal magnets. The permanent magnetic material in the magnetic circuits does not give up its strength to the system. The energy source comes from a slight pressure drop which occurs when the fluids pass through the venturi of the tool.

The secret to the successful application of the MFC is the accurate determination of the environment in a given well. If the well fits into parameters treatable with magnetics, an MFC can be properly engineered for that specific well.

The insert model for a pumping well, constructed of 300 series stainless steel, attaches to the bottom of the pump and fits through the seating nipple, requiring only the rods and pump to be pulled to install the tool. The insert model for flowing and gas lifts wells is set in the seating nipple or on a collar lock via wireline. Tubing tools thread onto the tubing string of high volume flowing wells or below tubing or ESP pumps. Surface tools fit in line and are sized to match production rates and transmission line pressure.

MFC installations are environmentally safe and cost effective without the potential damage to the formation and production equipment associated with chemical, thermal or mechanical methods.

## PRINCIPAL OF OPERATION

Many early designs consisted of nothing more than permanent magnetic material (ceramic or alnico) clamped around or suspended in a carbon steel case, usually a short section of production tube.

The energy product (BH) max of ceramic and alnico 5 varies from one to five G-Oe x $10^6$. Some rare grades of alnico are as high as 9 MG.Oe. New rare earth magnetic material is now commercially available in the 30-40 MG.Oe range. (See Fig. 1).

The bulk (physical size) of the ceramic and alnico material handicapped the design. The magnetic energy developed by large clamp on ceramic magnetics first saturates the carbon steel production tube, so only a small residual amount of energy is left to do the work in the fluid passing inside the production tube.

Field tests proved that the amount and density of magnetic flux in the treatment area is one of the primary considerations in designing an MFC. The areas of treatment in an MFC are commonly referred to as intersects where the fluid is accelerated through an area of condensed magnetic fluid.

The American Petroleum Institute (API) funded the Baylor University Magnetic Group to evaluate the principles of magnetic water treatment. The resulting paper was released at the 45th Annual Meeting of the International Water Conference in 1984. The group states, "A fundamental law of physics states that the motion of a conductor through a magnetic field will cause a voltage to be produced. This principle of electromagnetic induction was first demonstrated by Faraday...and applies not only to conducting solids such as wires, but also to conducting fluids such as aqueous solutions containing dissolved electrolytes." Therefore, the passage of water containing dissolved ions through an MFC should produce a voltage.

The Baylor researchers measured the magnetohydrodynamic effect of an MFC as the result of a series of electrical measurements made within the intersects of the device while various flow rates of a sodium chloride solution were circulated through it. Both voltage and current were measured. The more dense the magnetic flux, the more current flowed. Also the results of the voltage measurements indicated that the measured voltage was a linear function of solution flow rate.

The performance of MFCs placed in oil wells has proven that flux density (gauss) and the velocity of the crude oil and water in the magnetic intersect correspond with Baylor's findings.

Because some corrosion was observed on the stainless steel electrodes of the voltage measurement probes, it was thought that electrolysis was taking place. It was postulated that the electrolysis products, which result from the process, could be involved in causing preferential precipitation of calcium carbonate in the bulk of the solution rather than on plumbing surfaces. This is not the case in actual field applications where no sign of sacrificial disentegration of the MFC was found after years of use in oil wells.

Professor John Donaldson and Dr. Sue Grimes researched the effects of magnetic fields on fluids in the Chemistry Department of City University, London. They have a different approach and state, "A magnetic field will interact with any substance that carries a charge, however small, in any fluid. The nuclei on which the crystals start growing and the growing crystallites are very small and will have charged surfaces. As they pass through the magnetic field, these charged particles encounter considerable forces as the magnetic field interacts with them. The magnet field acts at the surface of the crystallites modifying the nature of the charges at the surface. This alters the growth of the crystal in general and on specific planes."

This will change the shape of the crystals as has been recorded by electron micrographs and X-ray diffraction patterns of precipitates of calcium carbonate. Before magnetic treatment, the precipitate of calcium carbonate contained calcite and aragonite in the ratio of about 4:1. After treatment, the ratio was about 1:4.

As crystals grow differently, their solubility or levels of supersaturation in fluids alters. This explains why scale starts to dissolve and the cloud point in crude oil is lowered.

The cloud point of oil is the temperature at which paraffin begins to come out of solution. Additional cooling brings more wax out of solution. Wax crystals can nucleate forming agglomerates that slowly develop an interlocking network. Eventually the crude becomes so thick it reaches its pour point.

Wax crystals normally have a needle-like shape, and if they remain as single crystals they tend to disperse in the crude instead of depositing on a surface. Nucleating centers gather crystals into bushy particles that attach and build deposits in the well tubulars. Water can also become entrapped by these bushy agglomerates increasing the BS&W.

Asphaltenes, along with scales, formation fines and corrosion products can be nucleating centers for wax crystals. Cooling is the most common cause of wax deposition as it lowers its solubility in the crude oil. Loss of gas and light hydrocarbons from crude also decreases wax solubililty.

The concept that a magnetic field will interact with crystallization nuclei explains most of the phenomenon observed in crude oil and water treatment.

Many samples of oil taken from oil wells before and after magnetic treatment show significant changes in viscosity, cloud point, pour point and deposition temperature of paraffin wax.

## MAGNETIC CIRCUIT DESIGN

Gruber and Carda (South Dakota School of Mines), in a research report presented at the Water Quality Association Annual Meeting in July 1991, grouped basic designs of magnetic devices into four classes as follows:

Class I. This design is essentially magnets fastened to the outside of a pipe, sometimes short lengths of production tubing (pup joint), so the device can be screwed into the production string. This group is the least likely to succeed.

Class II. This type of device makes provision to control the direction of flux (perpendicular to the fluid flow) and to compress the flux to increase flux density in the fluid passage. This class lends itself to more sophisticated and effective designs.

Class III. This design consists of a magnet or magnets suspended as a core in the center of a ferromagnetic tube or pipe. The magnets are usually set longitudinally with close packed opposing poles. This design does not have the benefits of flux density and control of flux direction.

Class IV. This class contains some electromagnetic types which are not practical in oil wells.

Improvements in Magnetic Fluid Conditioner design have come from Class II.

The basic characteristics of a magnet are evident in its hysteresis curve (Figure 2). The suitability of magnetic material and its dimensions is calculated by formulas and information taken from its hysteresis curve. The secondary quadrant of the curve known as the demagnetization curve is the most important indicator of the characteristics of a particular magnetic material. It is important to know the amount of magnetic energy available outside the magnet. The maximum energy available is the magnetic energy product. The CGS unit of maximum energy product is the Gauss Oersted (G.Oe), but as common values are in the order of $10^6$, the more manageable Mega Gauss Oersted (MG.Oe) is commonly used.

The demagnetization curve, which shows the magnetic characteristics of a magnet, is usually drawn with magnetic induction (B) on the vertical axis and magnetic field strength (H) on the horizontal axis (Figure 3). The B-H curve compensated for down hole temperatures should be used.

Claims made by vendors about the strength of their devices need to be carefully evaluated as errors in terminology are often made. For example, magnetic induction (B) is referred to as gauss or kilo gauss, also the unit of residual induction ($B_r$) is gauss.

Often promoters who are not technically proficient read magnetic properties from technical data sheets such as residual induction 11,600 gauss and assume their gadget has 11,600 gauss. This is far from true, it is the density of flux (gauss) available in the fluid treatment area that causes the desired effect. High energy rare earth magnetic material can be as ineffective as ceramic or alnico material if it is not in properly designed circuits.

The magnetic "conduction coefficient" or "permanance coefficient" which relates to length/diameter (L/D) ratio of rare earth magnetic material allows a very compact design, ideal for limited space in oil wells.

Most "rare earth" material has a very high "intrinsic coercive force" or resistance to demagnetization forces. Physical impact, pressure, vibration and stray electrical and magnetic fields have virtually no degaussing effect.

As an MFC can operate for years, stainless steel is an excellent choice of material to construct the casing for the magnetics. Also, some stainless steels have magnetic properties that, if incorporated in the design, can render the device essentially self cleaning of ferromagnetic debris.

## LIMITATIONS OF EFFECTIVENESS

The credibility of magnetic fluid conditioners has been seriously damaged by overrated performance claims and ineffective installations. Too often MFCs are touted as cure-alls for any problems in the oil field, instead of limiting installations to problems they can solve.

To date the 90% success rate in pumping wells that the Mag-Well MFC has attained can only be attributed to sound magnetic design and rigid parameters in selecting wells for sizing tools. Mag-Well will not ship an MFC to a customer until a complete information sheet has been provided for the particular well to be treated. Inaccurate information causes failures.

For example: a customer purchases an MFC for installation in well "A" and is pleased with its performance. The customer then requests another MFC for neighboring well "B" with similar characteristics but does not provide specific well parameters. The second installation fails to perform as well as the first. Upon investigation, it is discovered that well "A" has a 144" stroke, 9 strokes per minute with a 1-1/2" diameter plunger. Well "B" has an 86" stroke, 6 strokes per minute and a 1-1/4" plunger. The volume of fluid in well "B" has been reduced by approximately 75%, causing poor results. An MFC can be manufactured for well "B" that will perform as well as the first, but only after the specifics of the well are known. However, a user may possibly outfit an entire field with the same model MFC. It is possible to do that if the low and high rates are within the operational parameters of that MFC.

## CASE HISTORY #1: SAND DUNES UNIT, CASPER, WYOMING

Problem: Flowing Well with Paraffin

Sand Dunes, Well #23-7 in Casper, Wyoming was flowing 832 barrels of oil a day. With paraffin in the well being cut twice a day, lost production was a constant fear. After installing the MFC, the necessity to cut paraffin was completely eliminated along with the man-hours and attention required for the cutting. Consistency of the paraffin in the well changed from hard before installation to very light paraffin that sluffs off in the system.

CASE HISTORY #2: PINE TREE UNIT, WYOMING

Problem: Pumping Well with Scale

In this well, the pump was changed every thirty days due to scale problems. An analysis of the scale indicated the following composition: Siderite ($FeCo_3$) was the major percentage, and Barium/Strontium sulphate was a trace percentage. Scale was depositing on the ball and seat in the pump. Ninety days after installing the MFC, the rods and pump were pulled for inspection. No scale, including the previously existing scale on the rods, was found. The well has not been pulled for scale related problems since installation of the MFC in March, 1992.

CASE HISTORY #3: A CLUSTER OF WELLS IN EAST TEXAS

Problem: Pumping Wells with BS&W and Paraffin

The following analysis details the "before" and "after" conditions in the subject wells, as well as the increase in savings and revenue.

"Before" conditions: Paraffin deposition in flowlines. Tank high bottoms.

"Before" treatment: Hot oil treating flowlines an average of every two to four weeks to disperse paraffin. Continual chemical treating to reduce BS&W in tanks.
Average monthly treatment cost per well: $274.00.

"Before" results: Flowline paraffin deposition continued. Tanks continued to be rejected frequently by buyers because of BS&W.

| Well# | MFC Installed Date | TOTAL PRODUCTION Before MFC BOPD/BWPD | | TOTAL PRODUCTION After MFC BOPD/BWPD | | BS&W% Before MFC w chemicals | BS&W% After MFC w/o chemicals |
|---|---|---|---|---|---|---|---|
| A | 05 Nov 91 | 38 | 32 | 47 | 35 | 6/10 | 4/10 |
| B | 10 Dec 91 | 33 | 35 | 38 | 30 | 6/10 | 4/10 |
| C | 19 Dec 91 | 22 | 103 | 24 | 110 | 4/10 | 4/10 |
| D | 23 Dec 91 | 47 | 50 | 42 | 38 | 4/10 | 4/10 |
| E | 30 Dec 91 | 32 | 60 | 40 | 65 | 4/10 | 4/10 |
| F | 01 Jan 92 | 62 | 87 | 61 | 88 | 5/10 | 5/10 |
| G | 07 Jan 92 | 58 | 96 | 67 | 90 | 5/10 | 5/10 |
| H | 10 Jan 92 | 51 | 38 | 58 | 35 | 5/10 | 4/10 |
| I | 10 Jan 92 | 42 | 38 | 39 | 38 | 5/10 | 4/10 |
| J | 10 Jan 92 | 34 | 58 | 35 | 44 | 6/10 | 4/10 |
| K | 14 Jan 92 | 34 | 126 | 33 | 124 | 4/10 | 4/10 |
| L | 16 Jan 92 | 35 | 16 | 38 | 26 | 5/10 | n/a |
| M | 17 Jan 92 | 24 | Tr | 21 | Tr | 4/10 | 4/10 |

"After" conditions: No paraffin deposition in flowlines. Tank high bottoms reduced.

"After" treatment: Hot oil treatments and continuous chemical injections discontinued.
Average monthly treatment cost per well: $0.00

"After" results: Flowlines clear of paraffin. No tank rejections recorded on any of the above wells since Mag-Well MFC installation.

Notes: Increased oil production attributed to downhole breakup of emulsions by MFC.
When clear water drained from tanks, no emulsion was left in remaining oil.
Combined net production increase:
31 BBLS/DAY = 930 BBLS/MONTH = 11,315 BBLS/YEAR.
Combined revenue increase @ $18/bbl:
$558.00/DAY = $16,740.00/MONTH = $203,670.00/YEAR.
Combined reduction in treating costs:
$118.73/DAY = $3,561.99/MONTH = $42,744.00/YEAR.

Total increase in savings and revenue = $247,006.45/year.

CASE HISTORY #4: MANISTEE COUNTY, MICHIGAN

Problem: Pumping Well with Severe Paraffin

Prior to the installation of the Mag-Well MFC, chemicals, hot oil and workovers were all used in efforts to control the wax problems in this well. The production chart (Figure 4) shows the increase in production after the Mag-Well MFC was installed, and chemical and hot oil treatments were stopped.

## REFERENCES

Busch, Kenneth W., Marianna A. Busch, Deborah Parker, James L. McAtee, and Ralph Darling, **Magnetic Water Treatment Devices: The Results of a University Study**, Presented to 45th Annual Water Conference, Pittsburgh, Pennsylvania, October 22-24, 1984, 22 pp.

Donaldson, John and Sue Grimes, "Lifting the Scales From Our Pipes," New Scientist, February 18, 1988; 3 pp.

Gruber, Carl E. and Dan D. Carda, "Measurable Parameters in Water Conditioning Equipment as Determined in Laboratory Simulations at Rapid City, South Dakota," Final Report Issued to the Water Quality Association, July, 1981.

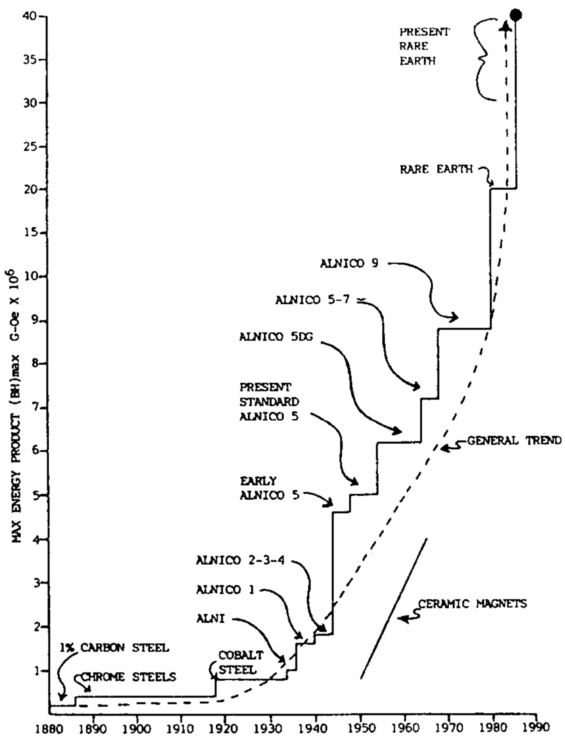



**Figure 1 - The progressive increase in available energy (BH) max for commercially common permanent magnet materials**

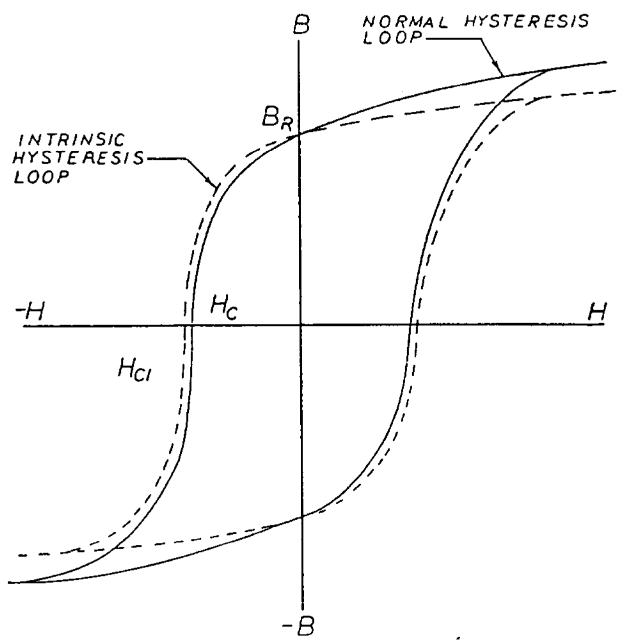



**Figure 2 - Second quadrant demagnetization curve**

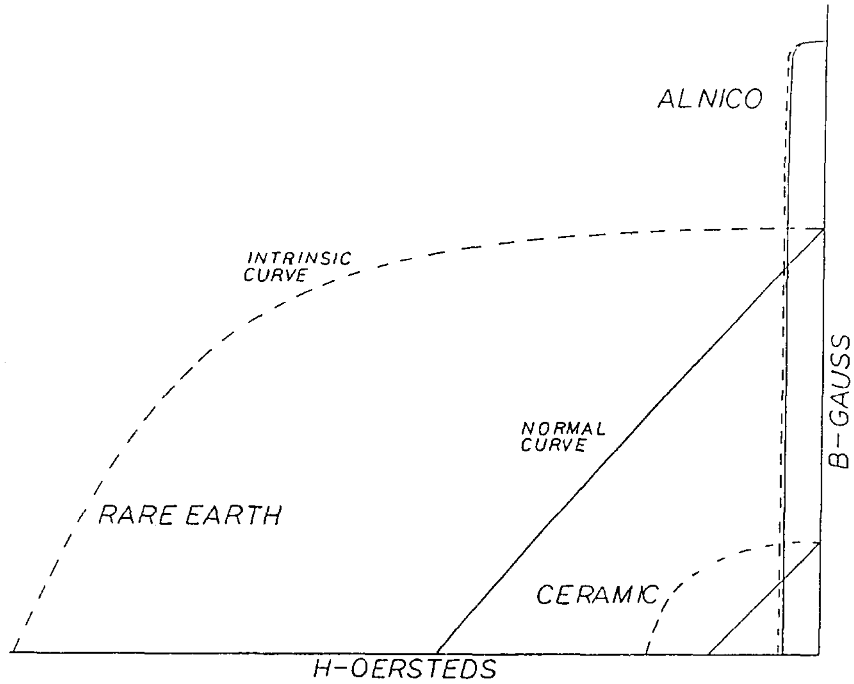
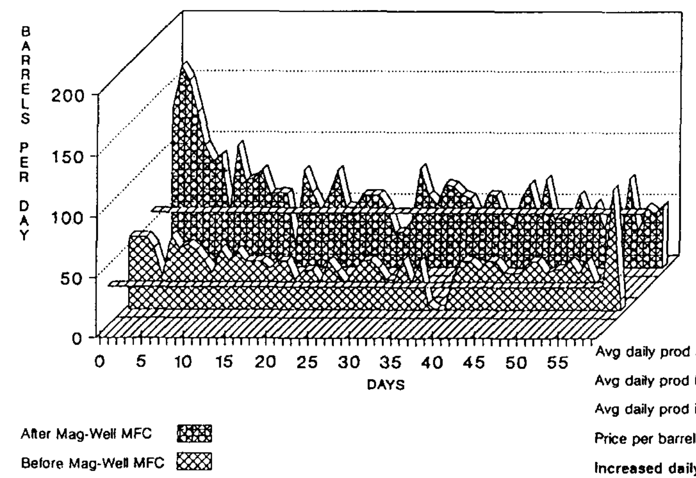



Figure 3




| | |
|---|---|
| Avg daily prod after MFC | 62.48 |
| Avg daily prod before MFC | 36.35 |
| Avg daily prod increase | 26.13 |
| Price per barrell | x $ 20.00 |
| **Increased daily income** | **$522.60** |
| Number of days on chart | x 60 |
| **60-day Increased income** | **$31,356.00** |
| 60-day treatment savings | 2,353.99 |
| ***60-day Total increased revenue*** | ***$33,709.99*** |

OWNER: WESTERN RESERVES OIL CO., INC.
WELL: JOHNSON 4-25
*LOCATION: MANISTEE COUNTY, MICHIGAN*

Figure 4 - Production chart: Comparison of production with and without the Mag-Well MFC