SCALE REMOVAL WITH DOWNHOLE SHOCK WAVES

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INTRODUCTION

Wellbore flow barriers, such as scale deposits, can be pulverized by a new technique that utilizes high-intensity sonic shock waves of microsecond duration. Improvements in well productivity have been realized in field tests at costs substantially below those of conventional remedial services.

The Sonic Shock Tool is lowered in the well on a wireline. It is powered by a high-voltage arc whose shock waves in well fluids hammer the casing walls and openings with a high-intensity impact of microsecond duration. Mineral deposits, such as barium sulfate, gypsum and calcite (alone or mixed with each other or with oily residues), are susceptible to these high-intensity shock treatments. The tool can operate in acid or organic solvents if special conditions warrant their use. The rarification following the shock wave causes a large part of the scale in the casing perforations to fall down inside the casing. These pulverized deposits are bailed out of the well.

Due to reductions in pressure and temperature as reservoir fluids enter a producing well, solid deposits of minerals and/or asphaltic or waxy materials tend to build up in the openings into the wellbore and inside the well. Serious interference with well productivity often results.

About five years ago, Sonics started working on a downhole tool aimed at breaking up these deposits and restoring productivity with shock waves produced under liquid opposite the perforations.

First efforts were with a high-power ultrasonic transducer which produced a strong cavitation and shock waves. This did successfully break up the scale. However, it had two fatal shortcomings: ambient pressures above about 200 psi stopped the cavitation - and the shock waves - and the cleaning. Also, when the power was increased, it began tearing up the surface of the transducer. Efforts were then changed to the use of repetitive high-voltage shocks to break up the wellbore restrictions.

DESCRIPTION OF THE TOOL

Surface equipment consists of a wireline truck equipped with a generator, control equipment, a multiple conductor cable and hoisting drum, and auxiliary equipment. This equipment is shown in Figs. 1-3.

Figure 1 shows the general setup. The truck contains the power generator, converter, necessary controls, and a drum for the multiple conductor cable. The trailer carries a mast for holding the tool above the well.

Figure 2 shows the tool poised above the well (the tubing has been pulled from the well, of course). The

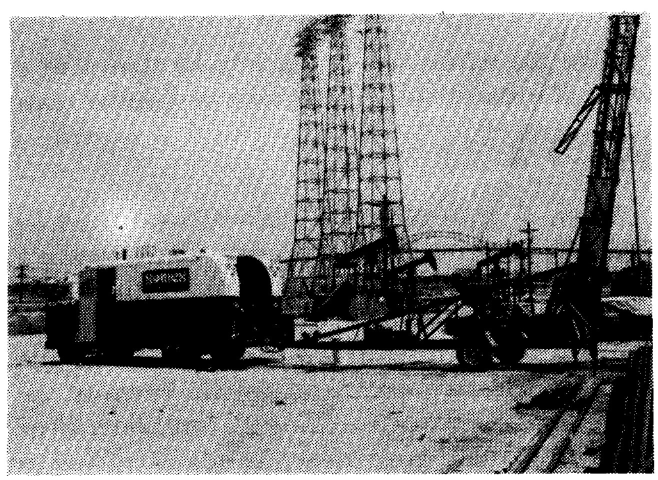

FIGURE 1

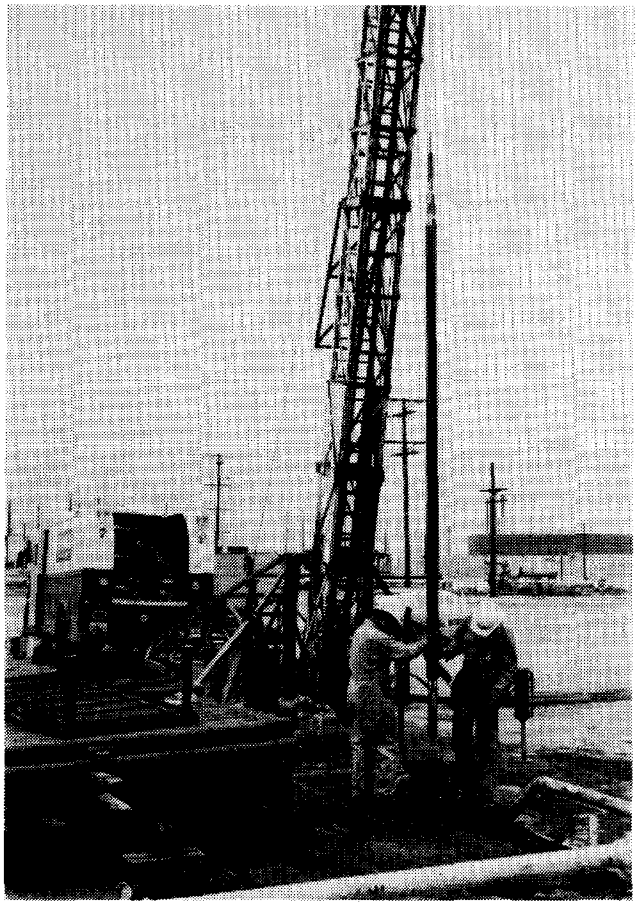

FIGURE 2

FIGURE 3

tool is 4 in. in diameter and about 14 ft long. It will go into 5-1/2 in. casing, or larger. Now on the drawing board is a smaller diameter version which will go into 4-1/2 in. casing. Figure 3 shows the lower part of the tool.

HOW THE DEVICE WORKS

How the device works can best be shown by a series of operational sketches with descriptive text.

Figure 4

Figure 4 represents two electrodes (at the left) under liquid at the bottom of a well. To the right is a perforation plugged by the scale. Before each explosion, a fine wire is automatically placed between the electrodes. This serves to concentrate the electrical flow path and greatly intensify the explosion. It also permits firing the tool under oil or solvents or other nonconducting liquids as well as water or acid c other conducting liquids.

The wire resistance is low, and the imposed voltage high, so that the wire is almost instantly melted, vaporized and ionized. It and the surrounding water molecules, which are broken into fragments and highly ionized, form a "plasma" - a highly ionized gas.

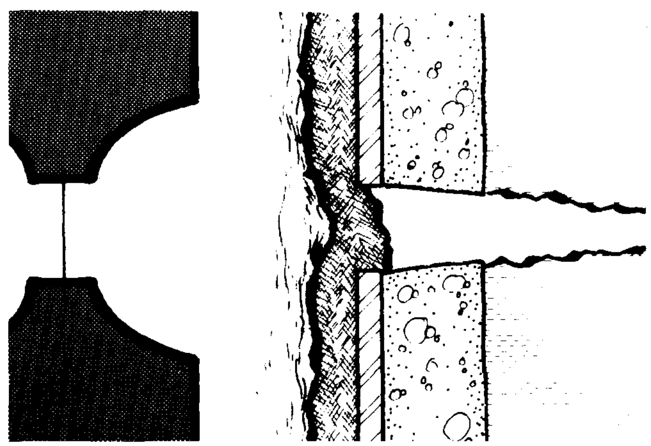

FIGURE 4

Figure 5

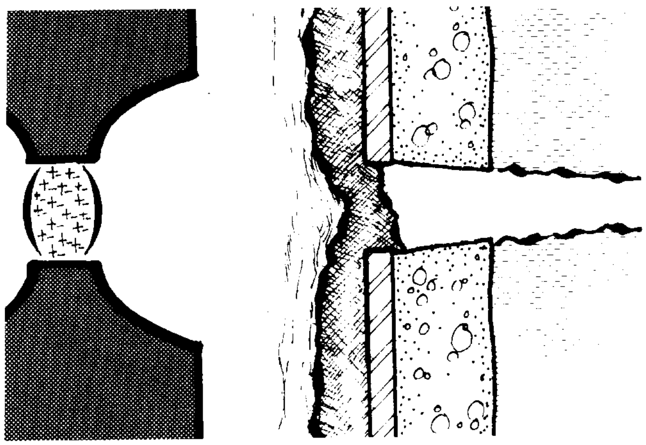

FIGURE 5

This plasma has an even lower resistance than the wire, so that very heavy currents flow — tens of thousands of amperes. This means the discharge is over in a very short time — a few millionths of a second. At this point there has not been time for the water to be pushed back appreciably, and nearly all the energy initially stored in the electrical charge is now present in the plasma. The plasma temperature may reach 50,000°F, causing extremely high pressures in the dense plasma. Pressures as high as 300,000 psi have been reported in the literature for underwater discharges. The expanding plasma maintains a high pressure on the liquid. There is a very sharp boundary between this high-pressure liquid — say at 50,000 psi — and the ambient pressure liquid — perhaps 1000 psi — ahead of it. This sharp boundary proceeds across the water to the scale inside the casing at a velocity much greater than the velocity of sound. This is the shock wave. Most of the energy originally stored electrically winds up in the shock wave.

Figure 6

When the shock wave reaches the scale, it pulverizes it, particularly brittle deposits such as barium sulfate and calcium sulfate. The energy of the explosion is about equivalent to that of a 30-lb weight dropped 10 ft onto the scale.

Each explosion treats about a 6-in. height, all the way around. An explosion is made every two

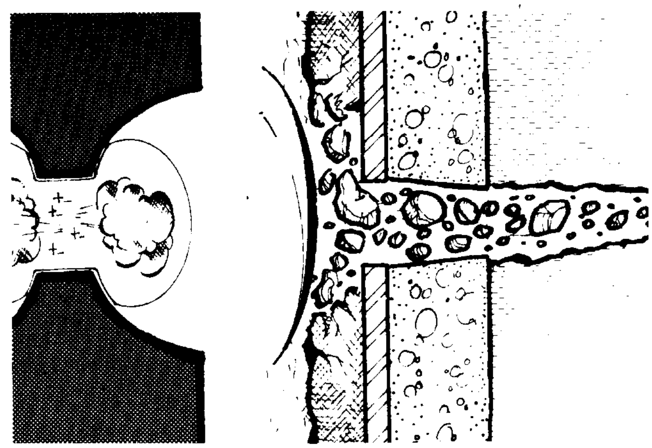

FIGURE 6

seconds as the tool is pulled through the production zone at a rate of 2 min/ft. Each point on the casing is treated with 30 shocks.

Figure 7

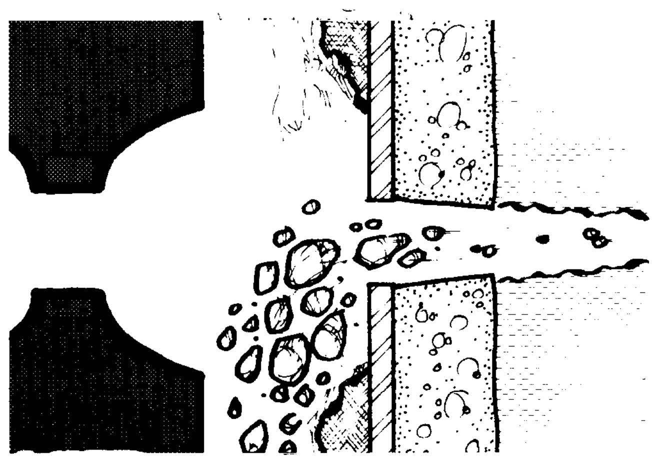

FIGURE 7

As the plasma expands, it cools and finally becomes a stream bubble, which then collapses and draws fluids back into the well. The tests in the laboratory with slotted liners have shown that most of the debris falls down inside the pipe where it can be bailed out.

FIELD OPERATIONS

Rods and tubing are removed from the well to permit access of the 14-ft. long, 4-in. diameter tool containing the downhole electronics for the high voltage discharge. The zone to be treated must be liquid filled. Presence of a free gas phase reduces the shock strength. It operates well under deep liquid columns, oil or water, and static pressures of 4000 psi have been encountered with no trouble. Collapse pressure of the tool is well above 10,000 psi. Our trucks carry the necessary equipment to lubricate the tool into the well under surface pressure; however, most wells treated to date have not required this operation.

The tool is started at the top of the zone to be treated. Present field practice is to fire the tool at 2-second intervals. Each discharge is effective over approximately a 6-in. interval of casing. It is lowered at about 2 min/ft so that each point on the casing is subjected to about 30 shocks. The treatment may be repeated over zones of particular interest.

The time of treatment for each 6-in. of the zone of interest may be tailored to meet the expected need. The intensity of the discharge is readily controlled at the surface. Nonproductive streaks, or water zones, can be skipped. Thus a part of the zone most needing treatment can be given special attention. Too often with solvents or acids the part of the pay which is already open is the part which receives the lion's share of treatment.

Since brittle materials are most susceptible to breakage by shock waves, deposits of barium sulfate and calcium sulfate, which resist chemical treatment, are readily handled by the shock treatment. Calcium carbonate, of course, may be handled by acid treatment, except that often the presence of tarry deposits along with the carbonate protects the bulk of material from attack by the acid. The shock waves are effective in cleaning the casing openings in this situation. The technique has not been tried on paraffin deposits which would not be subject to fracturing. But, where warranted, if a paraffin solvent were spotted opposite the point of interest, it would be expected that the high degree of agitation caused by the shock waves would greatly facilitate the solution of paraffin. Other solvents may be used in connection with treatment of other types of deposits when desired.

Openhole completions have been successfully treated. Of course, if the open hole diameter is large, the intensity of the shock waves reaching the formation will be correspondingly reduced.

EXPERIENCES IN THE FIELD

The following case histories show performance of the Sonic Shock Tool in different types of wells and with different types of problems.

Case History No. 1

KMA 3708-3738 Perforated 7-in. casing
$BaSO_4$

February, 1975	53 oil	187 water
March 4 - Treated		
March 10	94	200
March 12	96	200

Added Oil	7,560
Value at $8.19/bbl	$61,916
Cost including well cost	$ 1,500
Profit/Investment	40
Payout, days	4.4

This well, in the KMA field in Texas, at 3700 ft had 7-in. perforated casing and was badly scaled with barium sulfate. It was, however, a good well, making 53 BOPD. It responded well, increasing to 95 BPD.

The added oil is calculated on the basis that the improvement in rate declined on a straight-line basis until at the end of one year the well would be back on the decline curve it would have had if it had not been treated. In other words, it is equal to half the improvement in rate for a period of one year. This was based on an analysis given by a major oil company for whom Sonics treated 12 wells. They provided the actual decline curve these wells showed over a three-month period, and also the anticipated decline if the wells had not been treated. Straight-line extrapolation gave about one year for the period of improved production. The same basis is used for calculating the production increase shown for all the wells here.

The value of the added oil is figured on the basis of selling it at $10.50/bbl., with one-eighth going to the royalty owners and a cost of $1.00/bbl for lifting the added oil, leaving $8.19 net value to the operator. This value is probably too low, because (1) new oil is now selling for more than $10.50/bbl and (2) the added lifting cost may be very little. For example, in this case there is a substantial increase in the oil but little increase in the water production. The lifting equipment already on the well would, no doubt, handle the added production, so that there would be practically no added cost for lifting the new oil.

The cost of the treatment, including the cost of pulling and running the tubing, was $1500. The profit/investment ratio is 40 and the payout 4.4 days. This is, of course, an unusually good return.

Case History No. 2

Stonewall County Conglomerate

6030-6070	Perforated		
6030-6040	Treated		
$CaCO_3$			
December 20, 1974	2 oil	20 water	
December 20 - Treated			
February 22, 1975	7	20	

Added Oil	900
Value at $8.19/bbl	$7,371
Cost including well cost	$1,500
Profit/Investment	4
Payout, days	39

This is a perforated casing which was producing oil in the top 10 ft and water only in the lower 30 ft. We hoped to be able to treat only the top 10 ft so as to increase the oil production and not the water. This was done and the oil, in fact, increased from 2 to 7 bbl while the water remained constant at 20 bbl. This, of course, could not have been done unless there were horizontal barriers in the reservoir to prevent coning into the well. Horizontal barriers in a reservoir are a common occurrence.

Since the scale was calcium carbonate, one might wonder if acid treatment might not have done as well. However, acid could not have been used in this particular well because the formation was highly bentonitic, so that aqueous injections tended to plug the well up solid. Since this well produces only 2 BPD, it is doubtful whether either acidizing or fracturing would have been economically attractive. The low cost of the shock wave type of treatment gave a profit/investment ratio of 4 and a payout of 39 days, which, of course, is very attractive.

Case History No. 3

Stephens County

3956-3962 Perforated 5-1/2 in. casing

Mud Blocking Flow - 6 ft of fill

December 18, 1974	19 oil	132 water
December 21, 1974 - Treated		
January 11, 1975	36	165

Added Oil	3,060
Value at $8.19/bbl	$25,000
Cost including well cost	$ 1,500
Profit/Investment	15.7
Payout, days	11

This is also a well with perforated casing. It was thought that another scaling problem existed, but after the shock wave treatment, it was found that 6 ft of fill (largely mud) had been added to the bottom of the casing. When the well was completed, it had not received a treatment of any kind. It is suspected that there was caked mud behind the casing, blocking the flow passages, which the shock waves served to clear. At any rate, this well responded well, increasing from 19 to 36 BPD and giving a good profit/investment ratio and payout time.

Case History No. 4

Wilmington, California

2962-3554 Slotted Liner

FeS, $BaSO_4$, Organic

June 5, 1975	60 oil	290 water
June 5 - Treated		
June 10	99	448

Added Oil	7,020
Value at $8.19/bbl	$57,500
Cost including well costs	$ 3,000
Profit/Investment	18
Payout, days	10

This is a slotted liner completion in the Wilmington field, California. It had a complex scale of iron sulfide, barium sulfate and organic material. The entire perforated section was treated, and both the oil and the water increased about 50%. The cost of this treatment was unusually high because of the necessity of sending a truck from Dallas to California for a set of wells. However, the job showed a good economic return.

Case History No. 5

Shallow Slotted Liner

FeS, $CaCO_3$, - Fire Flood

July 1, 1975	7.87 oil	2.86 water
July 11 - Treated		
July 18	7.60	2.70
July 23	10.80	1.63
July 28	9.54	12.48

Added Oil	260
Value at $8.19/bbl	$2,120
Cost including well cost	$ 460
Profit/Investment	4.1
Payout, days	37

This was a shallow well with a slotted liner in a fire flood. The scale was iron sulfide and calcium carbonate. It was a rather small well, producing a little less than 8 BPD. It increased to a little over 9 BPD, averaging the last three numbers. Because of the low cost of treating this shallow well, the return on the investment was good.

Case History No. 6

Wilmington, California
3145-3620 Slotted Liner
FeS - Bacteria
Injection Well

June 3, 1975	1072 BPD at 1160 psi
June 3 - Treated	
June 9	1230 BPD at 1160 psi

This is an injection well with a slotted liner in the Wilmington field. It had an iron sulfide-bacteria scale, which is all too common in injection wells. The injectivity increased about 15%.

Case History No. 7

Wasson 4920-5130 Open Hole
FeS, $CaCO_3$, SiO_2, S
Injection Well

January 6, 1975	225 BPD at 1300 psi
January 15 - Treated	
January 24	1000 BPD at 250 psi
January 29	1000 BPD at 930 psi
February 1	1000 BPD at 930 psi
February 2	1000 BPD at 1080 psi

This is another injection well in an open hole in the Wasson field. This well had been acid-treated prior to shock wave treatment and had failed to respond to acid. The shock waves were very effective in this case, increasing the injectivity index by a factor of 5.

The above illustrate a few individual cases of different types of situations in which the shock waves were effective in improving wells. Over-all results on all the wells treated to date with this tool are discussed below.

Total Results on All Wells Tested in 1975

Before, Total Rate	1,337
After, Total Rate	1,719
Added Oil	69,715
Value at $8.19/bbl	570,966
Cost, Sonics	56,400
Well Cost	50,995
Profit/Investment	5.3
Payout, days	34

This gives the total results on all 47 wells that were treated (except two or three for which evaluation data were not provided.) The total rate for these wells before treatment was 1337 BPD, and after treatment, 1719 BPD - an average increase of 29% in productivity. The total charges by Sonics for these wells were $50,995. The over-all profit/investment ratio was a little over 5.3 and the payout 34 days.

Injection Wells Treated

BPD		BPD/psi		
Before	After	Before	After	Ratio
225	1000	0.173	0.926	5.35
1072	1230	0.924	1.090	1.18
1288	3100	1.360	3.10	2.29
2380	1400	0.152	0.176	1.16
630	1300	0.463	0.929	2.01
				2.40 Avg.

This table shows the result on all of the injection wells we have treated (5 wells). The average improvement was better than 100%, suggesting that injection wells respond even better than production wells. Perhaps the injection well scale is more completely accessible to the shock waves.

CONCLUSIONS

1. If water and oil come from different levels in a well it may be possible to improve the water-oil ratio by treating only the oil zone. Note that this control is quite different from the situation when one is using solvents or chemicals, such as acid. In that case, the injected fluid most readily goes into that part of the pay which is least in need of treatment. Zones which are most in need of treatment may receive no treatment at all. Also, the

effectiveness of acid decreases with repeated usage.

2. The low cost of this service makes it possible to consider it for stripper wells which are too small to justify acidizing or fracturing.
3. Even in cases where chemicals are deemed advantageous to the removal of a plugging material, the selective, severe agitation created by the shock tool, permits the use of small volumes of the chemical, spotted with a dump bailer, at the desired depth for treatment.
4. Obviously, if it were known in advance which wells have skin damage (scale) service could be recommended only for those wells most likely to benefit from it. To achieve this, a new service is being offered which acoustically determines pressure buildup curves for pumping wells. Included is a rapid standardized analysis that provides the client with measures of pump efficiency, estimates of skin damage, formation permeability and reservoir pressure.