TECHNICAL PUBLICATION

Title:	**An Alternate Method of Reducing SKIN in Oil and Gas Wells**
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ABSTRACT

A near-wellbore reduction in permeability can drastically reduce the productivity of a well. This technical overview will review the causes of this reduction, and the various solutions available to remediate the problems. Traditional and more recently developed technologies are discussed.

NEAR-WELLBORE DAMAGE

Many wells experience a near-wellbore reduction in permeability at some point in their life that can drastically reduce their production rates. This damage, or “skin”, doesn’t only occur during production (from material such as scale, fines and organics), but can also occur during drilling or completion of the well. In the latter situations, the well will usually never reach its production potential. With production related formation damage, an adequately producing well can suddenly become a poor producer. Regardless of when the damage occurs, a well producing below its potential can quickly become an uneconomical well. See Figure 1 for an example of the effect of near-wellbore skin damage on the pressure drop across the reservoir, due to the reduced permeability in the formation adjacent to the borehole. The net result is decreased fluid flow into the borehole.

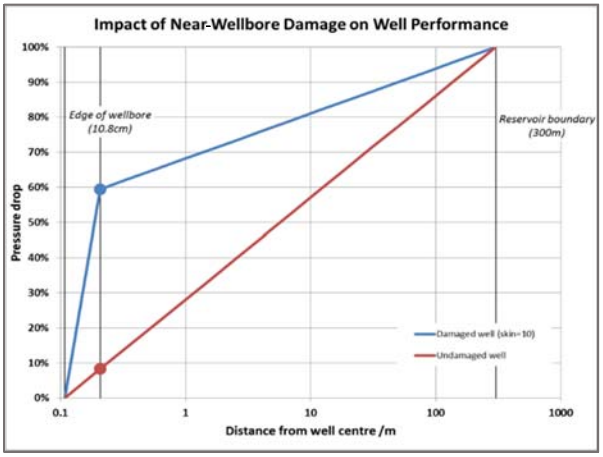


Figure 1. Near-wellbore Damage Plot – SKIN causes a reduction in the pressure drop across the reservoir, reducing the flow rate of fluids into the wellbore.

CAUSES OF SKIN

Near-wellbore damage, skin, can occur at any time during the life of a well, from drilling the well through the production life cycle. Each stage of a well has its own unique causes of skin. A well with no near-wellbore damage has a skin value of zero, while a well with severe damage might have a skin of 20 or greater. Very severely damaged wells can have a skin value in the 100s.

Most wells are drilled overbalanced, and if the mud system is water based, there are several incompatibilities that can cause formation damage as the fluid is lost:

- Clay particles that swell when contacting drilling mud (for formations that contain some shale)
- Precipitates that form when the water in the mud (filtrate) interacts with the formation water
- Emulsions that restrict the flow through the pore throats can form when the drilling mud filtrate reacts with the reservoir oil
- Drilling mud solids and the ground-up formation rock can also directly cause plugging of the pore space and natural fractures that may exist in the rock

Even formations drilled with oil-based mud systems can experience formation damage during drilling, although not usually as extensively or often as with water-based mud. The damage is generally due to the incompatibility of chemical additives in the mud with the formation oil that creates emulsions.

During completion of the well, the most common cause of near-wellbore damage is perforating. Although the purpose of perforating is to connect the wellbore to the reservoir, the over 10 million psi jet that creates the perforations also crushes the adjacent rock, reducing the permeability of the near-wellbore by up to 50%. The intense heat that is generated causes "glazing" in the perforation tunnel, further reducing the permeability. Perforating in an underbalanced state helps reduce these effects, but cannot totally eliminate all skin damage.

Lastly, precipitates (scales and solids) and extremely small formation material (fines) can be created during the production of a well, causing formation skin, thereby reducing the permeability of the formation. Precipitates can also cause operational problems by coating the inside of tubulars, valves, and pumps.

THE TRADITIONAL SOLUTIONS

Of the traditional methods of improving connectivity to the reservoir, hydraulic fracturing is probably the most successful of the methods, since a well-executed "frac" will create pathways into the formation rock that extend well beyond the near-wellbore damage created during drilling and/or completion. In some cases, the fractures can reach 100s of meters out from the borehole (larger fracs of this nature use 100s of tonnes of proppant and 1,000s of m^3 of fluid). Fracturing is particularly effective in low permeability (tight) formations such as carbonates, coals and shales. Fracs can be done at any time during the life of a well, although they are most commonly done during the initial completion of a well. Occasionally fracs are done several times on the same well. Doing the frac after production begins helps connect the wellbore to the reservoir beyond any skin damage that occurred during production. Hydraulic fracturing can improve the skin value to zero or even negative numbers.

Matrix acidizing is also commonly used to improve productivity in damaged wells. Hydrochloric acid (HCl) is most commonly used in carbonates, and hydrofluoric acid (HF) in sandstone wells. Acidizing dissolves the sediments, mud solids, and precipitates that plug up the pores, thus improving the permeability of the rock. In the case of carbonates, it may also aid in the formation of wormholes, small continuous channels through the rock. Matrix acidizing on its own can also improve the skin value to zero or slightly negative.

Another type of treatment to remove damage is the use of propellants. These are solid chemicals that burn or "deflagrate" at a high rate, creating pressures up to 20,000 psi that last several milliseconds (perhaps up to several hundred milliseconds). This intense pressure is enough to create fractures in the formation rock, creating pathways beyond the near-wellbore damage. In theory, propellant stimulation can create more than just two fractures, as hydraulic fracturing does.

The last traditional method is perforating, or if used as a method of improving skin caused by production damage, "re"-perforating. As mentioned earlier, perforating in itself in the primary cause of completion damage, but is still a viable way of improving the connectivity between the wellbore and the reservoir. It may introduce its own skin, but that could certainly be less than that which is caused by production damage, resulting in an overall improvement in production. The new access to the reservoir created by perforating will generally extend beyond the near-wellbore damage. Perforating can also be followed by chemical methods such as acidizing, or can be combined with propellants.

ISSUES WITH THE TRADITIONAL METHODS

As with almost everything in the oilfield, the above methods can have their inherent risks, as well as some disadvantages.

For hydraulic fracturing, the method can be very costly, and may require a huge footprint on the lease. It requires large quantities of fluids, mostly water, which may not be easy to acquire, depending on the location of the well. The chemicals often used can be toxic, requiring special transportation and handling. Additionally, if there are multiple zones to complete, each zone must be completed separately using packers, since once it's initiated, the fluid and proppant will follow the path of least resistance. And from a safety point of view, there are always risks when pumping at such high pressures and rates. Some jurisdictions are now restricting the use of hydraulic fracturing due to environmental concerns, if not outright banning it.

When using acid, as with any chemical, there are always safety related risks when both transporting and handling the chemicals. There is also the risk of not having the optimal chemical for the type of rock being treated. If there are incompatibilities between the acid and formation solids or fluids that aren't anticipated, there can be precipitates formed that could result in more damage to the formation than improvement. Also, the acid will tend to follow the path of least resistance, and may therefore not always treat as large of a volume of the formation as intended. As with hydraulic fracturing, acid use is being restricted in some jurisdictions due to environmental concerns, including ground water contamination.

For propellants, there are also safety related risks, due to the nature of flammable materials, therefore requiring special procedures for transportation and handling. Some propellants have also had issues with random ignition and unpredictable flame spread.

Perforating is potentially the most dangerous of all the stimulation methods due to the nature of the explosive material. The transportation of explosives is highly regulated and stringent safety precautions are required during a perforating job. As mentioned earlier, there will always be skin associated with perforating, although the overall value of skin may be reduced if there is already near-wellbore damage. Also, multiple zones could require multiple runs in the hole, and horizontal wells require deployment on either tubing or coiled tubing.

FLUIDIC PULSING

Recent technological developments have brought a new class of stimulation techniques that operate by creating a sudden increase in the localized pressure in the wellbore at the position of the hardware being deployed, without the use of chemicals or explosives. These methods increase the pressure of the fluid in the borehole either in the form of a concentrated, pulsing jet or as a radial pressure wave, concentric with the borehole. Both are different than a conventional jetting tool, which does create a high pressure fluid stream, but does not pulse.

The first type involves a tool with a precision machined nozzle that can be deployed on tubing or coiled tubing, in open or cased holes, and in vertical or horizontal wells. The tool utilizes either a proprietary chamber configuration inside the tool to generate a "vortex" effect or an electronically operated servo. Both are capable of generating "pulses" with pressure that can reach up to 1,200 psi at velocities up to 200 m/sec and can pulse at frequencies up to 120 Hz. These tools are much more effective that a traditional jet nozzle. The nozzle can be configured with a variable number of ports that can be directed forward or backward, and can also be self-adjusting. Any liquid can be pumped through the tool. This tool is especially effective at cleaning out the inside of casing, tubing, and other hardware

The second category of fluidic pulsing involves converting electrical energy into a fluidic pressure wave, and hence is called electro-hydraulic stimulation. A relatively small amount of electrical energy comes from a wireline unit through the logging cable to the downhole tool, where it is amplified, stored, and then released in an extremely short time. By compressing the time frame, a large amount of power can be generated that is used to create a "spark" (a plasma arc) that superheats the liquid present, vaporizing the liquid into a gas. The gas is generated so rapidly, at such great pressure, that it expands rapidly, thus creating a shock wave and a pressure pulse. These two forceful mechanisms can dislodge material in both the wellbore and the formation rock.

Whether using explosives, propellants, mechanical forces or fluidic pressure pulsing systems to interact with underground rock formations, all the energy in the system is ideally released in a short period of time to generate useable power. Based on the speed of the energy release, tremendous power can be utilized from relatively modest energy sources.

ELECTRO-HYDRAULIC STIMULATION

Electro-hydraulic stimulation (EHS) tools utilize the method described above to generate thousands of repeatable, high-power pulses on each trip into the well. EHS tools are run on regular wireline cable, with no special power source required. A non-compressible fluid is required in the borehole to conduct the shock wave created into the formation rock, but only needs to be covering the interval being stimulated. The fluid can be water, brine, or produced fluids, including light or heavy oil.

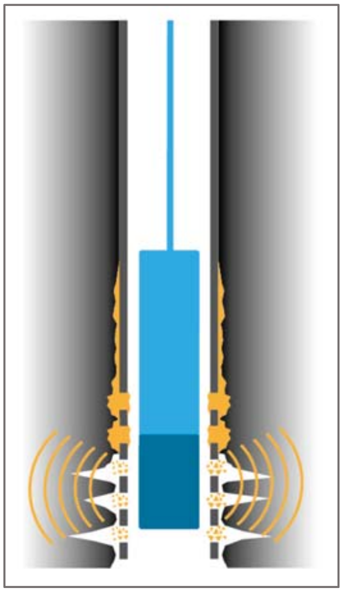


Figure 2. An electro-hydraulic stimulation (EHS) tool generates both a shock wave and a pressure pulse, causing tensile failure of geomaterials.

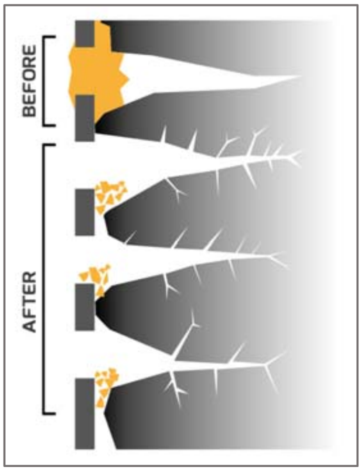


Figure 3. EHS tools cause geomaterials to disaggregate and become mobile, while causing tensile cracking in the near-wellbore.

EHS tools can discharge stored energy in as short a time as a few microseconds, for which the pulse generated by the transducer reaches power levels of several hundred megawatts. This creates a very intense shock wave and pressure pulse. The shock wave occurs first, and travels faster than the pressure pulse. The waveform travels in liquids, radiating laterally away from the tool at the speed of sound, which is approximately 1500 m/s in water (Figure 2). It contains a range of wave frequencies that create a complex polarization field that mechanically interferes with the formation immediately in front of the transducer. This polarization field is a result of the pulse wave and other physical phenomena such as shear conversion scattering, reflection and high pressure. When the acoustic shock wave interacts with a material possessing a different acoustic impedance than the liquid through which the wave is propagating (steel or a geomaterial), there is an energy reflection and/or energy absorption event. Due to the acoustic impedance difference between a liquid and a geomaterial, a tensile stress results. The stresses generated through this interaction are significant enough to exceed the tensile strength of most reservoir rocks, thereby causing fracturing of the formation, but are much less than the yield strength of steel, protecting the integrity of the casing and cement. The tensile strength of waxes, gels, organic and inorganic scales is also exceeded, causing these materials to disaggregate and hence become mobile (Figure 3). The cumulative effect of the repetitive shock waves (pulse delivery is repeated several times each minute) creates increasingly deeper tensile cracking in the near-wellbore, creating pathways that allow increased inflow. The service is designed to stimulate the near-wellbore region of a completed interval, out to 0.9 meters (3 feet) from the well center (see Figure 4).

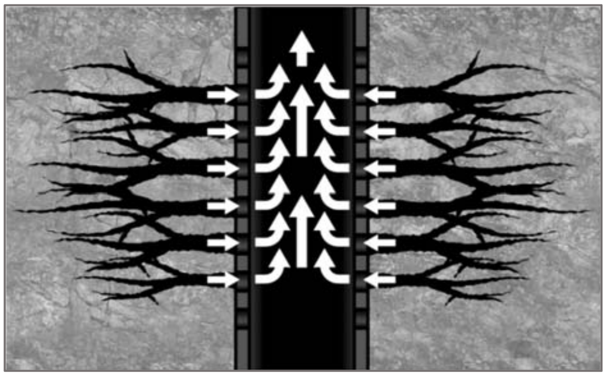
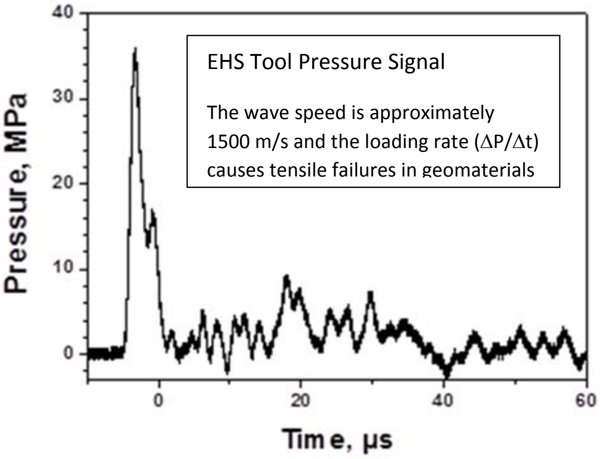


Figure 4. The removal of organics and scales up to 0.9 m (3 ft) from the borehole reduce the skin value and allow for improved fluid flow into the borehole.

The pressure – time characteristics of the typical pressure pulse generated by an EHS tool are illustrated in Figure 5.



The wave speed is approximately 1500 m/s and the loading rate (ΔP/Δt) causes tensile failures in geomaterials

Figure 5. Shock Wave Characteristics of an EHS tool at a distance of 15 cm (6 in) from the point source. A very sharp peak is seen that is approximately 5 microseconds wide. The peak pressure is 35 MPa (5,000 psi) at 15 cm (6 in).

When compared to the other forms of stimulation that cause an increase in pressure in the wellbore, the pressure pulse from an EHS tool occurs in a time frame that is similar to explosives (several microseconds), but at a pressure much less than explosives, falling between that of hydraulic fracturing and propellants (see Figure 6).

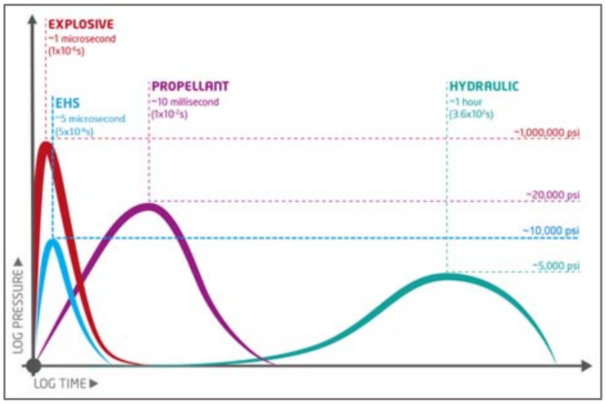


Figure 6. Comparison of Stimulation Types – EHS tools cause a pressure pulse similar in time to explosives, but with pressure falling between hydraulic fracturing and propellants.

Secondary effects of the pressure pulse from an EHS tool are cavitation and dilation. Cavitation also creates shock waves when the bubble of gas collapses, further creating forces on the formation rock. Dilation can also occur due to the shock wave, which can result in a realignment of the rock matrix grains, effectively increasing the pore space between the grains. These effects are not as prominent as the tensile failure of the geomaterials caused by the pressure wave.

An EHS tool can be run in open hole or cased hole. Stimulation can be performed in any type of completion, including perforations, sand screens, gravel pack, slotted liner, or open hole. The use of a wireline tractor or e-coil also allows deployment in horizontal wells.

DESCRIPTION OF THE DOWNHOLE TOOLS

A typical EHS downhole tool is depicted in Figure 7. The main components of the entire stimulation tool system include:

- Power Panel, Cable, Cable Head, Charge Unit**,** Energy Storage**,** Power Amplifier and electrodes.

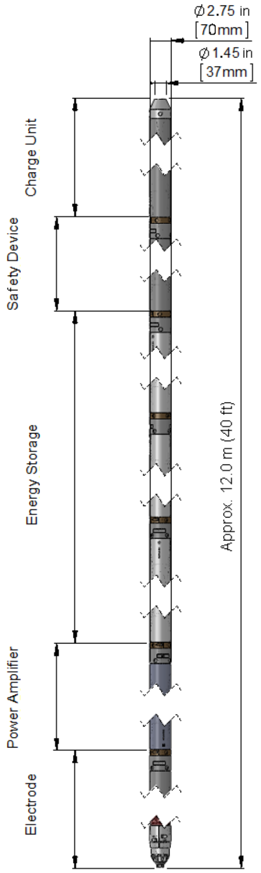


Figure 7. A typical downhole EHS tool

Within the electrode section of the tool's transducer are an anode and cathode that are immersed in a control fluid, housed within a packer element. Periodically, when the power amplifier dumps the energy storage devices, an arc occurs between the anode and cathode. This arc occurs with such intensity that the energy is converted into heat, causing an instantaneous and localized phase change in the control fluid, from a liquid to a gaseous state. The vapor state occupies more volume than the liquid, so a volumetric expansion occurs. Being submersed in a non-compressible fluid environment, the gas expands rapidly, triggering a shock wave.

As the packer element expands instantaneously, within a few microseconds a high pressure (35 MPa at 15 cm), high velocity (1500 m/s), short wavelength shock wave is emitted. This pulsing process can occur every 5 seconds, for several thousand cycles, until the electrode needs to be refurbished.

ADVANTAGES OF EHS

- Fast deployment on wireline (mono or multi-conductor cable), utilizing a small footprint on the lease
- Accurate correlation using GR-CCL tool
- Can be combined with production logging tools for optimizing inflow performance
- No mechanical isolation of zones is required
- Environmentally friendly, using no water or chemicals
- Safe, low risk operation, as no explosives, flammables or extreme surface pressures are required
- Creates near-wellbore fracturing of the matrix rock to create new pathways for flow
- Minimal vertical growth of fractures, reducing the risk of communication to water zones
- Volume of influence is not restricted to path of least resistance, due to the time frame of the pulse

OPERATIONAL ASPECTS OF EHS

- Fluid is required in the borehole, covering the zone to be stimulated
- Will work in open or cased hole, with no risk to the formation rock integrity
- Can be deployed in vertical, deviated or horizontal wells (using a wireline tractor or e-coil)
- Lithology independent stimulation (clastics or carbonates)
- Proven to cause no damage to cement or casing
- Precision tool placement enables selective treatment of only the hydrocarbon zones
- Diluents, surfactants and acids may be added to the wellbore to enhance stimulation
- Works for both producing and injecting wells

CONTACT INFORMATION

For further information on Electro-Hydraulic Stimulation, please contact Blue Spark Energy at 1-855-284-1568 or info@bluesparkenergy.com .