TECHNICAL PUBLICATION

Title:	**Cleaning Scale from Upper Completion Equipment with EHP**
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ABSTRACT

Scale is a problem that can cause upper completion equipment, particularly Sub-Surface Safety Valves (SSSV), to not function properly, which can compromise the integrity of a well, both offshore and onshore. In most jurisdictions, a non-operational SSSV becomes a compliance issue, which can result in a well having to be shut-in. This technical overview will address the issue of scale build-up in upper completion equipment and how it can be removed using Electro-Hydraulic Pulsing (EHP).

SCALE BUILDUP

Scales generally form as a precipitant that is dependent on minerals that are present, most commonly in the formation water or in injected water. Changes in pressure and temperature are the catalysts that generally initiate the formation of scale. The typical scale types that would be encountered in upper completion equipment are calcium carbonate (CaCO3) and barium sulphate (BaSO4). The first is usually treatable with chemicals/acid, but the latter is not considered to be treatable with chemicals/acid.

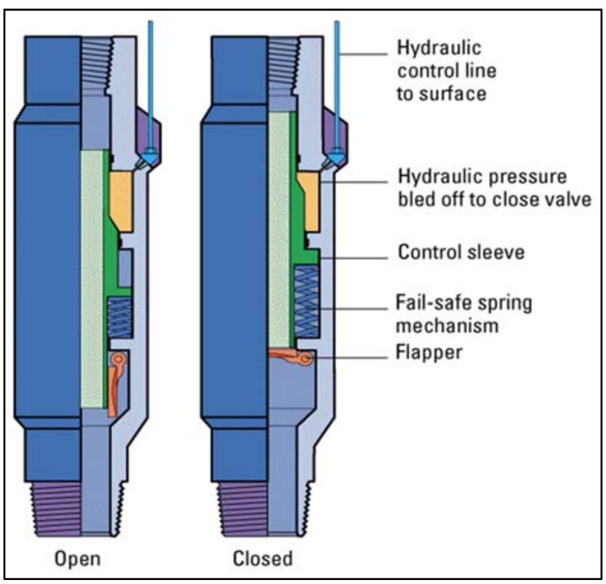

Figure 1: Typical flapper style Sub-Surface Safety Valve (SSSV)

For Sub-Surface Safety Valves (SSSV), they do occasionally become inoperable for various reasons, one of which is a build-up of scale. Scale can either cause the control sleeve, and hence the flapper valve, to become jammed, or can build up on the valve seat, preventing a complete seal of the flapper (Figure 1).

Another type of upper completion equipment that can be impacted by the buildup of scale is a Side Pocket Mandrel (SPM), especially if the equipment inserted into the SPM is a Gas Lift Valve (GLV) (Figure 2). Because the GLV is offset from the center of the wellbore, its individual components are not within the main bore diameter, making access for cleaning of those components difficult

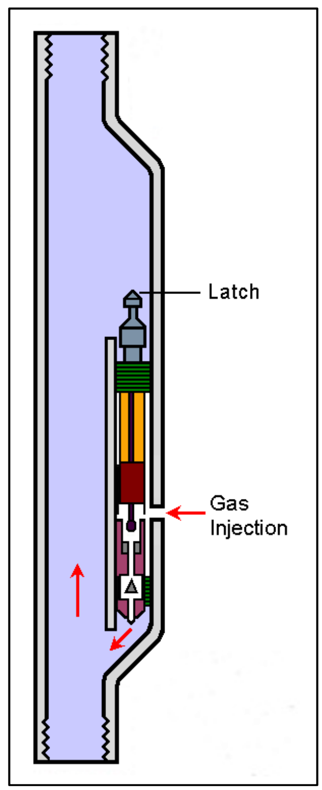

Figure 2: Side Pocket Mandrel (SPM) with retrievable Gas Lift Valve (GLV)

by some mechanical methods of scale removal.

THE TRADITIONAL SOLUTIONS

The method of removing scale will depend on the type of scale and the component to be cleaned.

When it is determined that scale is the reason for the inoperable state of a SSSV for instance, the traditional methods that are attempted to remove the scale are acid, brushes and exercising tools.

If the scale is acid soluble, a 15% HCl solution is usually spotted across the SSSV, often using a dump bailer. The acid is allowed to soak, typically for 15 minutes or more, and then an inflow test would be attempted. A wire brush (Figure 3) can be used in combination with

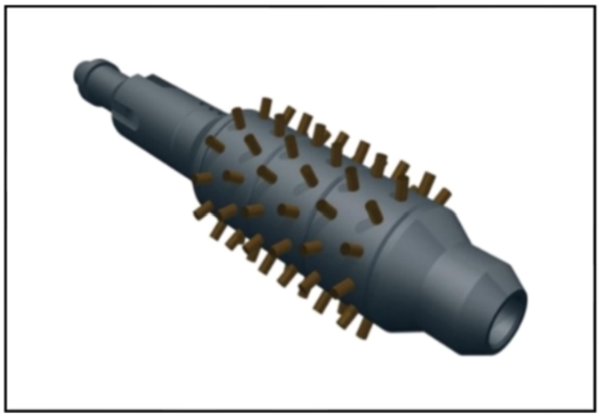

Figure 3: Typical wire brush which can be used to remove some types of scale

acid or on its' own and is moved up and down over the SSSV to remove the scale. This could require several runs in the hole. Lastly, an exercising tool can be used to engage the bottom of the SSSV control sleeve to pull it upward, and then the control sleeve is pushed downward using the hydraulic controller. The control sleeve can be cycled up and down several times to help free it up. Generally, these methods separately or together result in making the SSSV operational again only 50% of the time.

For GLVs, due to the location being in the SPM offset from the centerline of the main bore, brushing cannot effectively reach the GLV, particularly the latch at the top. This leaves acid or fluid-jetting tools as the primary treatments to remove scale from GLVs. Acid may work if the scale is soluble. Harder scale like BaSO4, which is not very treatable by chemicals, is similarly difficult to remove with jetting tools unless abrasives are used. The abrasive particles can also tend to remove metal, therefore have to be used with caution so as not to damage the GLV components.

ISSUES WITH THE TRADITIONAL METHODS

All methods have advantages and disadvantages, which are very dependent on effectiveness, operational constraints, budget, scheduling, safety concerns (handling and transportation), jurisdictional regulations, and environmental concerns & impact. Acids and chemicals have the greatest environmental impact and the most stringent transportation & handling regulations. There is also the risk of acids and chemicals being produced back into production lines, and that they could also damage sealing surfaces.

For most mechanical methods, success will depend on the type of scale and the complexity of the equipment. Brushes are not effective on complex and/or offset profiles, such as GLVs, and abrasive material can damage delicate equipment.

ELECTRO-HYDRAULIC PULSING AS AN ALTERNATIVE

A more unique and newer technology for cleaning scale in the upper completion is with a form of high-pulsed power (HPP) called electro-hydraulic pulsing (EHP). EHP uses a relatively small amount of electrical energy that is amplified, stored, and then released in an extremely short time. By compressing the time frame, a large amount of power can be generated and released, creating a shock wave and a pressure pulse (Figure 4). These two forceful mechanisms can dislodge material in the wellbore that may be coating casing, tubing, or upper completion equipment. Due to the speed of the energy release, tremendous power can be generated from a relatively modest amount of energy.

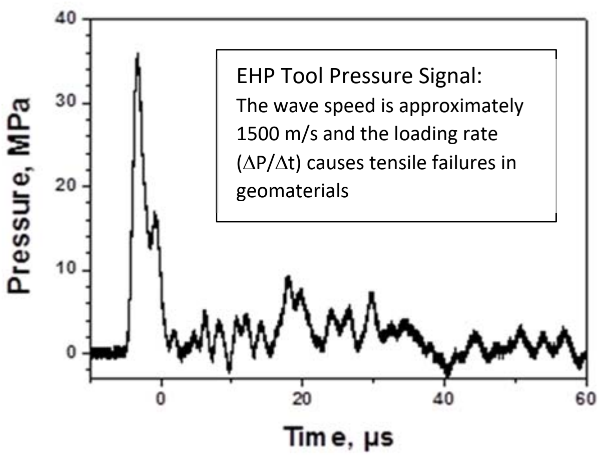

Figure 4. Shock Wave/Pressure Characteristics of an EHP tool at a distance of 15 cm (6 in) from the point source. A very sharp peak is seen that is approximately 5 microseconds wide. The peak pressure is 35 MPa (5,000 psi) at 15 cm (6 in).

EHP tools generate thousands of repeatable, high-power pulses on each trip into the well. When the acoustic shock wave interacts with a material (steel or a geomaterial) possessing a different acoustic impedance than the liquid through which the wave is propagating, 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. In general, the tensile strength of a geomaterial is only 10-20% of its compressional strength. Hence, the stresses generated through this interaction are significant enough to exceed the tensile strength of most scales but are much less than the yield strength of steel, protecting the integrity of the casing and cement. This mechanism works for both organic and inorganic scales, causing these

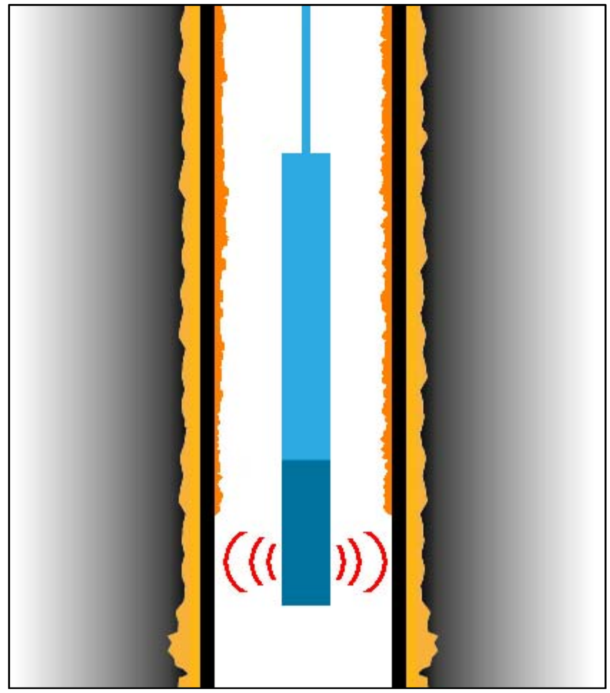

Figure 5. An electro-hydraulic pulsing (EHP) tool generates both a shock wave and a pressure pulse, causing tensile failure of geomaterials. These two effects can break up scale on the inside of casing (above), tubing, or in upper completion equipment.

materials to disaggregate and hence become mobile. The cumulative effect of the repetitive shock waves (pulse delivery is repeated every few seconds) is to remove the scale completely, in most cases leaving bare metal (Figure 5).

A secondary effect of an EHP tool is cavitation. Due to the short time-frame of the EHP tool pulse, cavitation can occur in the liquid immediately adjacent to the tool, creating a second shock wave when the bubble of gas

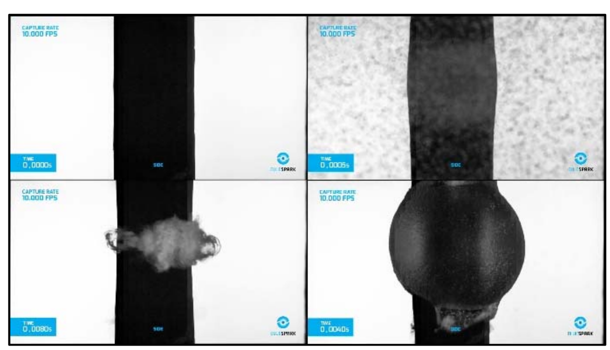

Figure 6. Clockwise from top-left, high-speed photos of an EHP tool pulsing, showing the creation and subsequent collapse of a cavitation bubble.

collapses (Figure 6). If the wellbore conditions are such that cavitation can take place, this effect further aids in removing scale from the wellbore. Like the initial shockwave and the pressure pulse, the effect from the cavitation does not directly contact the equipment being cleaned such as with a brush and is therefore potentially less damaging to sensitive equipment.

LAB TESTING OF SCALE REMOVAL WITH EHP

To test whether a particular type of scale can be removed from a specific type of equipment or tubular using EHP, the ideal situation is to obtain a piece of equipment that has actual scale buildup on it. This is not always practical. A reasonable alternative is to obtain the exact piece of equipment from the potential customer and to simulate scale using a material with similar properties. For this task concrete works well, as it can be mixed to have a variety of compressive strengths and sets up relatively quickly. This method has been routinely used to demonstrate the removal of blockages from perforated casing but can also be used for upper completion equipment.

When a particular customer was interested in determining whether a non-operational SSSV could be made functional again, they provided an SSSV for testing. To simulate scale, the problem that the customer was encountering with their SSSVs, the test SSSV was "fouled" using concrete. The SSSV was placed in the open position by normal hydraulic means, then concrete was applied in a thick coating and allowed to cure. An EHP tool was used to remove the concrete, which resulted in a fully operational SSSV (Figure 7).

Another customer was interested in doing similar testing for a Side Pocket Mandrel (SPM). They provided an SPM which was

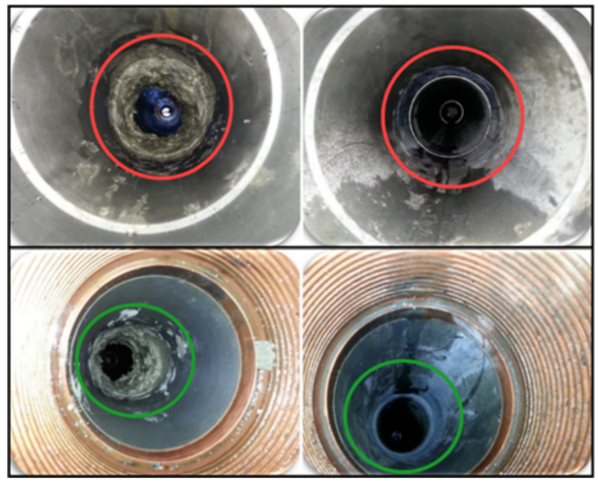

Figure 7. Top photos – upper view of SSSV showing concrete fouling the SSSV on the left, and the cleaned SSSV on the right. Bottom photos – lower view of SSSV showing concrete fouling the SSSV on the left, and the cleaned SSSV on the right.

covered with a thick coat of concrete over the opening, including the valve seat. The concrete was easily cleaned by the EHP tool, leaving an undamaged, fully functional SPM (Figure 8). One of the advantages of EHP is that is does not damage equipment.

Figure 8. Removal of concrete from a Side Pocket Mandrel (SPM) showing the concrete on the left, and the cleaned SPM with the opening visible on the right.

Occasionally a customer will provide equipment with scale buildup for testing, although this is generally only available for tubulars. One customer provided a piece of 9-5/8" casing that was covered in thick iron carbonate scale ($FeCO_3$) for a live demonstration. $FeCO_3$ scale is quite hard, and an attempt was made to remove the scale with a hammer and screwdriver, but after several minutes only a very small amount was removed. The entire section of casing was then cleaned with an EHP tool in approximately 5 minutes (Figure 9).

Figure 9. Removal of iron carbonate scale ($FeCO_3$) from 9-5/8" casing using EHP. The photo on the left shows the scale, including where an attempt was made to remove scale with a hammer and screwdriver (red arrow). The photo on the right shows the piece of casing after only 120 pulses.

CHOOSING CANDIDATES FOR EHP

Every type of scale can be removed with EHP, from all surfaces. EHP will never damage the surface of the equipment/tubular either, as 94% of the energy of the shock wave reflects off steel. When choosing candidates, the first task is to determine whether the environment is suitable for the EHP tool (temperature, pressure, H_2S/CO_2 concentrations & wellbore fluid) and whether the wellbore geometry is compatible with the tool dimensions (minimum restriction and dog-leg severity (DLS)). Deviation is not a limitation, as the EHP tool can be deployed by wireline tractor or electric coiled tubing (eCoil) in horizontal or highly-deviated wells.

Wellbore fluid can be a particular concern though. Although the EHP tool will pulse in most liquids (fresh water, produced water, oil, solvents, etc.), that fluid must be non-compressible. If there is gas present in the wellbore, its compressible nature causes a tremendous attenuation of the shockwave. If the wellbore fluid has gas in solution, and the pressure is such that gas starts coming out of solution (i.e. bubble point), the EHP treatment will not be effective. There are also situations where a fluid column cannot be reliably maintained over the interval to be treated. Whenever there is a lack of a non-compressible fluid at the treatment interval, the EHP tool will be ineffective. For both of these situations, the Fluid Hold-Up Tool was developed.

FLUID HOLD-UP TOOL

Maintaining a column of non-compressible fluid over the EHP tool while it is pulsing is critical to a successful treatment, and the Fluid Hold-Up Tool (FHUT) (Figure 10) was developed to accomplish that, regardless of the fluid in the wellbore. The FHUT is connected to the bottom of the EHP tool and is configurable with multiple rubber disks to seal against the wellbore inner diameter. The size and number of disks are chosen to hold enough of a fluid column (usually water) to cover most of the tool, while minimizing the amount of drag to allow the tool to travel downhole under its own weight. Tapered washers can be added to increase the stiffness of the disks. When running the FHUT, the usual procedure would be to pump fluid into the well at a small but steady rate, as there will be some fluid leakage past the rubber disks.

Figure 10. Fluid Hold-Up Tool (FHUT) attached to the bottom of the WASP® tool

CASE STUDIES

In the first case study in the Danish North Sea, after not being able to perform a routine inflow pressure test of their SSSV due to calcium carbonate scale (CaCO3) buildup, the customer attempted two interventions using traditional chemical and mechanical methods, but both failed to reactivate the SSSV. The EHP tool was deployed as an alternative, and after two treatment runs the SSSV was successfully pressure tested. Scale was also removed from tubing, which was verified by caliper logs.

In the second case study in the Norwegian North Sea, barium sulphate scale (BaSO4) had caused the SSSV to fail an integrity test, and conventional methods could not be used due to restrictions in the tubing from the scale build up. An EHP tool was run and was able to reach the SSSV and successfully remove the scale in one run, resulting in a successful inflow test.

Another case study in the Danish North Sea involved a problem with BaSO4 scale causing a side-pocket mandrel (SPM) with gas-lift valve (GLV) insert to leak. Three types of mechanical interventions were attempted, but none allowed the kickover tool (KOT) to be able to latch onto the GLV to retrieve it. After two runs of pulsing with an EHP tool, a lead-impression block (LIB) was run, which verified that the GLV latch was now free of scale (Figure 11). The GLV was then successfully retrieved and replaced, allowing for a positive pressure test of the SPM.

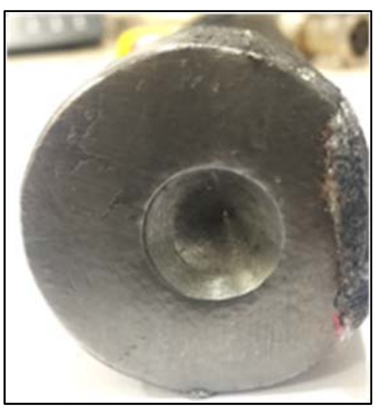

Figure 11. Lead-impression block (LIB) used to show the successful scale removal from the top of the GLV

In a case study involving tubulars in the Danish North Sea, two sections of tubing were required to be cleaned of CaCO3 scale to be able to do a plug-and-cut, prior to pulling the completion. The customer decided to use EHP for the intervention, rather than waiting for a jack-up rig and using a coiled-tubing unit. The EHP tool successfully cleaned the two sections of tubing, as verified by a multi-fingered caliper log (MFC) (Figure 12). The tubing was successfully plugged and cut in the zones cleaned by EHP. The customer also saved 8 days of jack-up rig time and the cost involved with the rig and a coiled-tubing unit.

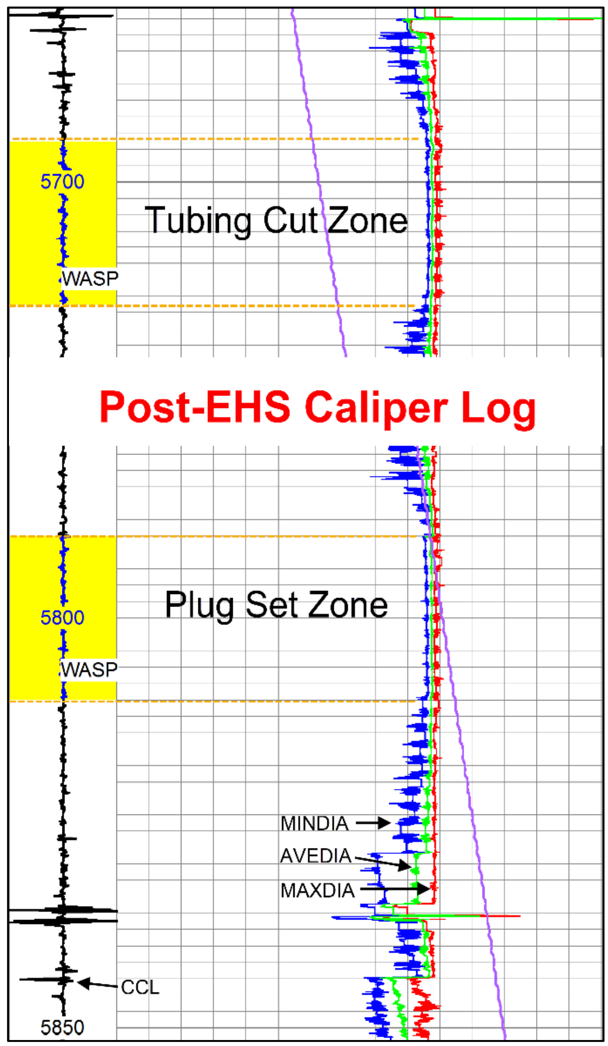

Figure 12. MFC log showing two sections of tubing cleaned by EHP

SSSV CAMPAINS

Two major operators in the North Sea have used EHP to treat over 30 inoperable SSSVs to remove scale to make the SSSVs compliant again. The evolution of the EHP service for SSSVs in the North Sea involved working closely with those operators to develop procedures and equipment that would address specific issues. One of those issues was ensuring that a non-compressible fluid was always present in the wellbore. In some of the first wells attempted, it is believed that phase redistribution was occurring in the wellbore, creating a condition where non-compressible fluid was present, drastically reducing the effectiveness of the EHP tool. The inability of the operator to reliably control this condition led to the joint development of the FHUT, mentioned earlier. Once the FHUT was designed, built & tested, and the procedures were fine-tuned, the success rate of treating SSSVs was significantly improved.

Another issue that can make treatment of SSSVs difficult is when the problem causing the SSSV to be inoperable is not absolutely known. Scale could certainly be an issue, but mechanical and hydraulic issues are also possible. In cases where neither EHP, brushes, acid nor exercising tools could make the SSSV operational, it is unlikely that scale was the only problem. The operator would try all methods available in an attempt to reactivate the SSSV, but it wasn't always successful.

To confirm the presence of scale, both cameras and calipers have been successfully used. Both methods have also successfully confirmed the removal of scale using the EHP service. When the removal of scale was confirmed, and the SSSV would still not pass an inflow test, it was very likely that a problem other than scale was still present.

SUMMARY

Electro-hydraulic pulsing (EHP) is an efficient, economical method of removing scale from upper completion equipment and tubulars. The EHP tool is also environmentally friendly and has minimal hazards involved with its deployment and operation since it does not involve chemicals or pressure. It does require a non-compressible fluid to be present in the treatment interval, but this can be accomplished using the fluid hold-up tool (FHUT) if required. When the wellbore fluid is appropriate for EHP treatment (which may include running the FHUT), and the problem is known to be scale, the treatment success rate is over 90% for upper completion equipment.

OPERATIONAL ASPECTS OF EHP

- Fast deployment on wireline (mono or multi-conductor cable), utilizing a small footprint on the lease or platform
- Non-compressible fluid is required in the borehole, covering the interval to be treated. A FHUT can be used if necessary.
- Can be deployed in vertical, deviated or horizontal wells (using a wireline tractor or e-coil on the latter)
- Precision tool placement enables selective treatment of only the desired intervals
- Works for both producing and injecting wells
- Shorter treatment time and higher success rate than traditional methods for treating upper completion equipment
- Longer time between treatments when compared to traditional methods for treating upper completion equipment

CONTACT INFORMATION

For further information on Blue Spark's WASP Electro-Hydraulic Pulsing Tool or the Fluid Hold-Up Tool, please contact Blue Spark Energy at 1-855-284-1568 or info@bluesparkenergy.com