Pre-Frac DV Tool and Frac Port Repair Using High Pressure Inflatable Stainless Steel Patches

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As optimizing the recovery of hydrocarbon reserves has grown in importance, and effective reservoir management has become increasingly complex, the need for pre frac applications at high pressures and large ID's have become necessary to the success of a producing well.

The inflatable technology has proven effective in the expansion of stainless steel tubulars for downhole remedial pre-frac applications. Our product sets itself apart from other expandable technologies, due to both the unique setting process and the capacity of the tools to expand through the contact point with the casing or frac tools used, as well as achieving a high internal pressure rating while allowing the maximum ID. Thus, this technology has been used successfully in several countries as a precision intervention to resolve a variety of downhole pre frac problems.

As we grow here in the United States, we are seeing a significant increase in clients throughout the country using our product based on the large expansion ratios, which allows the client a large ID to pass frac plugs and balls through while still providing an internal pressure rating of 14,500psi. With this application the client is not limited to certain frac pressures in conjunction with more conventional methods.

This paper will:

- Provide an introduction to inflatable packer expandable steel technology, what it is and how it works
- Provide case histories using 2 examples of pre frac application (5.5 DV Tool repair in US, 4.5 Frac Port Western Canada)
- Summarize the features, benefits, and limitations of the technology
- Present the solutions available today in the United States

1) THE CONCEPT

The working principle is straightforward. A high pressure inflatable packer is inserted into a Saltel Expandable Steel Pre Frac Patch[i], connected to drill pipe or work string, and run in hole opposite the zone to be sealed. Hydraulic pressure is applied from the surface through the tubing to inflate the packer and expand the top of the Patch, anchoring it in place. The Packer is then deflated, run-in just below the expanded section, and re-inflated to expand the following section. This is repeated as often as necessary until the entire Patch is fully expanded, as shown in Figure 1 below:

Running Procedures:

- The down hole expansion tool is positioned inside the Saltel Expandable Patch
- The inflatable packer section is then inflated with 250psi enough to make it grip the inside of the expandable liner, (not enough to allow the packer to start expanding the sleeve).
- The assembly is RIH on tubing, drill pipe, or work string.
- The packer is inflated using pressure from surface to expand the top of the Patch, anchoring it in place
- The packer is then deflated, RIH another 3ft, and the next section is expanded.
- This is repeated as often as necessary until the full length is expanded, and BHA is pulled back to surface.

An elastomer outer skin is used to ensure a good seal between the body of the patch and the inside of the casing. The hydrogenated nitrile (HNBR) selected gives a good ageing performance in the aggressive environments encountered down hole. A machined sealing profile has been designed which will be energized by the setting pressure, and maintain a good seal with both internal (burst) and external (collapse) pressure differentials. A sealing zone of 3ft either side of the perforations or damaged zone is recommended.
The Patch is manufactured with a tapered entry cone machined into the steel top and bottom, to facilitate the future passage of tools.

2) SPECIALIZED RUNNING EQUIPMENT

The operation constraints will vary with the application, an expansion pressure of 4,000psi will be sufficient to expand a thin walled Patch, the thicker Patch's may require up to 8,000psi.
Some specialized equipment is required to run the Expandable Steel Patch:

- A Down Hole Expansion Tool is connected between the tubing and the inflatable packer. This will manage the down hole cycles and open the packer directly into the wellbore for rapid deflation. It includes various safety and emergency features, and a mechanism to compensate for a differential pressure between tubing and casing (for example if the static fluid level is several hundred feet below ground level).
- A hydraulic unit to pressurize the packer through the tubing. This needs to have a high pressure rating combined with the possibility of pumping at a low flow rate, a means of limiting the pressure, and a pressure recording system. Either a suitable pumping unit can be used or a Saltel Industries hydraulic skid can be supplied.

3) EXAMPLES OF RECENT APPLICATIONS

Within the last year, Saltel Industries has made a solid footprint in the North America. With jobs completed all around the US, we are willing and able to accomplish any task. We will describe two case studies from jobs that took place in 2012 and 2013 in United States and Canada.

Case history No.1: 5.5 in DV Tool Repair – Eddy CO, NM

Well Type and Conditions:
5.5 in Frac completion, leaking DV Port
Zone to seal: 7004ft (2,134.82m) to 7006ft (2135.47m)
The port, 2.15ft long was drilled at 4.75 in (120,65mm)
The pup joints above and below the port are 5.5 in 17 lb. /ft.:
Nominal ID=4.89in (124,26mm) - Drift ID= 4.77in (121,08mm)
Down hole temperature 120°F (49°C)
Work over rig, Tubing 2-3/8 - 6.6lbs/ft.
Running Assembly, Setting:
Patch 5.5 in Ultraslim, 321 SST – Wall thickness 0.14 in (3.5mm)
Total assembly length 28.7ft (8,75m); weight 500 lbs. (225 kg)
Patch length 19.7ft (6m) before expansion
Patch RIH OD =4.5in /114,40mm
Patch specifications and Results after setting:
Set Patch ID = 4.66in (118,37mm)
Set Patch ID Drift= 4.53in (115,11mm)
Expansion Pressure 4,000 psi (275bar)
Well drifted real time to 4.50in (114,40mm)
Patch length 18.76ft after expansion (5,72m)
Internal differential pressure rating 1in hole: 14,500 psi (1000bar)
External differential Service pressure 557psi (38bar)

The Patch was successfully set, as programmed and with no lost time.
Patch was logged with caliper to confirm 4.55 ID and continued with frac program.
14 frac stages
Peak pressure of 7613psi (525bar)
Average Treating pressure 4021psi (277bar) with pump rate of 51.1
3,150,000 lbs. of 20/40 Ottawa and 1, 120, 00 lbs. of 20/40 RCS were pumped

Case history No.2: 4 ½ in Frac completion – Red Earth, Alberta

Well Type and Conditions: 4 ½ in Frac completions, leaking cement port
Zone to seal: 7094ft (2162.4m) to 7098ft (2163.6m), 5900ft TVD (1800m)
The port, 2.6ft long (0,8m long), was drilled at 3.84in (97,66mm)
The pup joints above and below the port are 4 ½ in 11.6 lb. /ft.:
Nominal ID=4in (101,6mm) - Drift ID= 3.88in (98.43mm)
Down hole temperature 140°F (60°C)
Work over rig, Tubing 2-3/8 - 6.6lbs/ft.
Running Assembly, Setting:
Patch 4 ½ in Reinforced, 321 SST – Wall thickness 0.118 in (3mm)
Total assembly length 28.7ft (8,75m); weight 500 lbs. (225 kg)

Patch length 19.7ft (6m) before expansion (Patch 60lbs / 27kg))
Patch RIH OD =3.5in /89mm
Patch specifications and Results after setting:
Set Patch ID = 3.65in (92,8mm)
Expansion Pressure 5,200 psi (360bar)
Well drifted real time to 3.53in (89,6mm)
Patch length 19.3ft after expansion (5,9m)
Internal differential pressure rating 1in hole: 20,000 psi (1380bar)
External differential Service pressure 1,625psi (110bar)

The Patch was successfully set, as programmed and with no lost time.
Patch was pressure tested immediately after setting to 3,000psi (200bar): Solid
After the job, customer continued with the frac program:
18 frac stages at 1850gal/min (7m3/min)
Peak pressure of 9000psi (620bar)
850,000 lbs. of sand injected (425 Ton)

4) FEATURES, LIMITATIONS, AND BENEFITS OF THE TECHNOLOGY

Although the feed-back from the field shows many benefits from this technology, there are also a certain number of **limitations**. These include:

- Setting Temperature

The maximum temperature rating of the Down hole expansion tools is 300°F/150°C; however the Packers are limited to less depending on the model and the pressure. Testing is ongoing to qualify all models for temperatures up to 250°F/120°C; this is expected to be completed by late 2013.

- Working Pressures

The Down Hole Differential Working Pressures will vary depending on casing size and the thickness of Patch. The thinner models leave maximum passage to the well below and an excellent internal differential pressure rating (burst),, but the external differential pressure rating (collapse) is fairly low. The thicker patches have slightly less passage after setting but reach higher pressure ratings: 14,500 psi internal differential and 4,000 psi external are the highest that can be obtained.

- Minimum Length

Although there is no theoretical limit to the patch length, as many steps as necessary can be used to expand the steel, practical constraints will limit their length. The longest which can be easily transported is 40ft/12m. Most jobs have therefore been limited to 40ft/12meters, although in exceptional circumstances a Patch of 56ft/17m and even one of over 200ft have been set when the well economics justified it.

- Maximum Expansion

Expansion tests have been carried out with packers and stainless steel tubulars at ratios of up to + 40%
After safety margins have been included the largest expansion will be limited to plus 25%

Some of the most appreciable **benefits,** which distinguish the quality of an expandable stainless steel Patch from other possible solutions, include:

- One Patch will fit several diameters, the progressive expansion of the Patch means one model will fit a large range of different sizes, for example a Patch designed for 7in can be set in casing from 17 lb/ft to 35 lb/ft, and also in most 7.625in casings.
- The patch will work effectively with irregular or uneven casing diameters. Tests and trials have shown the Patch will set and seal in corroded or washed out conditions, even in ovalized casings. They have also been used to seal in open hole.
- Large clearance while running in, compared with other mechanical solutions the expansion ratio means the Patch can be run in hole with a large annular clearance, avoiding the risk of hanging up or swabbing the well.
- Good through bore access after setting, the wall thickness can be as low as 0.14in., which leaves a large access to the well below.
- Good corrosion resistance, the 321, or 304L stainless steel and hydrogenated nitrile used in the manufacturing ensure a long lifetime.
- Real Time Control, a calibrated drift integrated into the running tool will control the inside diameter of the Patch as it is being set. Any problem or anomaly would be immediately detected and cured.
- Repeatability, a second patch can be run through the first and set below, as many times as the well requires.

Other features which have become evident include the simplicity and reliability of the system, and the multitude of possible applications

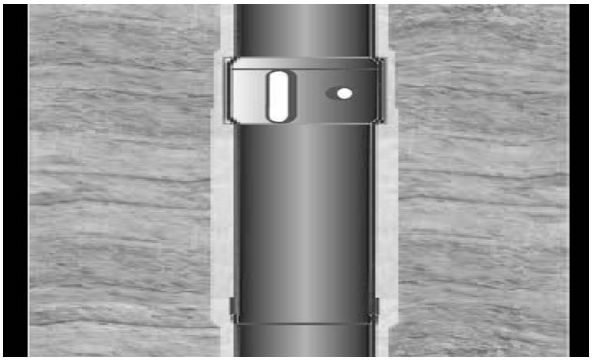
5) POTENTIAL FUTURE DEVELOPMENTS

In conclusion a full range of standardized Patch's for casings from 4.5in up to 13.375in (and all intermediate sizes) is available, with an ultraslim or slimline model to maximize through passage or a reinforced model to maximize external pressure rating. Typical job will take 2-5 hours once in place downhole, depending on length and depth.

The availability of very high pressure inflatable packers which can be inflated repeatedly in a down hole environment opens up a wide range of original applications for expandable steel technology.

- Following final developments using different perfluoro elastomers (FFKM) we have a range of high temperature Patches that will be available with service temperatures of up to 570°F/300°C, opening up applications in steam injection wells
- The capacity to adapt to different diameters could be used for treating leaking liner hangers, sealing inside sliding sleeves, and other "exotic" applications.
- The Saltel Expandable Steel Precision Frac Initialization Module (SES-PFIM) is an effective solution to increase the fracturing efficiency while decreasing the impact on the environment. It is a single module which is connected to the completion string.
- The AZIP can be used for effective zonal isolation in conventional wells, to make an efficient annular barrier either in open hole or in cased hole, either as a standalone solution or a back-up to cementing

The use of high pressure inflatable packers to expand stainless steel Patches provide a reliable and cost effective solution for DV tool repair and frac port repair. Many other applications have become feasible, and no doubt others will appear as the technology becomes established for providing effective solutions to complex down hole problems. Following the successful introduction of the technology in Canada in 2010, a first base opened in Midland/Odessa in June 2011 to make the service available throughout the entire United States. We stock A full range of pre-frac patches, packers, and setting tools for casings from 4 ½ in through to 13 3/8 in.



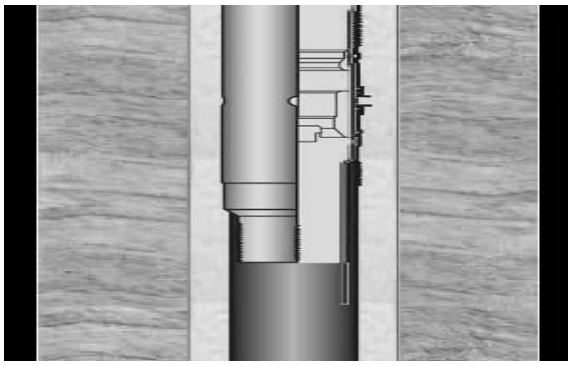


Figure 1, Patch set in Frac Port
Figure 2, Patch set in DV Tool

[i] TM Saltel Industries