Abstract
We introduce a new way to repair the casing affected by severe damage, even long rupture casing. These techniques consist to pump cement through a special design of cement retainer and fiber pipes call ERFV (Epoxy Reinforced Fiber Glass), to fill the annular space between the casing and ERFV pipes. The ERFV are used as a guide for a special pilot mill (a mill with a nose of smaller diameter). Thus, achieve the integrity, the passage and the continuity of the well.
This paper will explain the method to repair severe casing damage and show the results of wells repaired.

Introduction
When we operate in mature fields such as the San Jorge Gulf Basin, where most of the wells has 40 to 50 years of antiquity in production. Some were converted to water treated injection wells. Maintaining the integrity of the wells creates a great challenge for Workover Engineering.

These oilfields maintain their production based on drilling new wells and to keeping as low as possible the declination of all existing wells. To reach these objectives, the water flooding patterns are continuously being modified to maintain production levels; these changes generate much of corrosion damage on the casings, leaving many wells without possibility to keep active.

The production casing, as we know, is submerged, both inside and outside, in fluids of different combination of salinity and temperature, that helps to generate material loss ending of ruptures and pitting in the casing. The greatest damage is generating between the surface casing shoe and the top of cement.

These damages and ruptures could generate environmental contamination and creates difficulties to keep the well on production.

The solution that we found to repair that damage is easy and cheap, using simple materials. Like ERFV tubes, cement retainer and special drill mills.

This technique involves pumping cement through a special cement retainer. This retainer is located above the ERFV tubes. The cement will fill the annulus between the casing and the fiber tubes, helping to increase the pressure allowing put cement behind the casing to repair the damage.

In some wellbores, these damages came to be up to 240 m (787 ft) long.

Theory
By analyzing in detail the sequence of operation to remedy the severe damage to the casing, that means, all the maneuvers that were performing in the traditional cementation process, we realize that we are using a large volume of cement.
These large volumes of cement are placed within the casing as a balanced plug. Mostly of this cement stays within the casing and not behind it and within the rupture zone. The pressure applied to this process is only the hydrostatic of the cement. This is to avoid increasing the damage to the casing by applying extra pressure on the damage zone.

Resuming the traditional Operation:
Once defined the extent to the severe damage, we make the admission test and proceed to make the cementation as follows:
• RIH and set Plug and Packer, with the corresponding plug-pressure test.
• Decant sand on plug. POOH Packer and RIH tubing string.
• Cement is pump and balanced in front of the breakage.

This technique has three main difficulties:
• The volume of injected cement behind the casing is relatively low due it is not possible to apply enough pressure to the cement slurry. In larger damage zones, often it is not easy to achieve total hermeticity in only one cementing operation. It needs to repeat the procedure.
• After that, end the cementing operation and POOH the tubing string. RIH a drill mill and drill the cement remaining within the casing. Many times the cement itself presents a higher resistance than the corroded casing. Therefore, it is highly likely that the drill mill start to increase the damage on the casing walls, with the risk to open a window and to go out of the wellbore. This situation would imply to lose the access to the bottom of the wellbore, thus losing the well production.
• The cleaning of the wellbore generates a high cost of special services (motor mud, cutters, drills, etc). This generate a large amount of remaining cement cuts and high consumption of water to make up such waste to surface.

All these maneuvers to drill the cement are time consuming of equipment. Then we have to test that the cementation has been successful. These are pressure tests up to 300 psi. So, if this test is positive, clean the well and put it in production.

Resuming new methodology
Analyzing the local suppliers market, one local company was select to seek the possibility to modify tools for this project. They fabricated a cement retainer with a 3 1/2" threaded pin at the bottom, which is used to hang the fiber tube. This string is run in the hole and the retainer is set above the breakage, leaving the fiber tubes in front of the breakage. These retainers are easy to set up, because the tools for this purpose are often used. These aluminum retainers present no difficulty to be drilled out.

Once defined the extent of the casing damage. We make the admission test and proceed to make the cementation as follows:
• Set up a drillable plug below the base of the casing damage. That serves as a seal in the area of interest.
• Make pressure test to drillable plug.
• In some cases, we left a conventional bridge plug on the top cement zone and make balanced cement plug below the damage zone.
• Then the ERFV tubes are running in to the well bore. Those are running hanging from the aluminum cement retainer with a special thread connection to the fiber pipes.
• Set up the retainer over the damage zone and ERFV pipes facing the area to be repair.
• The procedure is to pump cement through a stinger into the aluminum cement retainer, filled the annulus between the casing and ERFV pipes guide.
• The cement is pumped under pressure from the top to the bottom and behind de casing trough the whole length of the breakage, thus achieving the sealing of the entire damage zone. These pressures depend of how big is the damage.
• During the process of clean up the wellbore with special drill mill, the first pressure test is at midway of the repaired zone. It let us know if the first part of repaired zone it is hermetic.
• After clean up the wellbore completely and just in front of the repaired casing damage, make a complete hermetic test.

Like show in the schematics. We can see how the theory works. Most of the pumped cement fills the annulus between casing and ERFV. Now when we drill it, the internal ERFV space is empty, allowing to use this space as a
guide for a special pilot mill (a mill with a nose of smaller diameter). This is to avoid generate more damage on the casing wall, drill and clean the wellbore faster and safe. The tools are kept inside the wellbore. With all these features, the first well was select to perform the first pilot.

**First pilot well**

With all this theory the first well was selected to perform the first experimental evidence.

**SAG-4 Injector well**

1) Background:
   - Field: Anticlinal Grande.
   - Antique: 54 years old.
   - Objective: put the well in injection.
   - Production: 14 m3opd associated
   - Risk: high.
   - The well has not a cement profile.
   - The first 20 mts below the wellhead is 7", then is 5 ½" diameter.
   - The guide shoe of 9 5 / 8".Is 90 meters.
   - The casing has a problem under the guide shoe (and with solids contributions already detected in + / - 90 m).
   - EWI shows red condition.

2) Workover intervention:

   Pulled out of hole the existing injection system was successful with good results. All the production assembly were recovery completely.

   1) Halliburton recorded the CAST-F mode Cement, Neutron log, CCL, CBL, VDL logs to understand the status of casing.

   2) WEATHERFORD recorded a CIT log (Corrosion Integrity Tool) and get data from how corroded is the casing.

   It was RIH the bridge plug and packer to locate the damage zone. It was detect from 91 meters to 217 meters. It was performed admission test to the damage zone.

   We were determining the base and the top of damage. Left we to proceeds to set a bridge plug "N" type hydraulically in 660 meters. Set a second bridge plug "N" type at 230 meters. This was set as the basis of the damage zone. The bridge plug was test with 800 PSI. The complete string of the casing aligner was armed with fiber pipe 3 1/2 inches diameter composed of 14 tubes (127 m long), all them hanging from aluminum cement retainer (Blinded at the bottom), with lower thread of 3 ½ " EUE. This was set at 88.95 meters. The cementing company proceeded to pump 220 sacks of special cemented. All the cement filled the annular space between casing and the fiber tubes.

   After 12 hour WOC, it assembled and RIH the BHA. This BHA was composing by high-speed deep motor with a concave pilot mill of 120 millimeter. The objective was to drill the cement retainer aluminum plug. After proving tightness with negative results underwent second balanced-type cement, failing to obtain the desired result.

   Then we finish drilled the fiber pipe completely. The hermetic test performed. In this test did not achieve total tightness. The second operation to finish the reparation was performing with traditional method. After the casing damage was fixed. The injection system was recovered, changed and lowered a new one. In addition, we keep this well in production.

   All this experience gives us a good background to establish a methodology to Repair Severe Casing Damage and good Practical Cementing Techniques.
Methodology resumes

1) Calibrate to ensure passage thru the wellbore (if necessary). It is important to rectify the area of interest as below it.
2) Record a corrosion log in order to select the depth of the k aluminum retainer and length of the fiber tubes.
3) Depend of kind of casing damage. Water admissions, solids contributions, fishing below the rupture zone or loss of passage thru the wellbore. We will choose the most appropriate bull plug. Among them are: drilled bull plug, recovery bridge plug or balanced cement plug.
4) The bull plug must be set it 15 meter under the base of casing damage.
5) RIH the bridge Plug and Packer to test the depth where the k aluminum retainer will set up. Verify the pipe tally to be in depth. Moreover, if necessary we must record a CCL log.
6) Make admission test for the zone to be cementing.
7) RIH the ERFV aligners with the aluminum cement retainer. Set up at determined deep with the fiber tubes in face a casing damage.
8) Pump the cement; WOC. Depend what kind of cement was pump.
9) Drill the cement, the aluminum cement retainer, with motor deep and drill pipes.
10) Use concave pilot drill mill.
11) Perform pressure tests with 300 psi (with the motor deep in to the wellbore). The first test must be doing in the middle of the zone to be repair and the second at the end of rotating fiber pipes.
12) If both tests are positive, clean all the wellbore and continue with the objective of intervention.

Results

Having used the last example as pilot to establish the working methodology. We proceeded to repair a eighteen wells, achieving successful repairs in almost all of them. Some of the wells repaired, with different length of damage, at different depths and different kinds of wellbores, are shown below.

<table>
<thead>
<tr>
<th>WELL</th>
<th>DAMAGE ZONE</th>
<th>RETAINERS DEPTH</th>
<th>CEMENT VOLUME</th>
<th>RESULTS</th>
<th>TYPE WELL</th>
</tr>
</thead>
<tbody>
<tr>
<td>SAG-4</td>
<td>91</td>
<td>217</td>
<td>88.9</td>
<td>230</td>
<td>220 BLS</td>
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<tr>
<td>PLM-816</td>
<td>194</td>
<td>415</td>
<td>185</td>
<td>1330</td>
<td>30 BLS + 75 BLS</td>
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<tr>
<td>PLM-814</td>
<td>231</td>
<td>286</td>
<td>230</td>
<td>1130</td>
<td>70 BLS DE CEMENTO</td>
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<tr>
<td>PZ-822</td>
<td>475</td>
<td>550</td>
<td>461</td>
<td>596</td>
<td>25 BLS + 60 BLS</td>
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<tr>
<td>PMC-71</td>
<td>488</td>
<td>600</td>
<td>465</td>
<td>677</td>
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</tr>
<tr>
<td>PZ-96</td>
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<td>472</td>
<td>233</td>
<td>568</td>
<td>40 BLS + 250 BLS</td>
</tr>
<tr>
<td>PMC-21</td>
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<td>279</td>
<td>116</td>
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<td>204</td>
<td>291</td>
<td>199 BLS</td>
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<tr>
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<td>46</td>
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<td>263</td>
<td>481</td>
<td>220</td>
<td>505</td>
<td>50/100 BLS + 15/30 BLS</td>
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<tr>
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<td>300</td>
<td>105</td>
<td>343</td>
<td>50 BLS</td>
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<tr>
<td>PMC-11</td>
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<td>625</td>
<td>510</td>
<td>652</td>
<td>180 BLS</td>
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<tr>
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<td>260</td>
<td>215</td>
<td>310</td>
<td>150 BLS</td>
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<tr>
<td>PMC-20</td>
<td>159</td>
<td>207</td>
<td>124</td>
<td>241</td>
<td>300 BLS + 110 BLS</td>
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<tr>
<td>PMC-36</td>
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<td>343</td>
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<tr>
<td>PC-1048</td>
<td>240</td>
<td>587</td>
<td>242-415</td>
<td>587</td>
<td>200 BLS</td>
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</table>

Costs and benefits

- First: Getting a barrier to maintain the integrity of the wellbore, avoiding contamination of freshwater aquifers (Patagonian formation) in cases where the casing shoe does not cover that area.
- Second: Comply with company policies relating to wellbore control, maintaining proper control of the sub-surface facilities.
- Third: Extend the life of the wellbore, avoiding having it to abandon the wellbore for integrity problems.
- Fourth: do not have to drill a replacement well.
- Fifth: could be the most important, it has to maintain inside the well. Avoiding go out of the well.

The operating costs are relatively low, because the tools that we are operating are daily used.
**Logs**
The Corrosion logs recorded before and CBL-VDL logs recorded after repaired well are show below

**Conclusions**
When we think in repairing a wellbore with a large breakage, the first thing to do is to think in the difficulties to achieve the target. With this technique, we managed to overcome this difficulty. This technique is reliable to repair casing damages in a simple and low cost way.