The Fragmenting Gun - An Entirely New Gun System

MENAPS 16-15

AUTHOR: Mark S Brinsden
Shell Global Solutions (UK)

NOV 13TH, 2016

MUSCAT, OMAN
AGENDA

The history of a new gun

- Setting the scene
- The Frac Pack Gun Development
- Recognizing the Wider Application
- The Development of the Fragmenting Gun
- Set up for the First Trial
- What’s the Next Application?
- Driving Change – Lessons Learned
Setting the scene

- Shell technology developments in perforating are being driven directly by operational demands to reduce cost safely and deliver more hydrocarbons.
- Each project has specific target fields/reservoirs for deployment.
- Contractors and manufacturers need Operators to be clear and focused on what they need, to offer improve well construction and deliverability.
- The Shell Global Perforating Team is working with a variety of contractors, with a focus to delivering the best perforating solutions to the Shell global operation.
Setting the scene
The Frac Pack Gun Scenario

- Requirement for run below screen gun for HP FracPack well in GoM. No room for a ‘Shoot and Drop’ rathole/sump, but possible to have small sump – say 20% of gun length. Major rig time and heavy brine savings possible!

- Conceived FragGun concept to have a gun that fragments into small heavy pieces that fall into the small sump.

- Can you build a Capsule/Strip gun that looks like a TCP Gun??

- All new HP (20kPsi) gun system developed by Shell and DYNAenergetics.
  - HP wet detonator and det. transfer system (donor / booster)
  - HP large 39g Big Hole capsule charges – 6-1/2in Gun – 21spf – Very Powerful gun system!
  - Load bearing charge loading tube and carrier – good to take layoff weight and 200 ft Gun.
  - Integrated dual electronic firing head – Shoot and drop off or run with Hanger.
  - Fragments to around 15-20% of gun length in sump with FH & Hanger/drop sub.
Setting the scene

The Frac Pack Gun Scenario

- How the concept should look
The FracPack Gun Development

My Early Concept Designs - 1 - Load Bearing Loading Tube

- A. Load bearing Loading Tube
- B. Perforated shroud – for mechanical protection only
- C. 2-1/2 BH Steel Capsules – 18,000psi rated
The FracPack Gun Development
My Early Concept Designs - 2 - Load Bearing Loading Tube – No Shroud

A. Load bearing Loading Tube
B. No Perforated shroud – for mechanical protection – rely on structural strength of loading tube and charges
C. 2-1/2 BH Steel Capsules – 18,000psi rated
The FracPack Gun Development

DYNA Design Work based on early concepts
The FracPack Gun Development
DYNA Design Work – actual gun system

- The large Big Hole gun is complete and ready to trial.
Recognizing the Wider Application

- While the large dia. BH gun system was ready to run, testing was more difficult and there was a clear application for one or more smaller diameter gun sizes – especially for DP or GH applications.
- Suitable for both Injectors and Producers.
- The lack of Free Gun Volume (FGV) and high shot density and high charge weight, leads to significant Dynamic Overbalance during shooting. Can pre-frac tunnels very effectively.
- So Powerful HSD charges excellent for –
  - Vertical injectors
  - Hard rock frac initiation
  - Cleaning tunnels in Natural Completion Producers.
The Development of the Fragmenting Gun

New Gun Sizes and Charges

- Recognizing that we would want to run this type of gun in most non high angle wells pushed us towards developing a whole range of gun sizes.
- Because we need so little sump – it can now be run on hanger or below completion in a whole range of well types and sizes.
- Examples are 3-1/2in Monobore wells – run on hanger thru a wide range of casings.

<table>
<thead>
<tr>
<th>Systems</th>
<th>OD</th>
<th>spf</th>
<th>charge</th>
<th>tube</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2 1/4</td>
<td>7spf</td>
<td>13g DP</td>
<td>2&quot;</td>
</tr>
<tr>
<td>2</td>
<td>3 1/8</td>
<td>9spf</td>
<td>15g DP</td>
<td>2&quot;</td>
</tr>
<tr>
<td>3</td>
<td>3 1/8 (3 3/8)</td>
<td>6spf</td>
<td>25g DP</td>
<td>2.5&quot;</td>
</tr>
<tr>
<td>4</td>
<td>4 5/8</td>
<td>18 spf</td>
<td>23g DP/BH/GH/DPEX</td>
<td>4&quot;</td>
</tr>
<tr>
<td>5</td>
<td>6</td>
<td>18 spf</td>
<td>30g BH</td>
<td>4&quot;</td>
</tr>
</tbody>
</table>
The Development of the Fragmenting Gun

New Gun Sizes and Charges

- The lack of a carrier enables the Frag Gun to run heavier more powerful charges.
- Need to be aware of high pressures from the gun – beneficial for tunnel cleaning – but could be a problem in weak casings.
- Need to develop next generation short and cost effective gun hangers in a range of sizes to deploy the frag guns.
Setup for the First Trial

- Setting up trials appears to be the largest obstacle in developing a new gun system. Trials make development look easy.
- Trial needs to be comprehensive enough and near enough to an actual application condition to be worthwhile and believable.
- Cost of trials is often one item not fully understood when undergoing a development.
- Then getting the first asset to actually run the first full application of the new technology!
What is the Next Application
Making the Frag gun work in High Pressure and High Temperature

- 4-5/8in 12 / 15 or 18 spf DP charges
- Temperature up to 375F of 3 weeks before firing
- Pressure Max Operating Pressure around 24kPsi.
What is the Next Application

- Hot, HP Injectors in GoM - Conventional vs Frag Gun

Conventional Gun makes 100% debris pile + FH & Hanger

- Hot, HP Injectors in GoM - Conventional vs Frag Gun

Fragmentation Gun makes 20% debris pile + FH & Hanger

Gun Hanger 27,920'
Perfs – 27,930-28,050'
Fragmentation fill and hanger top 28,100'
Cement Plug Fragmenting gun 28,150'
Cement Plug conventional 28,300'
Driving Change – Lessons Learned

- Identification of a problem – in this case issues with shoot and pull and lack of sump/rat hole below perforations for a dropped gun.
- A work around this would save considerable rig time and other costs including brine changes etc.
- Thinking out of the box – could we make a capsule charge design work in a TCP type environment?
- Identifying a suitable development partner – key to technology success – which company can actually deliver all the components themselves and give us flexibility in application!
- Ability to modify the course of the development mid way.
- Identification of asset partners to drive forward with trials.
QUESTIONS?
THANK YOU!