Multi-Stage Multi-Well Completion
Estimated 187 Trillion m$^3$ (Energy Information Administration 2011)
Land Drilling Activity by Type

From Spears & Associates, Inc
Horizontal Multi-Stage Perforating

- Pump Down Services (PDS) offers quick, efficient and cost effective deployment of multi-gun/plug runs for multiple stage completions
- PDS is a common deployment method used in horizontal unconventional wells primarily for guns and plugs but also for other e-line services (pipe recovery, logging, etc)
- Efficient PDS now allow up to 5 stages per 24 hour day
- A typical single E-Line stage consists of
  - Multiple guns (3 foot - 6 spf carriers) ((Selective Perforating))
  - Explosive setting tool
  - Composite plug
Horizontal Multi-Stage Perforating- Pump Down Service
Most PDS completions are perforated in a geometrical spacing
Perforating Objective

- Create a conduit between the wellbore and reservoir
- Choices to be made:
  - Size of gun and charge
  - Type of shaped charge
  - Shot density and phasing
  - Perforation interval
Perforating for Stimulation

- Interval
  - Stage Length
  - Perforation Spacing
- Orientation
  - Phasing
- Charge Selection
  - DP, GH or FRAC
Perforation Phasing

- Perforation phasing reduces near wellbore tortuosity. ([SPE 24823 & 39453])

- Run in conjunction with FRAC charges, a measurable improvement in stimulation treatments is observed. ([SPE 159085])
Perforation Phasing Test

From ‘Oriented Perforations – A Rock Mechanics View’ SPE 28555

SLAP-29
What role do perforations play?

“Unless a perforating gun is centralized, the perforation casing hole diameters are a function of gun phasing. This means that the injection rate is different for different perforation diameters.”

– SPE 39453
Why hole size matters

\[ \sigma_1 = \frac{T_{\text{fail}}}{K} \]

\[ \sigma_1 = Kp \]

\[ p_{bd} = \frac{T_{\text{fail}}}{K} \]
Studies demonstrate a difference.
Frac Charge Results

Comparison of 24 different stages:
- Increased injection rate by 27%
- Lowered treating pressures 500-1,000psi
### TABLE 4—COMPARISON OF STAGE #5, FIELD TRIAL 2.

<table>
<thead>
<tr>
<th></th>
<th>Old Charge</th>
<th>New Frac Charge</th>
</tr>
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<tbody>
<tr>
<td>Clusters</td>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td>Holes</td>
<td>57</td>
<td>48</td>
</tr>
<tr>
<td>Time to Rate</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Rate</td>
<td>65</td>
<td>60</td>
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<tr>
<td>Pressure</td>
<td>2,212</td>
<td>2,175</td>
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<tr>
<td>ISIP</td>
<td>1,004</td>
<td>1,013</td>
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### TABLE 5—COMPARISON OF STAGE #8, FIELD TRIAL 3.

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<tr>
<td>Holes</td>
<td>58</td>
<td>52</td>
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<tr>
<td>Time to Rate</td>
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<td>2</td>
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<tr>
<td>Rate</td>
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<td>65</td>
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<tr>
<td>Pressure</td>
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<tr>
<td>ISIP</td>
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<td>745</td>
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### TABLE 6—COMPARISON OF STAGE #6, FIELD TRIAL 4.

<table>
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</thead>
<tbody>
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<td>6</td>
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<tr>
<td>Holes</td>
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<td>52</td>
</tr>
<tr>
<td>Time to Rate</td>
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<tr>
<td>Rate</td>
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<td>Pressure</td>
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<tr>
<td>ISIP</td>
<td>507</td>
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</tbody>
</table>

- Fewer holes
- More rate per perforation
- Faster time to rate
- More rate
- Faster time to rate
Comparison of 13 different stages:
- Improved treatment success to 100% - previously experienced early screenouts 30% of time
- Decreased fluid volume to obtain designed rate
13 Stage Comparison

Comparison of 13 different stages:
- Improved treatment success to 100% - previously experienced early screenouts 30% of time
- Decreased fluid volume to obtain designed rate
Studies demonstrate a difference.

Comparison of 24 different stages:
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- Lowered treating pressures 500-1,000psi

Comparison of 13 different stages:
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THANK YOU