Perforating Factors Affecting Flow Efficiency

- Shot Density, Gun Phasing
- Depth of Penetration
- Hole Diameter
- Casing, Cement Sheet & Rock Density
- Skin Effect (Crushed Zone)
- Method of Perforating
Depth of Penetration

Skin and CFE

Towards wellbore
What We Often Get
Method of Perforating

Over Balance

Under Balance
Pre job Planning

- Kept the hole open, no casing and cement
- Drilled 6” hole to minimize the formation damage
- Used best penetrating charges for the Gun size
- Perforated the interval twice to improve SD, PH
- Perforating Under balance to minimize Skin Effect
- Plan the operation to achieve 1000 psi under balance
- Stimulate the perforation using Acid
WELL X
Acid Injection After Open Hole Perforation

07:00 4.00 PTEST 26 PERFORMED ACID JOB [R-2]
09:00 2.00 PTEST 5± CIRCULATED OUT ± 36 BBL ACID [R-3]

R-2: MIXED 45 BBL HCL 15% @ 03:00 HRS.

- PUMPED 36 BBL ACID THROUGH C.T, CLOSED CHOKE MANIFOLD,
- SQUEEZED 6 BBL ACID INTO FORMATION @ 1400 PSI MAX. WHP, USED
HESITATION METHOD AND RECIPROCATED C.T ACROSS INTERVAL
Stim Technology The Basic Process

- Energy Source (Propellant, Perf Gun, Explosive, etc.)
- Expanding Gasified 'Bubble'
- Tamping Liquid
- Possible Surface Overpressure
- Flow into Fracture (One of 1-12 Shown)
- Fluid Motion in Well
- Wellbore Interior
The Effect of Energy Release Rate

Explosive

\[ P \approx 10^5 \text{ psi} \]

\[ P \text{ vs. } T \]

- Rock Crushing
- Fracturing

Microseconds

Propellant

\[ P \approx 10^4 \text{ psi} \]

\[ P \text{ vs. } T \]

Fracturing

Milliseconds

Hydrofracture or Overpressured Gas

\[ P \approx 10^3 \text{ psi} \]

\[ P \text{ vs. } T \]

Fracturing

Seconds
StimGun Surface Test

OWEN / HTH
SURFACE TEST #3
CAMERA # 1
StimGun Surface Results
Propellant Lab Stimulation (90 Phased Perforated Core)

Figure 3 – Propellant stimulation with 90° perforation phasing (Laboratory Scale).
StimGun in the Field
StimTube Tool Before and After

Before

After
WST Carriers

- The reusable carriers have holes sizes from 0.75-2.75” and several hole densities. One inch holes at 12 per foot is the standard.
PulsFrac™ Computer Software

Simulates the Event:

– Pressure vs. Time
– Perf Breakdown
– Frac Extension
– Fluid Motion
– Casing Differential
PulsFrac Pressure Wave Calculation that Matches Data

- Pressure vs. Depth
- Time (0 – 80 ms)
## Well X
### LBM Formation Stimulation

<table>
<thead>
<tr>
<th>Intervals (ft)</th>
<th>Propellant Load (ft)</th>
<th>Propellant Depth (ft)</th>
<th>Estimated Peak Pressure (psi)</th>
<th>Estimated Fracture Length (ft)</th>
<th>Assumed Skin Before StimGun™</th>
<th>Estimated Skin After StimGun™</th>
</tr>
</thead>
<tbody>
<tr>
<td>Run 2</td>
<td>15 ft</td>
<td>Run 2</td>
<td>6,545</td>
<td>20.07</td>
<td>+3.3</td>
<td>-2.8</td>
</tr>
<tr>
<td>Run 1</td>
<td>15 ft</td>
<td>Run 1</td>
<td>6,563</td>
<td>20.60</td>
<td>+3.3</td>
<td>-2.8</td>
</tr>
<tr>
<td>Run 3</td>
<td>6 ft</td>
<td>Run 3</td>
<td>6,489</td>
<td>15.54</td>
<td>+3.3</td>
<td>-2.8</td>
</tr>
</tbody>
</table>
WELL X
Acid Injection After the Propellant Stimulation

R-1: GUN FIRED 100%.

R-2: SQUEEZED 40 BBL HCL 28% INTO FORMATION, STARTED
W/ 0.4 BPM @ 1200 PSI AND ENDED W/ 1.1 BPM @ 1200 PSI.
- OVERDISPLACED ACID W/ 5 BBL F. WATER THROUGH C.T
& 5 BBL F.W THROUGH C.T/ TBG ANN. W/ 1.3 BPM @ 1200 PSI.

CONT'D FLOWING THE WELL FOR MAIN FLOW PERIOD THROUGH 24/64" +VE CHoke.

[R-1]

CHANGED CHoke SIZE TO 20/64" +VE CHoke.  [R-2]

SHUT-IN THE WELL @ CHoke MANIfOLD FOR PBU.  [R-3]

R-1: CHoke SIZE = 24/64" +VE, WHFP = 172 PSI, OIL RATE = 412 BPD, GAS
RATE = 0.1197 MMSCF/D, GOR = 294 SCF/ BBL, H2S = 0%, CO2 = 5%.
Conclusion

• Knowing the low Permeability Rocks need deep perforating tunnels, and

• The High Permeability Rocks need
  ➢ deep perforating tunnels simultaneously with
  ➢ large hole entry diameter

• The depth of penetration is indirectly proportional with hole diameter, as well the CFE.

The solution is
The StimGun