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Nitro-Lift™ De-Liquification of Gas Wells
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http://www.nitrolifttechnologies.com/
Frac Water Results in Liquid Loaded Barnett Shale Gas Wells

- Barnett Shale is a Fairly Thick Formation, 300+ of Pay.
- Fractured Porosity has Huge Amount of Gas in Place
- Permeability is Low or Non-existent
- Frequently Cost More to Frac Well Than to Drill the Well.
- Wells TVD Varies From 7000 to 9000 Feet Deep
- Most Wells are Now Being Drilled Horizontally

- High Well Head Pressures are a Problem:
  1. Need More Compression on the Collection System.
  2. On a Daily Basis New Wells are Added to System

- After Frac Some Water Must Be Removed Before the Well Begins to Naturally Flow (Gas Rates 2-10 MMscf)
Barnett Shale is an Unconventional "tight gas" Reservoir Covering 5000 sq. miles (13000 km²) with an Estimated 30 TCF Gas in Place
Operators in the Barnett and Woodford Shales Kill Gas Wells with Frac Water

- Barnett Shale, Woodford Shale and Other Unconventional Gas Plays Have Problems With Frac Water Killing the Well.

- 50,000-150,000 Bbls Frac Water Used to Open the Shale Fractures; Often Wells **DO NOT** Flow-back

- Conventional De-water Lift Methods **NOT Cost Effective** (Swabbing, Gas Lift, Pump Units, Submersibles, Coiled Tubing & Foam Units)
Barnett Shale Production History

Source: IHS Energy and Pickering Energy Partners
Conventional De-Liquification Lift Methods ARE NOT Cost Effective

- **Swabbing** – Liquid Swab Rates often too low, after >62 days of swabbing Shale still Liquid Loaded
- **Coiled Tubing** – High Cryogenic Nitrogen Cost
- **Foam** – Well Dead no gas flow to create Foam
- **Gas Lift** – High Initial Cost but Good at unloading well, but no packer results in Fluid Cutting Bottom Valves when well flows up casing.
- **Submersible Pump** - High Initial Cost, Cannot pull from well without Killing, Frac Sand often destroys pump.
- **Pumping Units** – High Initial Cost, Typically low Liquid Production Rate requires long time to unload well, D/H equipment in way if well unloads
Average Working Pressures and Rates for Unconventional Shales

1. Well Depth of 7000' approx.

2. 2500PSI and 300MCF/D

3. Average recovery rate of 30 to 150 BWPHr.

4. Average completion 1.0-3.5 MMCF/D

5. Largest completed producer over 5MMCF/D

6. 3200 BPD Highest Nitro-Lift\textsuperscript{tm} Water Rates
Nitro-Lift™ Patent Pending Process Used for De-Liquification of Wells

- Extract Nitrogen From Air on Location
- Boosting the Pressure and Pumping the Nitrogen Down the Annulus
- Nitrogen Gas Displaces Liquid Around the End of the Tubing
- Process Is Working Very Well
De-Liquification of Gas Wells

How Do We Accomplish De-Liquification?
Nitro-Lift™ Trailer Is Spotted at Location Near Well-head
1. At trailer near well hold Safety Meeting.
2. High Pressure hose connected to std 2” API connection on casing.
3. Unit is started and prepared for Nitrogen Generation.
4. Rotary Screw Compressor takes in Air and Sends it to a Series of Filters for Pre-conditioning.
Hollow-fiber Membrane Technology Used on Location to Separate Nitrogen from Air

5) Membrane consists of bundles of hollow fibers packed into 4-10 inch diameter tubes.

6) Heated compressed air is forced through hollow fibers.

7) Holes in the walls of the hollow fiber membrane are small enough that Trace Gases and O2 can escape under pressure out the vent.

8) Nitrogen continues to pass through the tube into the booster compressor.
9. Once conditioned, the Nitrogen passes through Membranes to a Compressor Capable of 500MCF/Day @ 4000 PSI.
10. Compressed Nitrogen is pumped down Annulus.
11. Nitrogen Displaces Annular Water Column Down the Hole
12. Nitrogen Reaches End of the Tubing and U-Tubes to Surface
13. In Some Cases Well Continues to Flow Or Nitro-Lift™ Keeps Pumping Nitrogen down the Annulus of the Well until the well flows naturally.
Initial Fluid Level Identifies Required Tubing Intake Pressure

\[
P_i = 2128.7
\]

- **Casing Pressure**: 2128.7 psi
- **Casing Pressure Buildup**: 0.016 psi/min
- **Liquid Level Depth**
  - **MD**: 6073.23 ft
  - **TVD**: 6073.23 ft
- **Gas/Liquid Interface Pressure**: 2560.0 psi
- **Tubing Intake Depth**
  - **MD**: 7270.00 ft
  - **TVD**: 7202.77 ft
- **Formation Depth**
  - **MD**: 8828.00 ft
  - **TVD**: 7315.86 ft
- **Liquid Below Tubing**
  - **Oil**: 0 %
  - **Water**: 100 %
  - **% Liquid Below Tubing**: 100 %
- **Tubing Intake**
  - **3107.8 psi (g)**
- **PBHP**
  - **3162.6 psi (g)**
- **Reservoir Pressure (SBHP)**
  - **3162.6 psi (g)**
- **Required Tubing Intake**: 3107.8 ft
- **SBHP**: 3162.6 psi

**Deviated Wellbore**

- **TVD 7202.8 Ft**

**Pressure Traverse - Psia**
Injection Pressure of Nitrogen at Surface
Maximum of 4000 Psi @ 400 McF/D

Injection Pressure of Nitrogen at Surface
Maximum of 4000 Psi @ 400 McF/D

Ending Casing
Surface Pressure
2538

Required Tubing
Intake
3107.8
At 2538 Casing Injection Pressure, N2 Begins to Bubble up Tubing

<table>
<thead>
<tr>
<th>Casing Pressure</th>
<th>2538.3 psi (g)</th>
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<tbody>
<tr>
<td>Casing Pressure Buildup</td>
<td>-0.014 psi</td>
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<tr>
<td>Liquid Level Depth MD</td>
<td>6073.23 ft</td>
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<tr>
<td>Gas/Liquid Interface Pressure</td>
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<td>Casing Gas Flow</td>
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<td>Liquid Below Tubing</td>
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<td>Reservoir Pressure (SBHP)</td>
<td>3162.6 psi (g)</td>
</tr>
</tbody>
</table>

Tubing Intake Depth TVD 7202.8 Ft

Pf = 2538
In 2 Hours of Elapsed Time
Well Begins to Flow Naturally

Pressure Traverse - Psia

2000  2200  2400  2600  2800  3000  3200

0

1000

2000

3000

4000

5000

6000

7000

8000

Wellbore Depth - Feet

Pi = 2128.7
Pf = 2538

Formation Frac Water
Initial Gas Column
Final N2 Gas
2 Hrs to a Few Day Required to Unload Casing & Flow Well Naturally

Use Fluid Levels to Track Progress

Pressure Traverse - Psia

Wellbore Depth - Feet

Tubing Intake Depth – 8249 Ft
Conclusion

• Most Cost Effective Method for De-Liquification of Water Loaded Unconventional Shale Gas Wells

• Nitro-Lift™ has used the units for plunger-lifting, gas-flooding, fluid-jetting, un-sticking drill pipe/tubing and fluid lifting through conventional gas-lift valves.

• Has built units from 35 HP to 800 HP.

• Currently have 6-units working in Unconventional Resource Areas.