Casing Plunger Applications & Development

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Casing Plunger A.L. – Lift Without Tubing

- History of Development @ Multi-Products
- Unique Considerations
- Vertical Wells
- Horizontal Wells
- Case Studies
Casing Plunger – History of Development @ Multi Products

Original Purpose

- Extend life of older wells using “positive seal”
- Automatic swab tool

Expanded scope starting in 2007: High-Pressure Shale

- Developed pressure relief on plunger
- Operating depths increased to 10,000 ft.
- Surface equipment modified to accommodate pressure & plunger impact energy

Expanded into Horizontal Wells in 2009
Deliquification without Tubing

- **Casing**
  - Quality, uniformity
  - I.D. depends on “weight”, nominal vs. drift
- **Positive Seal or Velocity Seal?**
- **Horizontal vs. Vertical wells**
  - Standard technology on vertical
  - Limitations
Positive Vs. Velocity Seal

**Velocity Seal**

a. Turbulent seal with gas jetting around the plunger.

b. Gas passing plunger *Injects* the liquid column and creates bubble penetration.

c. Gas bubble expands with pressure drop and *Slugs* liquid to the surface.

d. Plunger interface prevents liquid fall-back to the bottom of tubing. However,

e. Plunger will drop to bottom if flow rate reduced – requires sustained, high gas flow

**Positive Seal**

a. Seals all gas below the plunger.

b. Lifts liquid column to the surface using formation pressure.

c. Provides Maximum lift from available pressure and volume.

d. No risk of plunger fall-back during lift. Gas pressure suspends plunger.

e. Can lift against variable line pressures & will not fall back, even if shut-in.
Vertical Wells

Basic Hardware Components
- Plunger & downhole equipment
- Surface equipment
- Sizes offered

Casing Size effect on lift capacity

Predictive Tools: BHP vs. fluid production, GLR, etc.

Marcellus Wells – shale gas
- Patented pressure relief design
- Control algorithm
JetStar™ Casing Plunger System

- No Tubing Required – Substantial Cost Reduction
- Patented System with Over 15 years in Field. Adapted for use in High Pressure Shale
- Lowest Cost Alternative to
  - Pump jacks – cost/maintenance
  - Gas lift – cost/maintenance
- Maintain low formation back-pressure for max. efficiency
- Baseline for move to horizontal wells
Petro-Casing Controller

- Designed specifically for safe, continuous operation of a casing plunger system
- Time-control standard
- Pressure-control optional
- Safety interlocks
4–½" JetStar™ Casing Plunger
Lift Capacity vs. Casing Size

- Brine Density ~ 10#/gal
- Max. casing wt.
- Includes plunger wt.

Positive Seal JetStar™ Casing Plunger Barrels per Cycle @ Specific Pressure

- 5-1/2" X 17#
- 4 1/2" X 11.6#
- 3-1/2" X 9.2#
- 2-7/8" X 6.4#

Casing Lift Pressure = ΔP Across Plunger (PSI)

Barrels per Cycle

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Horizontal Casing Lift

Objectives for Development Project started in 2009:

• Casing plunger @ 4–½” x 11.6#
• Run plunger down to 60° (from vertical)
• Keep up with fluids produced
• Develop complete, automated lift **system**
• Lift any fluid
• For use in sand (foam) or gas frac’d wells
Formation Back-Pressure Example

- Must reduce & keep it low to improve production
- Depends on:
  - Well bore
  - Fluid density
  - Fluid inflow
  - Curvature

![Graph of Hydrostatic Pressure due to Fluid](image)
Horizontal Casing Lift (3)

- Fluid accumulates in bottom of casing
  - Gas flow substantially restricted
- Fluid is pushed out through a combination of
  - Waves
  - Spray
  - Slugs
- Must keep fluid from dropping out of plunger-active region on shut-in
  - Standing valve used at max. plunger range and doubles as plunger stop & activator
Horizontal vs. Vertical Casing Lift

• Non-vertical drop generates:
  – Mechanical friction (~50° max. for steel plunger)
  – Lower effective weight (downward driving force)
  – Larger effective hydraulic forces
  – Wall contact that destroys sealing elements (cups)

• Upward Lift
  – Decreasing lift force with angle
  – Greater seal desired than descent → configuration change

• Other Issues
  – Packers, curvature, casing uniformity
Horizontal Well Constraints

- Force (gravity) available to move plunger decreases as it travels downhole
  - \( \frac{1}{2}W @ 60^\circ \)

- Force (pressure) required to lift fluid increases as plunger ascends

![Weight of Fluid vs. Angle Chart]

Weight of 1 bbl brine (Lb) vs. Angle (from Vertical)

- 4-½ x 11.6# CASING

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Horizontal Well Test Results

- Plunger operating max. proven depth @ 64°
- Brush interface: low friction but still needs flow-thru
- Liquid drops out quickly on shut-in – standing valve necessary to keep fluid in reachable zones.
- Casing quality may be degraded during completion
  - Plunger seals must conform to abnormalities
- Fluid levels difficult to measure
  - Must swab well at start or risk over-loading plunger
- ALL OBJECTIVES WERE MET
Horizontal Wells ~ Hardware Developed

Plunger
- Flow-through with valve
- Brush interface
- Pads

Downhole Equipment
- Standing valve & collar stop

Surface Equipment
- Lubricator & Controller
Horizontal Equipment Details

- Brush-QT Plunger
- Standing Valve
- Collar Stop
- Jetstar™ Surface Equipment
Case Histories

Vertical Wells
• High-Pressure Wells @ 4-½" & 5-½" in PA
• New Well @ 4-½" in OH
• Depleted Well @ 2-7/8" in TX
• Depleted Wells @ 4-½" in MT & OK

Horizontal Wells
• Devonian Shale #1 @ 4-½" in KY
• Devonian Shale #2 @ 4-½" in KY
Case #1~ Vertical Wells in Pennsylvania

- 12 installations, July 2009
- Total Investment Payback = 47 days
- Total Gas Sales Increase = $32,400/mo.
  - Assuming $5/MCF
12 vertical wells with JetStar Casing Plungers

- Marcellus Shale
- Two are 5½" x 17#, ten are 4½" x 11.6#
- $P_{\text{Rock}} \sim 2,500\text{psi}$ & $P_{\text{sales}} > 50\text{ psi}$
- 6,000 to 10,000 ft. casing stand setting depth
- 2 to 20 bbl/day brine water (frac. water flow-back)
- All wells originally on pump-jack
- Gas Flow prior to installation = 36.7 MCF/day (60d avg.)
- Gas Flow after installation = 52.1 MCF/day
  - Average gas increase = 42%
Case #2 ~ New Vertical Well in Ohio

- Clinton Formation
- 4-½" x 10.5#
- $P_{Rock} \approx 600$psi after 24 hrs.
- $P_{Sales} > 60$ psi, regulated by utility
- 2 bbl/d oil, 10% water
- 5 MCF/d avg. gas flow
- Plunger runs 1 cycle/day
- 6 hr shut-in & 45 min. open time, sold into utility lines
- Casing Stand set just above perfs. @ 3,100 ft.
Case #3 ~ Vertical Well in Texas

- Permian Basin
  - Lower Canyon Sands Play
- 2-7/8" x 6.4#
- $P_{\text{Rock}}$ ~ 400 psi
- $P_{\text{sales}}$ > 100 psi
- 1 bbl/day water
- ~2 cycles/day
- 6,560 ft.

2-7/8" Casing Plunger Evaluation

- 113 day Average Production:
  - Pre-Installation -- 7 mcf/d
  - Post-Installation -- 13 mcf/d

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Case #4~ Vertical Wells in OK & MT

• 4-½" × 10.5# Casing
• 19 wells in Oklahoma
  • 7 – 8 bpd w/ 20 – 30% oil cut
  • 7300 – 7400 ft. setting depth
  • Gas flow taken from 20-30 MCF/d to 50-60 MCF/d
• 2 wells in Montana
  • 2 – 4 BPD of produced water
  • 2000 – 2050 ft. setting depth
  • 25-30 MCF/d increased to 85 – 90 MCF/d
Case #5 - Horizontal Well #1 in KY

- Devonian Shale
- Brush-QT Plunger
- 4-½" x 11.6#
- 55° @ 3,675 ft.
- $P_{\text{Rock}} \sim 200 \text{ psi}$
- $P_{\text{sales}} \sim 50 \text{ psi}$
- Pure oil
- < 5 bbl/week
- Production up 50%
Case #6 ~ Horizontal Well #2 in KY

- Brush-QT Plunger
- Devonian Shale
- $P_{\text{Rock}} \sim 300$ psi
- $P_{\text{sales}} > 50$ psi
- 4-½" x 11.6#
- 44° @ 3,097 ft.
- 2.5 bbl/d water
- 203% ↑ gas flow
- Foam frac’d
Conclusions

• Casing plunger technology:
  • Increases production substantially
  • Can be more economical than other options
    • Payback typically < 2 months
  • In addition to extending life of older wells…
    • Has demonstrated safe application in
      • High-pressure vertical wells
      • Horizontal wells to 64°
  • Available for most casing sizes
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