Section 2
Well Completion and Its Impact on Water Production

- Completion options
  - Vertical versus horizontal
  - Open hole versus perforated
  - Single zone versus commingled
  - Other completion options
- Stimulation options
  - Natural
  - Acid
  - Hydraulic fracturing
  - Solid propellant technology

Vertical Versus Horizontal

- Advantages depend on reservoir properties, drive mechanisms and future EOR projects
- Horizontal drilling and completion costs are higher
- Basic benefit of horizontal is line sink versus point sink
- Horizontal makes more efficient use of reservoir pressure
- Radial flow in vertical versus linear in horizontal
- Horizontal can produce at higher rates at similar drawdown or similar rate at lower drawdown
- Horizontal delays coning (cresting) in case of bottom water drive reservoir

Rules-of Thumb for Considering Horizontal Versus Vertical

- Thin low permeability reservoirs
- Vertical permeability greater than one-fourth horizontal
- Layered formations
- Naturally fractured reservoirs
- Partially depleted and flooded reservoirs can be more effectively drained
- In bottom water drive reservoirs case histories have proven critical coning rates 3 to 20 times higher
- Economics are critical

Open Hole Versus Perforated

- Open hole
  - Initially cheaper
  - Permits testing of zone as it is drilled
  - Eliminates formation damage by drilling mud and cement
  - Allows incremental deepening to avoid water
- Perforated
  - Offers higher degree of control
  - Sections can be isolated and selectively stimulated
  - Hydraulic fracturing more useful
  - Productivity ratios are higher due to uniform treatment of pay section and stimulation benefit of perforating

Single Versus Commingled

- Things to consider
  - Compatibility of fluids, mixing different formation fluids tends to increase scale and corrosion problems
  - Reservoir pressure of the different zones
  - If unexpected things occur it is more difficult and costly to determine which zone is the culprit
  - Whether the well will ever be used as part of an EOR project

Natural Completions

- No stimulation required to achieve commercial production rates or required injection volumes
- Rare
  - Stimulation typically required to remove formation damage caused during drilling process
- More common in open hole
- Advantages
  - No risk of communicating to adjacent formations
  - More uniform sweep in an injection project

Acid

- Remove damage from carbonate and sandstone formations
- Stimulate production and injectivity in carbonates
- Matrix treatments
  - Performed below the fracturing rate and pressure of the formation
  - Travels through existing pores and fractures
  - Commonly used to increase injectivity in disposal and injection wells
- Fracture treatments
  - Performed above the fracturing rate and pressure of the formation
  - Rock is cracked and an etched fracture is created

Rules-of-Thumb on Acid Volumes

Treatment Type	Acid Volume (per ft of interval)	Area of Reservoir Affected	Resultant Skin
Wellbore clean-out	10 to 25 gal	Connect wellbore to formation	0 to -1
Near wellbore stimulation	25 to 50 gal	2 to 3 ft	0 to -2
Intermediate matrix stimulation	50 to 150 gal	3 to 6 ft	-2 to -3
Extended matrix acidizing	150 to 500 gal	Greater than 6 ft	-2 to -5

Hydraulic Fracturing

- Formation fractures along the plane perpendicular to the direction of the least principle stress
  - Horizontal fracture created if fracture pressure is greater than overburden pressure
  - Vertical fracture will occur if overburden pressure is greater
- Extent of induced fractures is function of pump rate applied after fracture is initiated
- Successful if reservoir fluid flow to fracture rather than wellbore
- Techniques for improving fracture conductivity
  - Increasing fracture perm (proppant, fluid cleanliness)
  - Increasing fracture width (technique, e.g. tip screen-out)

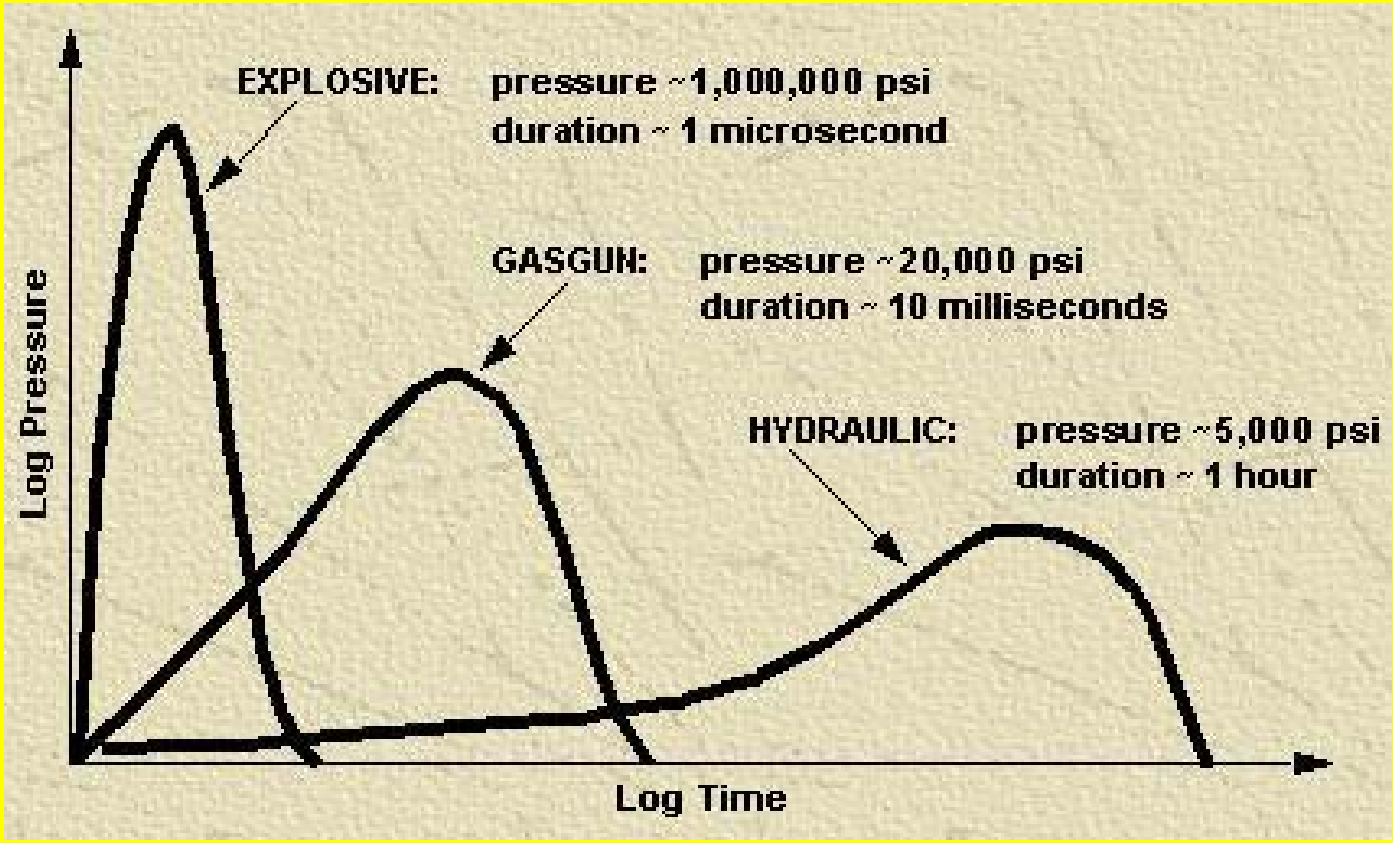
Hydraulic Fracturing (cont.)

- Conventional optimal fracture design
  - Pad volume completely leaks off to formation
  - Entire created fracture filled with proppant laden fluid
  - Too much pad, larger fracture than is effectively propped, not cost effective
  - Too little pad, premature termination may result
- Consider
  - Surrounding zones
  - If well may be used in future EOR project
  - Tag with radioactive tracer
- Record ISIP (provides estimate of formation parting pressure

Solid Propellant Technology

- The GasGun™
- Multiple radial fractures created by a gas-generating progressively-burning propellant
- Fractures radiate 10 to 100 feet from the wellbore
- Minimum vertical growth out of pay
- Entire zone stimulated
- Wireline conveyed
- Cased or open hole
- 300 to 5000 foot fluid tamp

Pressure-Time Profiles of Three Stimulation Methods



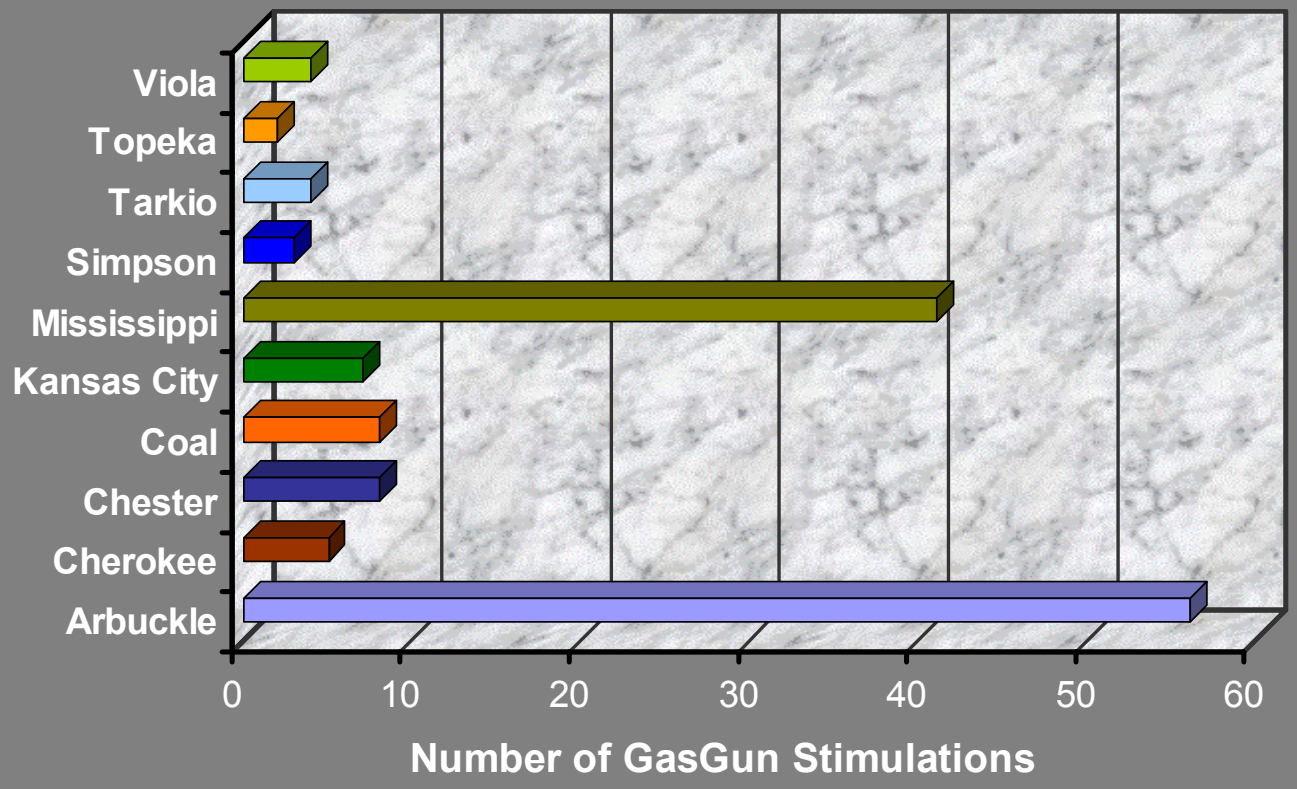
Solid Propellant Technology (cont.)

- Potential applications
  - Remove skin damage
  - Preparing formations for acidizing and fracturing
  - Stimulating naturally fractured reservoirs and lenticular sands
  - Increasing injection and withdrawal rates
  - Improving waterflood sweep efficiency
- Cost
  - $780 + $150 per foot of gun
  - Price does not include wireline or rig charges
- www.TheGasGun.com


GasGun™ - (503) 557 1370 - www.TheGasGun.com Made in USA

GasGun^{sm} Stimulations In Kansas

- Since March 2002 Technology Fair Workshop
  - Over 50 operators have applied the process in nearly 150 separate wells in 10 different formations



Typical Results

- 75% success rate
- 0-2 BOPD → 6-8 BOPD
- 0-20 BWPD → 20-30 BWPD

- One well
  - 3 → 28 BOPD
  - 60 → 170 BWPD

GasGun™ Certified Wireline Companies