HEAVY ARTILLERY

ADAM SCHMIDT, THE GASGUN, INC, USA, DEMONSTRATES HOW A STIMULATION TOOL CAN BLAST THROUGH NEARBORE DAMAGE AND IMPROVE PRODUCTION IN COLOMBIA'S HEAVY OILFILEDS.

Propellant stimulation tools have been used to fracture oil and gas wells for over 50 years. A variety of different propellant formulations including rocket fuel, potassium perchlorate, and progressively burning propellants have been used during that period with varying success. Progressively burning propellants have a unique burning characteristic in which the rate that the propellant burns increases with time, producing gas in increasing volume as the material is consumed. These propellants were proven by independent research conducted by Sandia National Laboratories to be many times more effective in creating fractures and increasing formation permeability.

A progressive burn is achieved with the use of a multi-perforated propellant grain. Other propellant designs typically have a solid configuration resulting in a regressive burn where the surface area decreases as the material is consumed. The design of the GasGun is based on the use of progressively burning propellants.

The GasGun is a solid propellant fracturing device based on ballistic technology from the US military. The propellant generates high-pressure gases at an accelerating rate that create a fracturing behaviour dramatically different to either hydraulic fracturing or explosives. The time to peak pressure is approximately 10 000 times slower than a high explosive but 10 000 times faster than hydraulic fracturing (Figure 1). The ability to produce these fractures in order to bypass near wellbore damage has been demonstrated experimentally and verified through extensive field applications.

The development of modelling software specific to GasGun progressively burning propellants is ongoing and incorporates a wide range of data including wellbore configuration, rock properties (Poisson's ratio, Young's modulus, fracture toughness, tensile strength, etc.), state of stress (pore pressure, overburden stress, horizontal stresses, etc.) and concentration stress around the wellbore. It will also include flow modelling that characterises the bubble/gas flow inside the fractures and will model the gas loss through fracture faces into the formation. Post frack test data is then used to calibrate the model, particularly as it pertains to applications in the same field, formation and basin.

Maximising production

Many companies in the oil and gas sector have been dedicated to maximising the production from reservoirs with near wellbore damage. Very sophisticated and expensive muds and kill fluids, acids, chemical washes and fracking have been used to either avoid damaging the formation in the first place or to reduce the impact of the flow restriction that near wellbore damage can cause in the event the preventative measures fail. The viscosity of the long chain hydrocarbons that characterise heavy oils exacerbates the choking effect. The correct application of progressively burning propellants has been proven to bypass near wellbore damage, increasing the effective permeability, the 'KH' of the interval. This can be achieved through the application of the technology associated with progressively burning propellants without the negative effects associated with chemical treatments or in the case of fracking, the high cost and the risk that a vertical fracture may communicate with other zones, perhaps water or gas bearing. This technology has the potential to add significant production and thus increase revenue very cost-effectively if applied to address the specific problems associated with near wellbore damage.

Statement of theory and definitions

A progressively burning propellant burns and generates gas at an increasing rate by virtue of its design. As it burns, more surface area is exposed, which accelerates the rate at which gas is produced as the propellant is consumed.

The idea for a progressively burning propellant originated long before the technology was applied in the oil industry and, as is the case for many new technologies, it was driven by the military who wanted to launch their shells much further than allowed by the traditional gunpowder charge utilised in the naval and land battles of the 19th Century. Basically, if a shell is to be accelerated up a long barrel using a propellant, it is essential that high-pressure gas be generated faster and faster to fill the rapidly increasing volume in the barrel behind the shell and to accelerate the shell. This concept is not very different to what it takes to propagate fractures originating in a wellbore in that after the fracture is initiated, increasing volumes of gas are required to ensure the fracture continues to propagate and thus bypass near wellbore damage or intercept a natural fracture system.

Practical benefits from the correct application of the technology can include the following:

- Creation of multiple radial fractures originating in open holes, perforation tunnels or slotted liners. Fractures in excess of 25 ft were observed in the Sandia tests.
- Bypassing of near wellbore damage caused by drilling mud, completion fluids, cement, fines, scale, or other chemical deposition leading to significant improvements in effective KH.
- Increase in production from naturally fractured reservoirs by intercepting more fractures.
- Reduction in costs of traditional fracking by reducing pressure and hydraulic horsepower requirements.
- Improved effectiveness of acidising by allowing more of the reservoir to be contacted.
- Increased injection rates in waterfloods, waste disposal, and gas storage wells.
- Reduced risk of communicating with other zones as 98.5% of energy is focused to the targeted reservoir. Vertical fracture growth out of the zone of interest is minimal which is often a major downside to conventional fracking. To illustrate why the energy is contained to the zone of interest, the following calculation is presented:

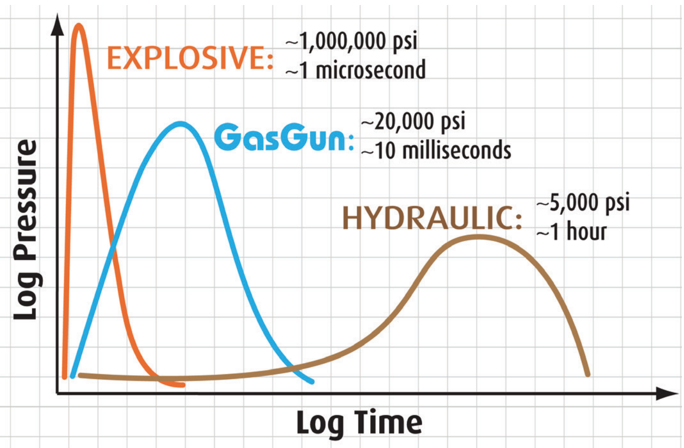


Figure 1. *Pressure – time profiles of three stimulation methods.*

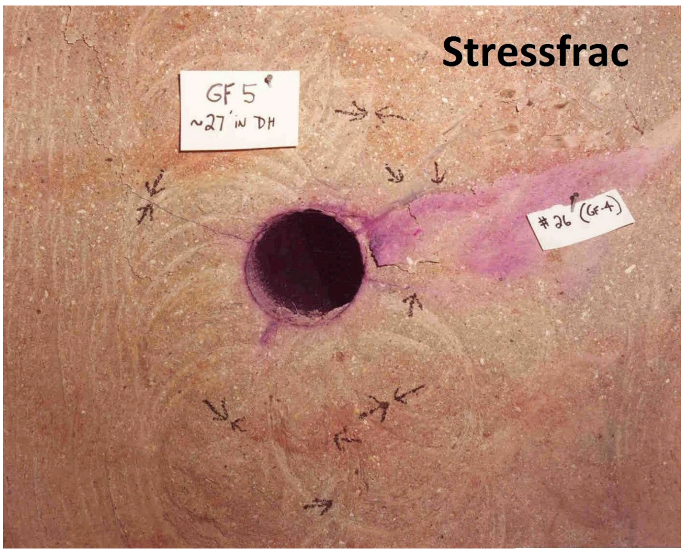
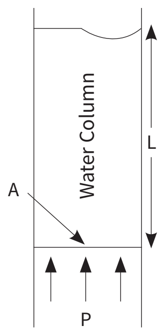


Figure 2. *Mineback observation after stimulation with regressively burning propellant tool (Stressfrac).*

Movement of water column above GasGun stimulation.



P = Pressure
L = Length
A = Area
t = Time
F = Force
m = Mass
a = Acceleration
V = Volume
V = Velocity
W = Weight
g = Acceleration due to gravity
p = Density
s = Distance

Values:

P = 20 000 psi
t = 20 msec
L = 1000 ft
p = 62.4 lb/ft^3 (density of water)
g = 32.2 ft/sec
A = 0.213 ft^3 (6 ¼ in. open hole)

Formulas:

$F = ma$ or $a = F/m$
$m = W/g$
$W = Vp$
$V = AL$
$s = \frac{1}{2} ar^2$

$a = F/m = PAg/W = PAg/ALp = Pg/Lp$

Distance water column moves in 20 msec is: $s = \frac{1}{2}at^2$

In this example, the water movement is 0.04 m, implying that the energy should have been kept well within the chosen interval.

Data and observations

Independent research performed by Sandia National Laboratories in the 1970s was conducted in a tunnel complex at the Nevada Test Site, and

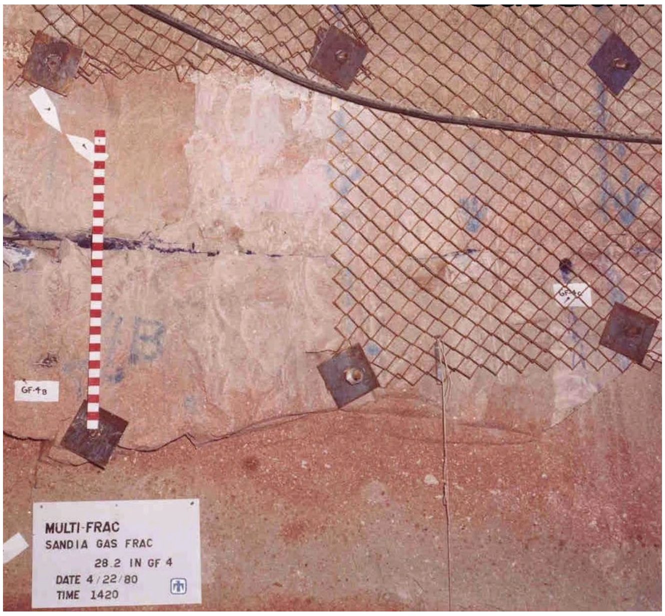


Figure 3. *Mineback observation after stimulation with progressively burning propellant tool (GasGun).*

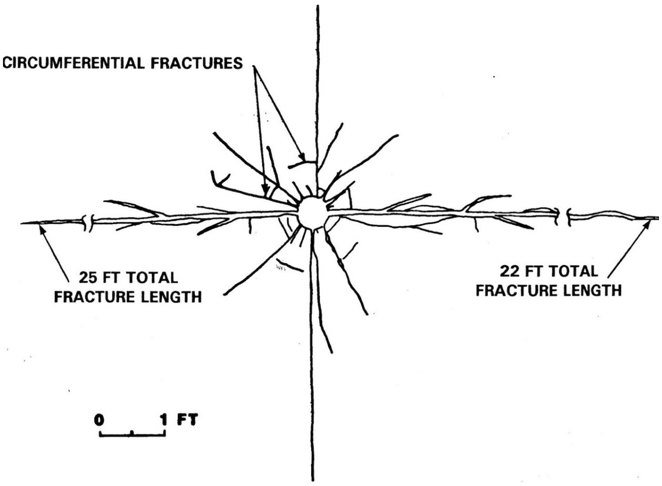


Figure 4. *Schematic of fracturing from GasGun tool observed during mineback experiments.*

direct observations of the fractures created by various propellant tools were made by mining out the boreholes after stimulation.

The Stressfrac tool was one of the propellant fracturing technologies tested by Sandia. Its design was based on the use of propellant with regressive burning characteristics similar to that of many other propellant tools currently available. While the initial burning creates high pressures and does in fact generate multiple fractures, the regressive burning characteristics do not allow for significant propagation of those fractures because gas generation is decreasing while fracture volume is increasing. Fractures that were mined out were less than a foot in length, which limits the ability of the tool to bypass near wellbore damage and to significantly increase flow rates (Figure 2).

The direct observations made by the researchers at Sandia demonstrated that progressively burning propellants produce a much more extensive multiple fracture pattern. The created fractures extended more than 25 ft from the wellbore. The longer fractures are a result of the increasing gas volumes produced over time from progressively burning propellants while at the same time fracture volume is also growing. This improved fracturing occurs while limiting peak pressures in the borehole and thus reduces the chances of damage to downhole equipment that is often associated with other types of propellant tools (Figure 3).

The fracture patterns were mapped out by the onsite geologist at Sandia to more clearly demonstrate the multiple fractures that were created (Figure 4).

Results

Ecopetrol ran the GasGun in a number of wells in various basins and producing horizons throughout Colombia. Pressure data indicated the presence of significant near wellbore skin in some wells. Other wells were inferred to have significant damage based on the behaviour of adjacent wells with similar petrophysical characteristics. Table 1 summarises the results in these initial wells.

Castilla is a very large heavy oil accumulation located in the Llanos Basin of Colombia. Discovered by Chevron in 1969, Ecopetrol assumed responsibility for the operation of the field in 2002 and since that time has built production to over 100 000 bpd. The main producing stratigraphic units are the Massive Guadalupe, or K2, and Upper Guadalupe, or K1. The K2 is a sand dominated system deposited in braided and meandering channels. The deposits are primarily gravels and sandstones, generally poorly sorted, fine to medium grained. The K1 Inferior unit consists of coastal plain sandstones and mudstones. The K1 Superior is predominantly a shale and siltstone interval. Several initial wells in Castilla were chosen based on the presence of significant skin damage inferred from pressure build up analyses. These initial results are outlined in Table 2.

Table 1. Results from initial Colombian wells.

Well	Well type	Before GasGun (bpd)	After GasGun (bpd)	Interval (ft)	Increase (bpd)
Los Mangos X X	Production	0	40	38	40
ACAEXX	Production	40	836	50	796
ACAEXX	Production	71	103	90	32
SantosXX	Production	4176	7344	68	3168
SantosXX	Production	2592	4176	205	1584

Table 2. Initial results from wells in Castilla.

Well	Well type	Before GasGun (bpd)	After GasGun (bpd)	Interval (ft)	Increase (bpd)
CastillaXX	Production	101	616	139	515
CastillaXX	Production	20	80	96	60
CastillaXX	Production	8	384	59	376
CastillaXX	Injection	0	2300	150	2300

Conclusion

The GasGun was able to cost-effectively increase production in a wide range of wells in various basins and reservoirs with the specific results depending on the degree to which the effective permeability was impaired by near wellbore damage and thus had positive skin factors. Ideally, the decision to employ the technology outlined in this discussion would be based on pressure build up analysis. However, this is not possible or is cost-prohibitive in many wells. Hence the decision can be based on poor well performance where petrophysical evidence suggests the presence of significant damage.