Petroleum Development Services – Free Zone

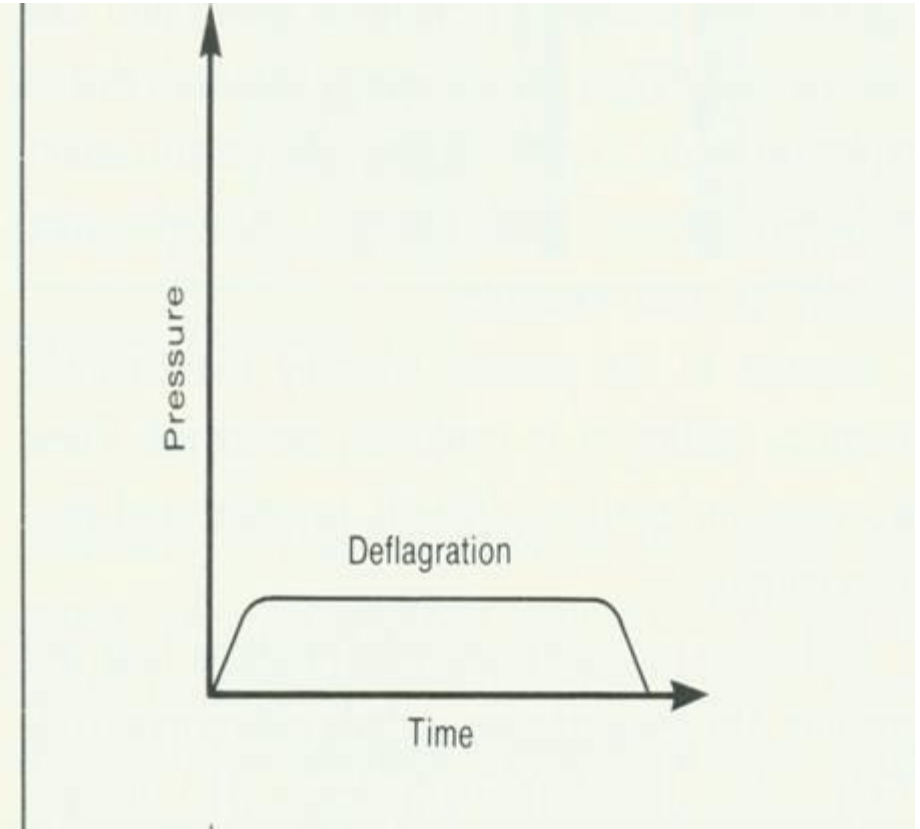
The GasGun™ -- Stimulating Oil and Gas Wells with a Solid Propellant

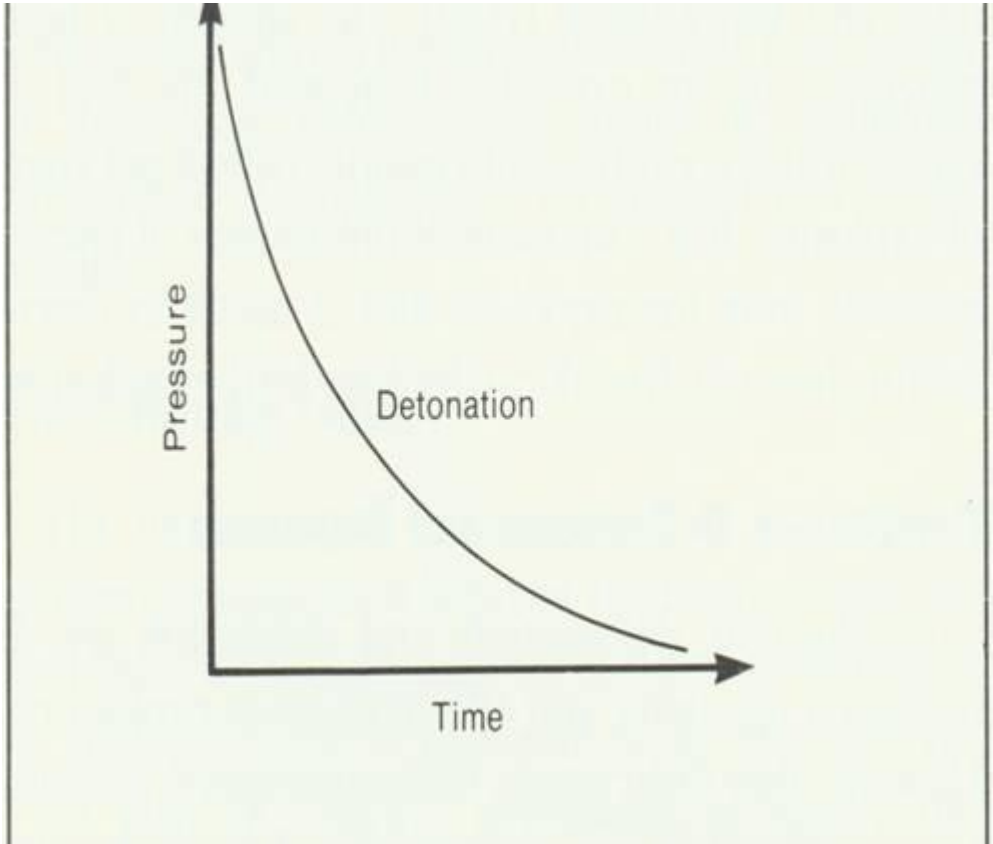
Multiple radial fractures created by a gas-generating progressively-burning propellant

What is the GasGun?

- *The GasGun is an advanced well stimulation technique based on high-pressure gas generation by propellant combustion*
- *The GasGun designed to enhance existing completion methods, and in many applications provide a more cost-efficient alternative.*
- *The propellant used in GasGun device do not detonate supersonically, it deflagrate at subsonic velocities.*
- *Deflagration can be simply explained as a burning process that takes place without an outside source of oxygen.*
- *The GasGun uses solid propellant, often referred to as a low explosive, to generate high pressure gas at a rapid rate.*
- *Propellants have energy densities approximating those of high explosives, and are thus more compact than any other prime energy source other than nuclear.*

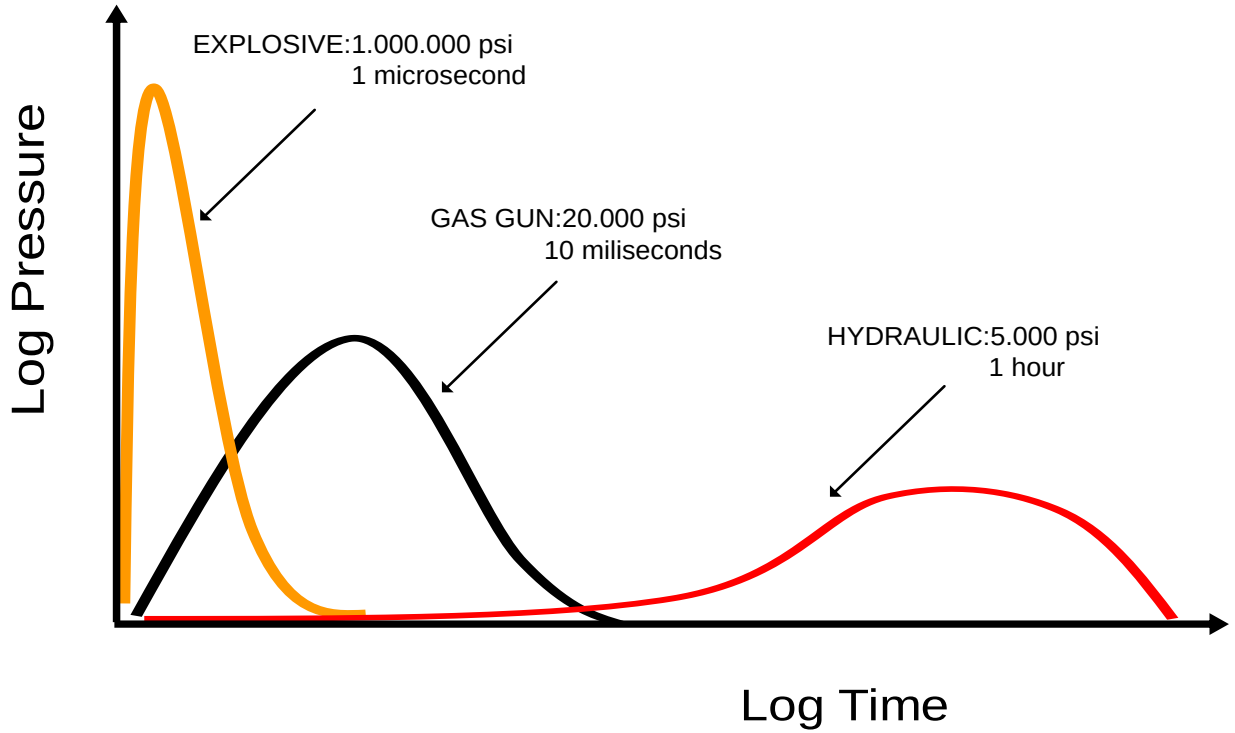
	COM	DEF	DET
Velocity (m/s)	10^{-2}	1	$>10^{3}$
Energy (cal/g)	10^{3}	10^{3}	10^{3}
Gas Volume (l/g)	1	1	1





What is the GasGun?

- *The propellant type devices typically produce a high pressure event lasting on the order of a few milliseconds to perhaps a few hundred milliseconds, as opposed to a few microseconds for high explosive well shots.*
- *This longer event time is the secret to producing multiple fractures and avoiding stress cage damage.*



What is the GasGun?

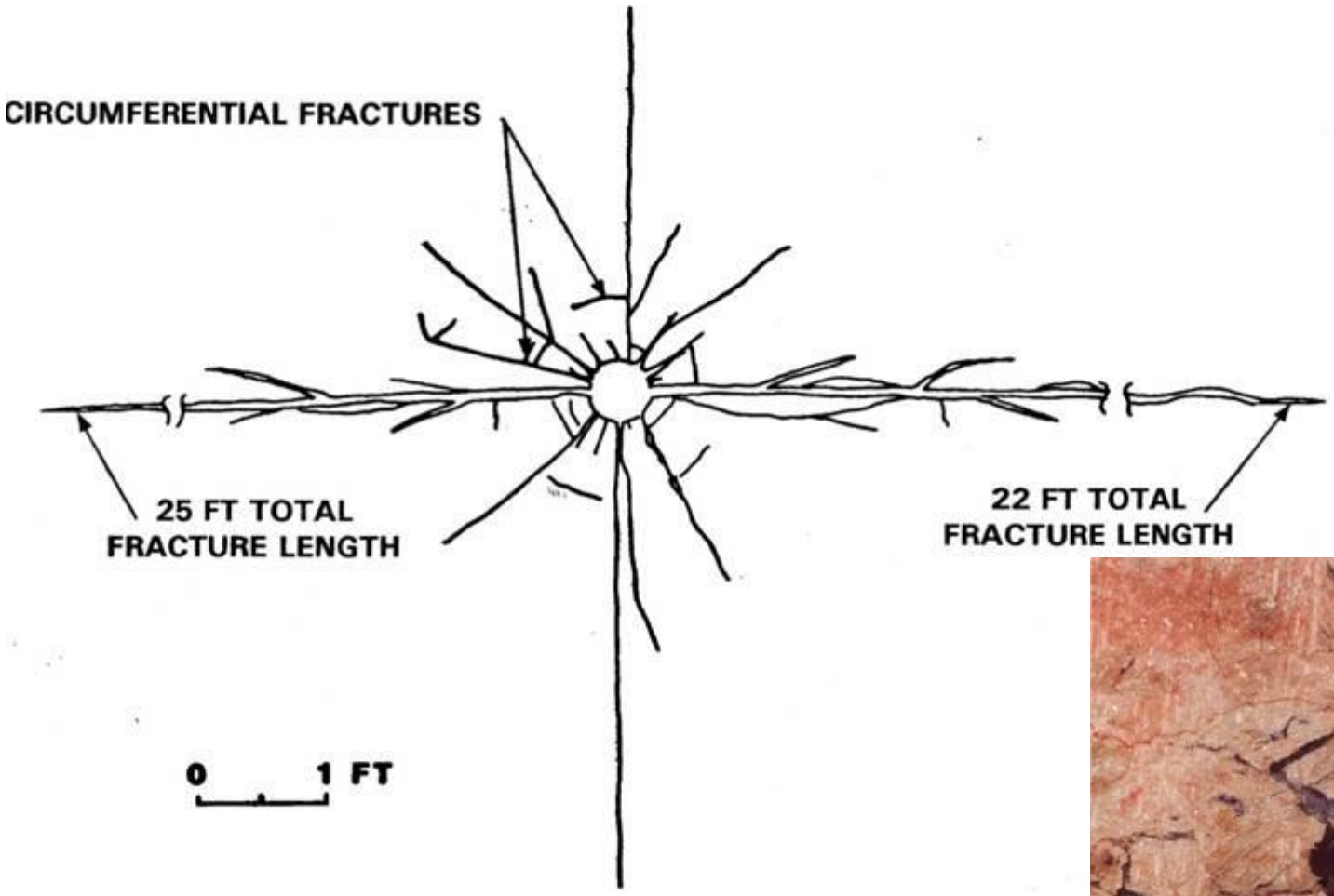
- *This process permits simultaneous initiation of numerous multi-oriented fractures at most well depths and conditions.*

- *Activated in-zone under a liquid column, the system acts as its own high capacity pump, and generates its own stimulation in the form of gas.*

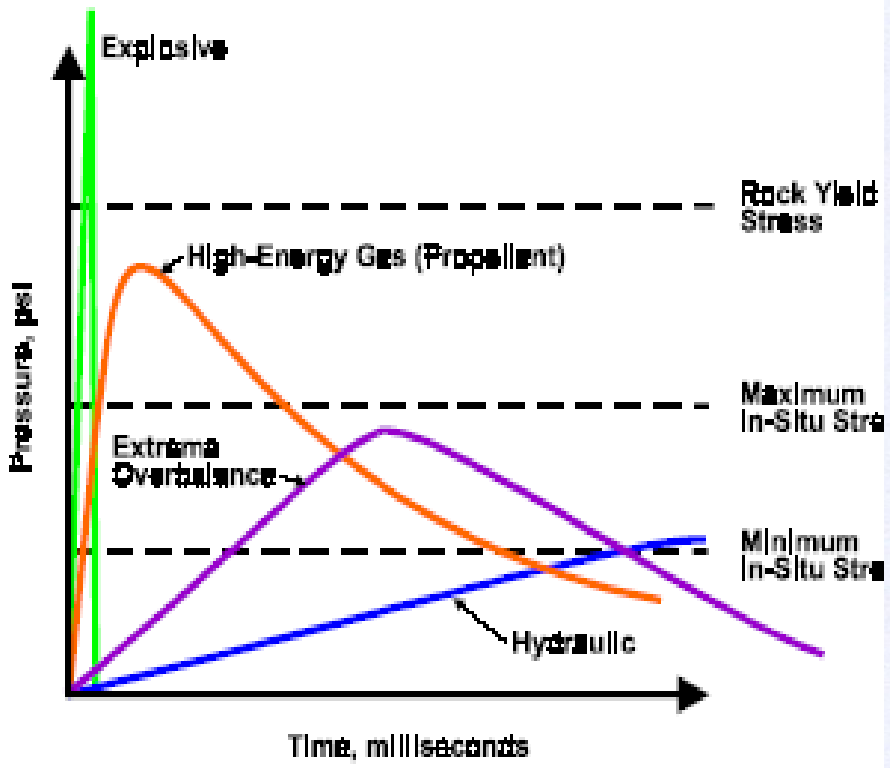
- *The rate is tailored to the formation characteristics to be rapid enough to create multiple fractures radiating 10 to 30 feet from the wellbore.*

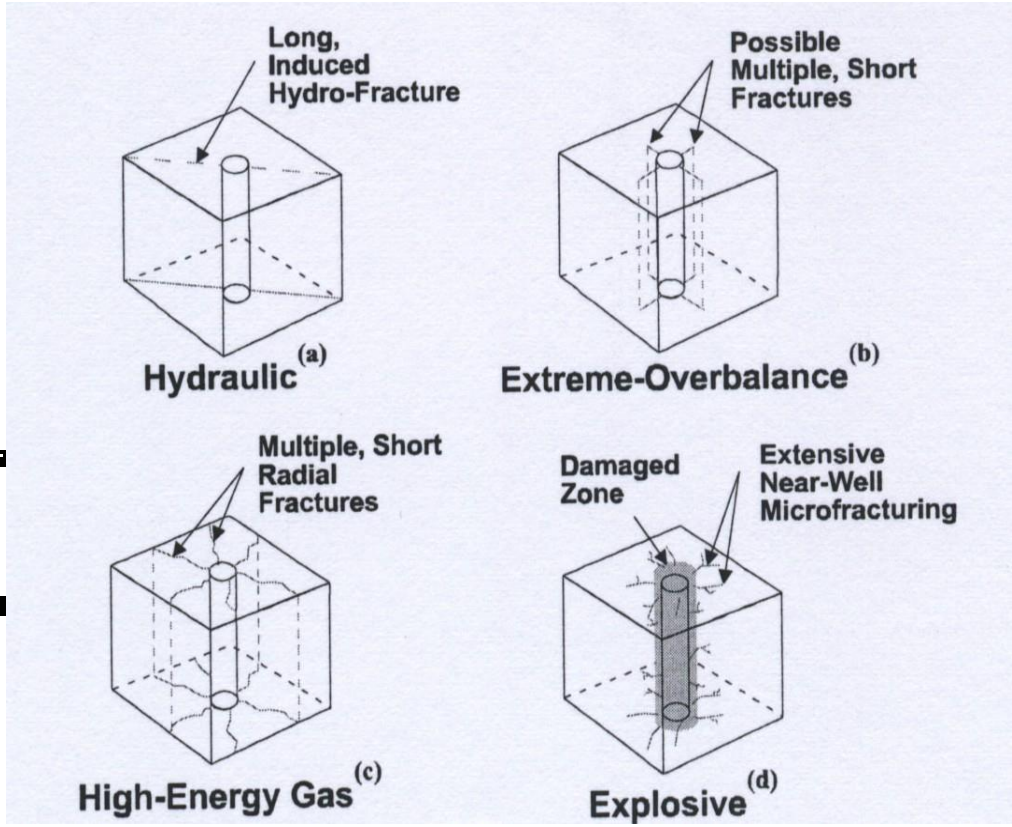
- *The star-shaped pattern of multiple fractures removes wellbore damage or blockage and increases the formation permeability near the wellbore.*

What is the GasGun?



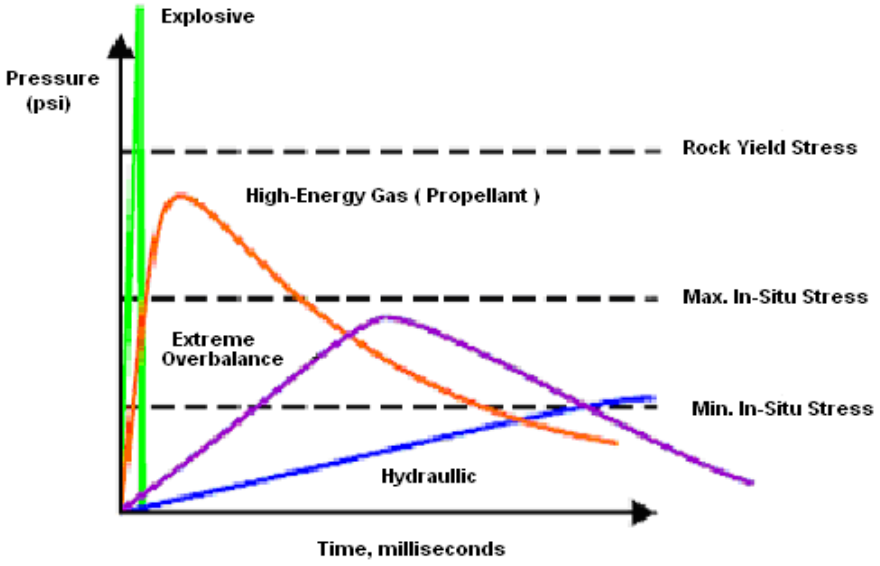
Classifications of various fracturing processes

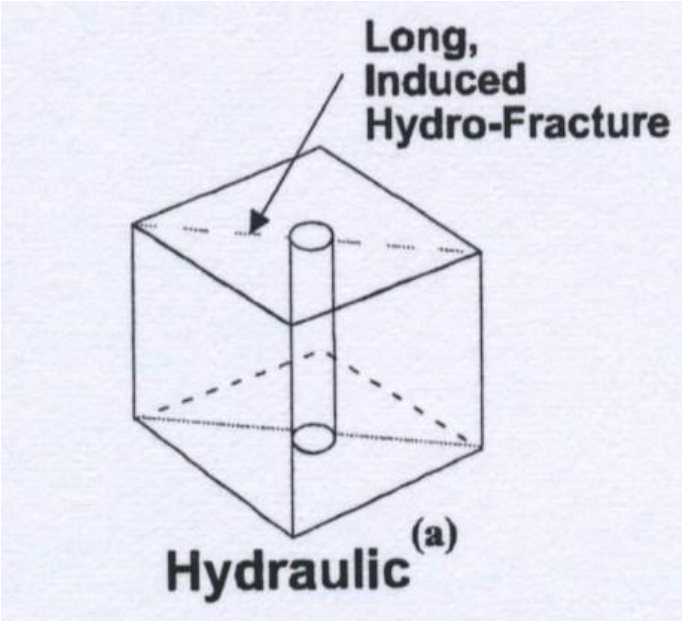




- *Fracture stimulation technologies can generally be categorized according to the rate at which energy is applied to the target horizon to induce fracturing.*

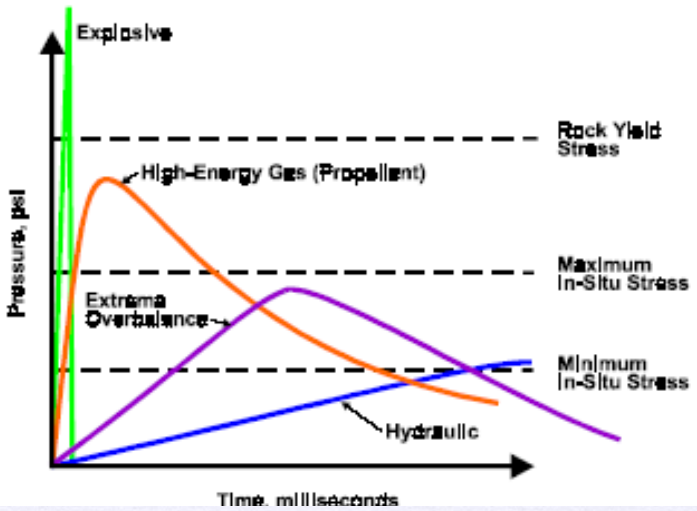
Classifications of various fracturing processes- hydraulic fracturing

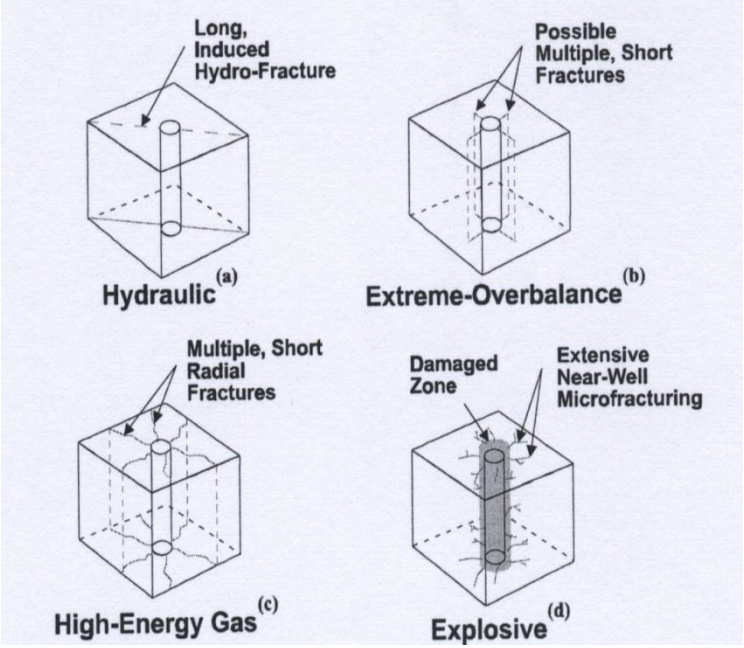




- *low rate of loading*
- *two-winged vertical fracture extending outward from a well*
- *oriented perpendicular to the least principal rock stress.*
- *max pressure will slightly exceed the min in-situ rock stress.*
- *the fracture opens and closes without any lateral shift.*

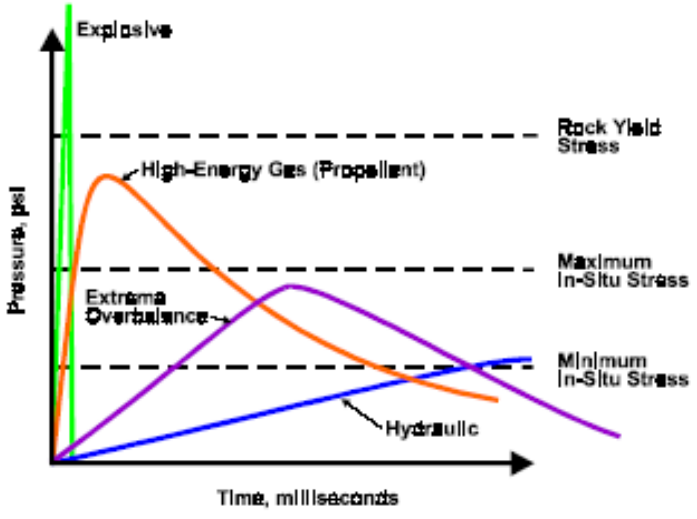
Classifications of various fracturing processes-explosive fracturing

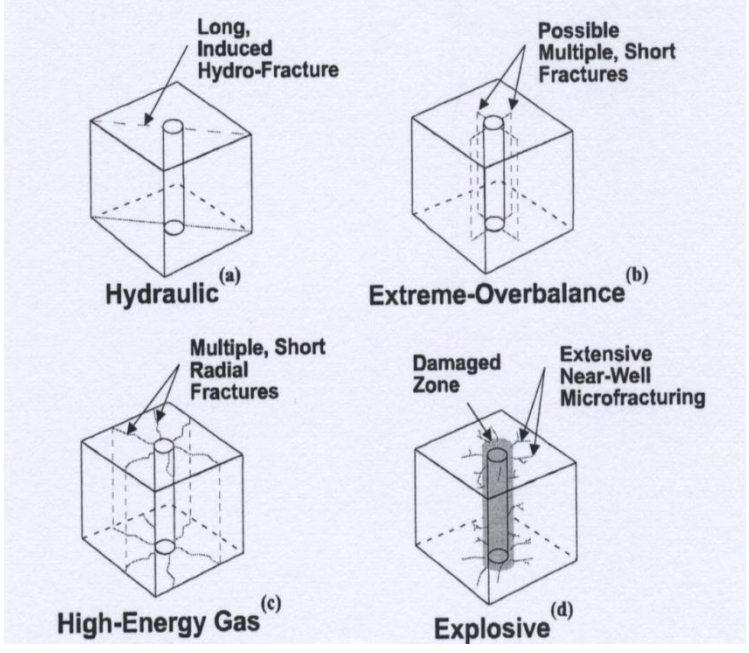




- *On the other extreme, explosive fracturing involves a very rapid loading of the target formation resulting in a highly fractured zone around the wellbore*
- *Because the peak pressures exceed both the minimum and maximum in-situ stress, fractures in all three dimensions are created.*
- *the peak pressure can also exceed the rock yield strength which, when coupled with the high induced compressive stresses in the vicinity of the wellbore, cause compaction to such a degree that permeability is actually decreased in the near-wellbore region, resulting in a damaged zone..*

Classifications of various fracturing processes-solid propellant fracturing

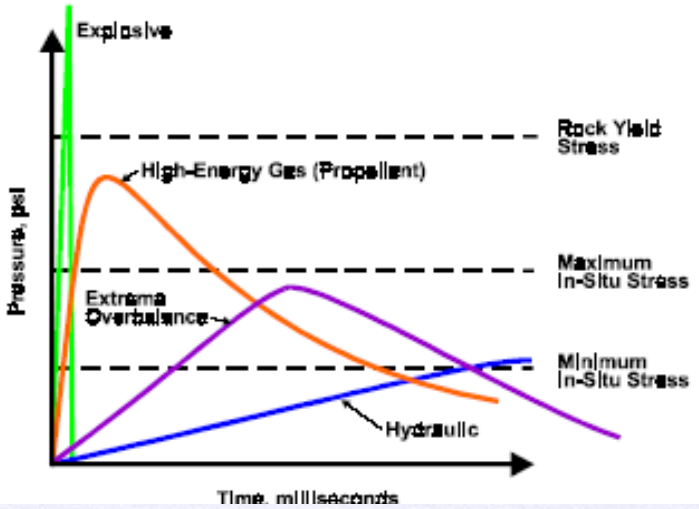


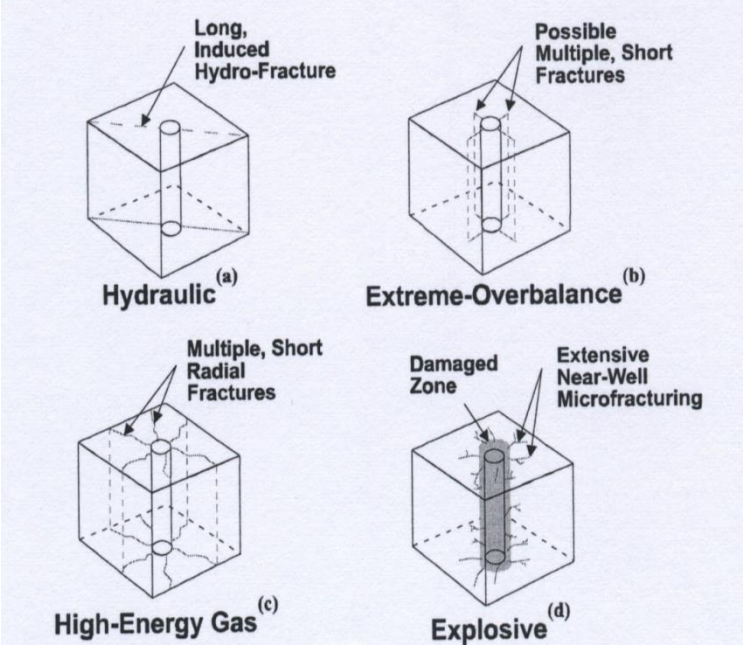


- *The solid-propellant fracturing tool generates high-pressure gases at rate that creates fractures dramatically different from either high explosives or hydraulic fracturing.*

- *The solid-propellant fracturing is characterized by peak pressures exceeding both the maximum and minimum in- situ stresses, but not to a level that exceeds the rock yield strength*

Classifications of various fracturing processes-solid propellant fracturing





- *The pressure from the propellant burn is above the tensile strength of the formation, but below the formation's shear strength.*
- *This produces fracturing rather than crushing or grain shattering.*
- *The stimulation occurs within a few 100's of a ms; fast enough to insure a preferential path is not followed*
- *all perforations are presented with a relatively equal pressure differential.*

Progressive burning-secret of Gas Gun effectiveness

- *the GasGun incorporates a vastly improved design with progressively burning propellants*
- *Progressive burning have been proven by independent research to be many times more effective in creating fractures and increasing formation permeability.*
- *Progressive burning means that gas is produced faster as the material is consumed,saving energy until late in the fracturing process when needed to drive the fractures deep into the formation.*
- *The progressive burning is much more effective in controlling peak pressures and advancing the fractures late in the process when crack volumes are the greatest.*
- *Independent research bears this out.*

Progressive burning

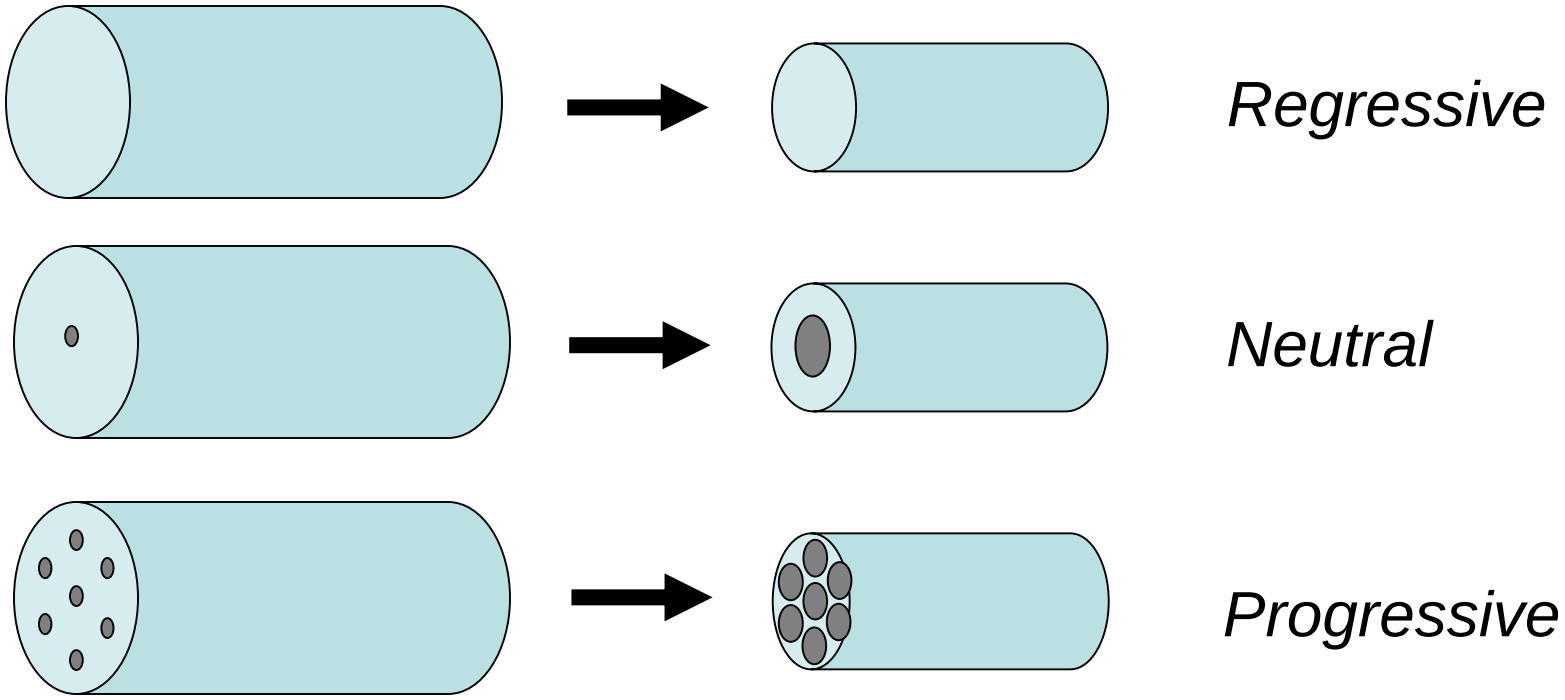
- *In a study conducted by Sandia National Laboratories (USA), a multi-perforated propellant was 300 times more effective in enhancing formation permeability than a standard solid propellant in a direct side-by-side comparison.*

- *progressive burning also provides an important benefit - allows us to put more propellant energy in the tool*

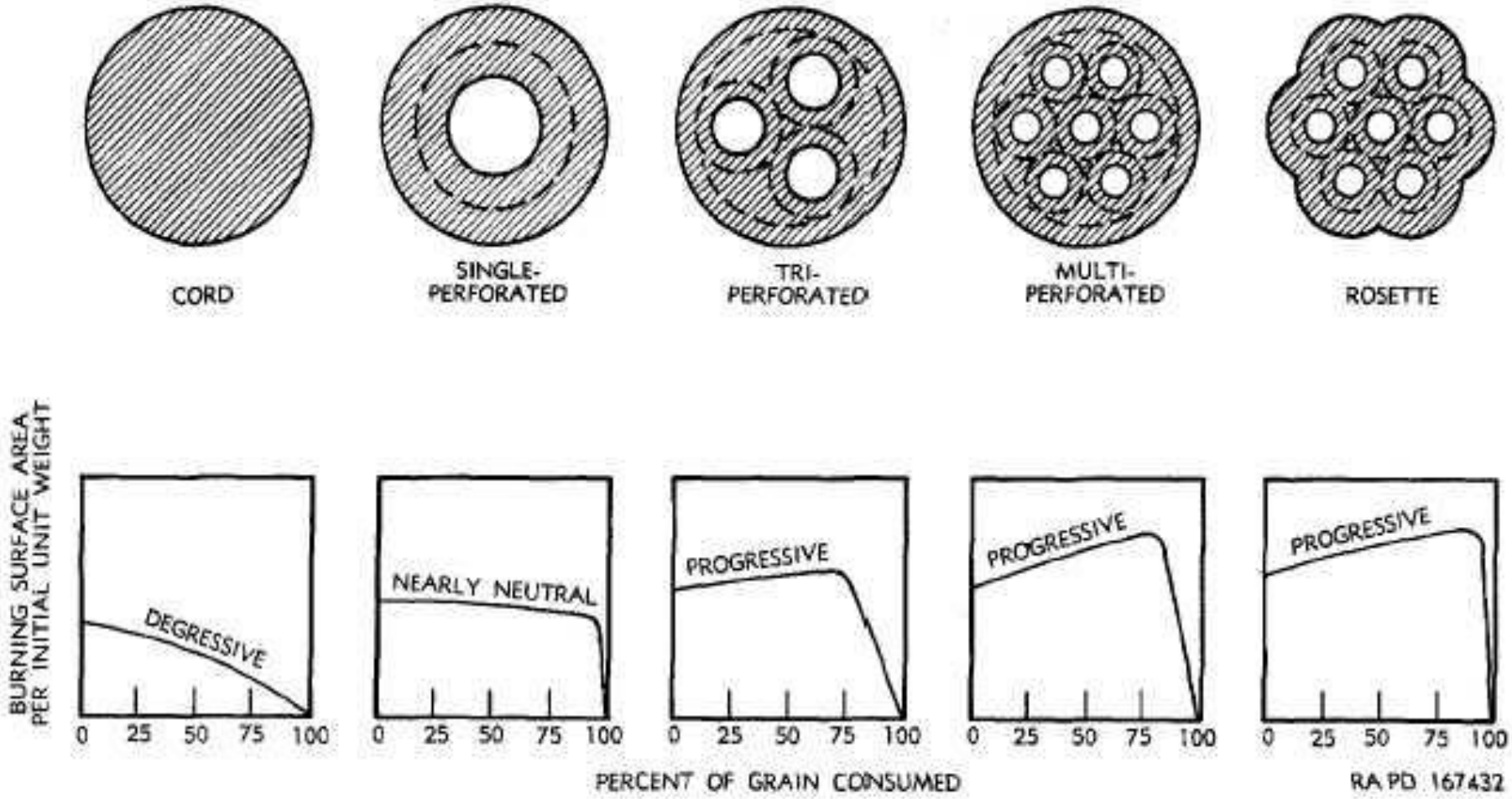
- *producing more gas volumen and longer fractures,while keeping the pressure from getting too excessive,which would damage casing.*

Progressive burning

Speed of burn front $r = a\,p^{n}$



Progressive burning

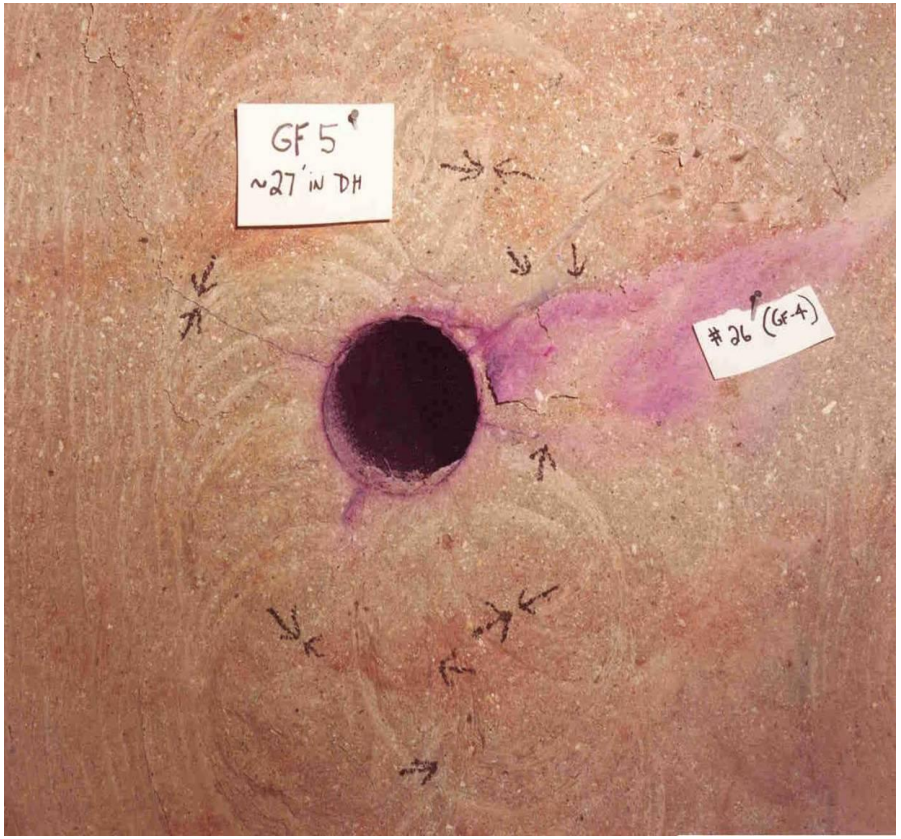


Progressive burning

The magic of multi-perforated propellants

- *peak pressures controlled*
- *no energy wasted in rock compaction*
- *no energy wasted in creation of short fractures*
- *majority of energy and gas production saved for fracture extension*

Photographs of the multiple fractures created by progressive and regressive burning propellant



Progressive-GasGun

Regressive-other propellant tools

Study conduced by Sandia National Laboratories

GasGun progressive burning-surface test

Self propping

- *fracture propping characteristics of solid propellant stimulations occur from two sources:*
- *The violence of the event produces some debris that is propelled into the fractures,*
- *there is some degree of "self propping" that occurs from shear motions on fractures that are not aligned with the principal in situ stresses.*
- *Hydraulic fractures orient themselves perpendicular to the least principal stress, taking the path of least resistance.*
- *That plane will have no shear stress on it, so the fracture opens and closes without any lateral shift.*
- *Solid propellant fracturing, when formulated correctly, produces multiple fractures, some of which are oriented at angles to the principal stress directions.*
- *These fracture planes have shear stresses acting on them, meaning that the fractures will shift slightly sideways while they are open.*
- *That way, as they close, the "jigsaw puzzle" does not fit back together neatly, and the fractures will remain partly open.*

Self propping

- *The best field evidence that these propping mechanisms actually work is the fact that production improvements from GasGun stimulations are typically long lasting.*

What the Gas Gun can do for your wells

- Remove skin and damage from drilling fines, paraffin, mud cake, cement, etc.
- Stimulate lenticular sands
- Improve effectiveness of acidizing
- Prepare well for hydraulic fracturing
- Increase injection and withdrawal rates in gas storage wells
- Improve waterflood efficiency
- Stimulate naturally fractured reservoirs

How does the GasGun compare with hydraulic fracturing?

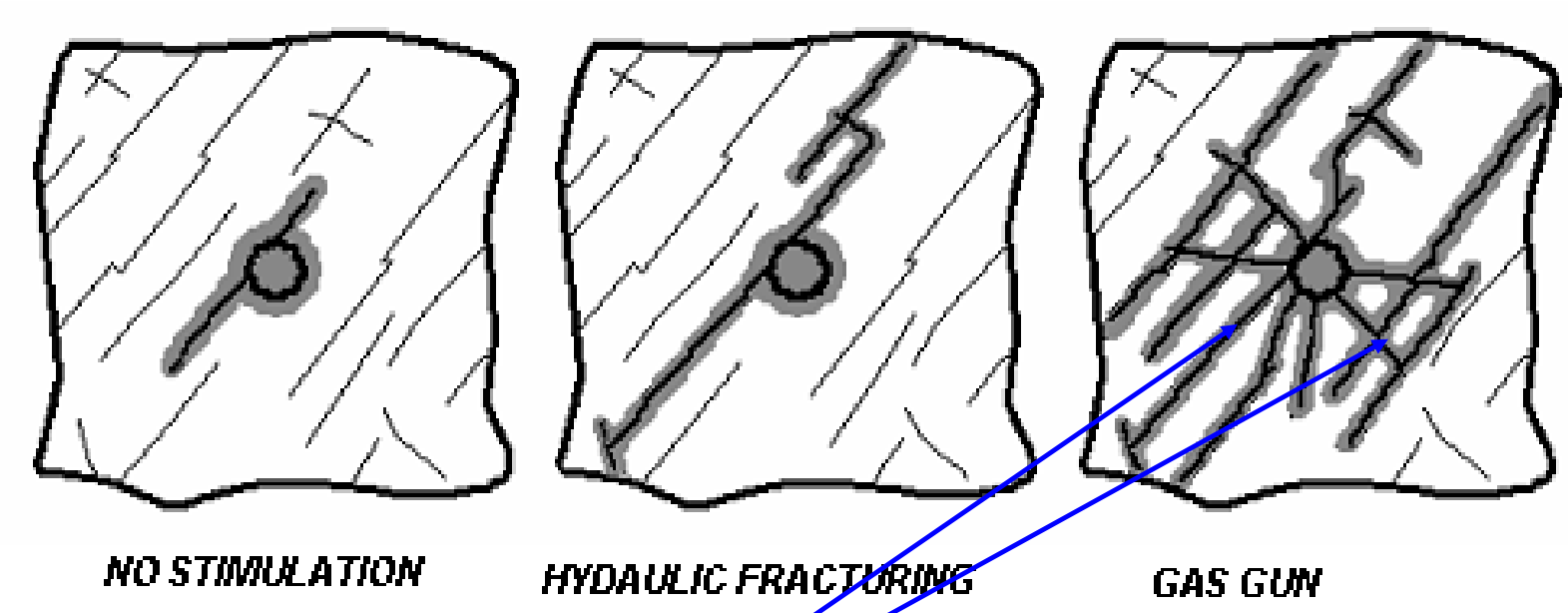
- *hydraulic fracturing creates a single fracture oriented perpendicular to the least principal in situ stress.*
- *the fracture propagates vertically as well as laterally seeking the path of least resistance.*
- *many hydraulic fractures have been known to break out of the producing formation and into aquifers and thief zones.*
- *While the fractures produced by the GasGun are more limited in length, gas pressures overpower in situ state of stress, creating multiple radial fractures with minimal vertical growth.*

How does the GasGun compare with hydraulic fracturing?

- *as a result GasGun fractures are much less likely to wander out of the producing zone.*
- *The multiple fractures created by the GasGun may also be much more effective than hydraulic fracturing in naturally fractured reservoirs.*
- *Hydraulic fractures commonly propagate parallel to most of the existing fractures or "with the grain".*
- *Multiple fractures may not extend as far, but may link the well to more of the natural fractures.*

GasGun vs. Hydraulic fracturing

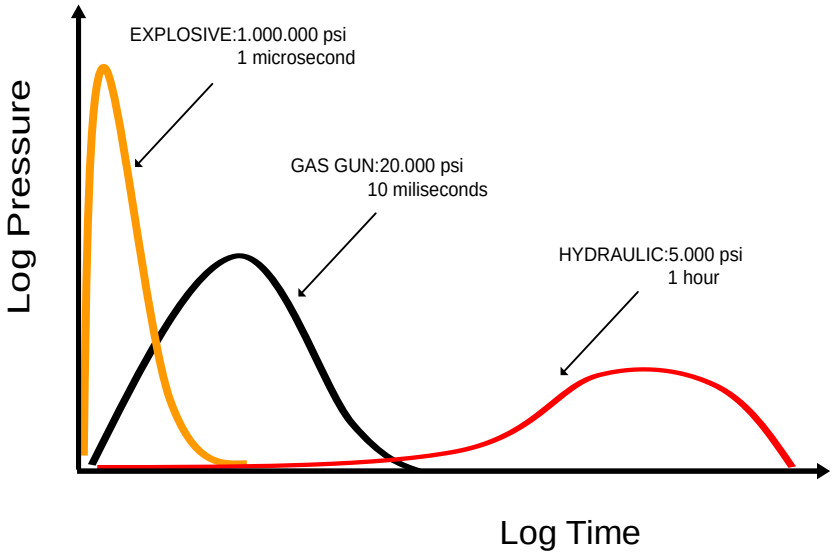
stimulation of naturally fractured reservoirs

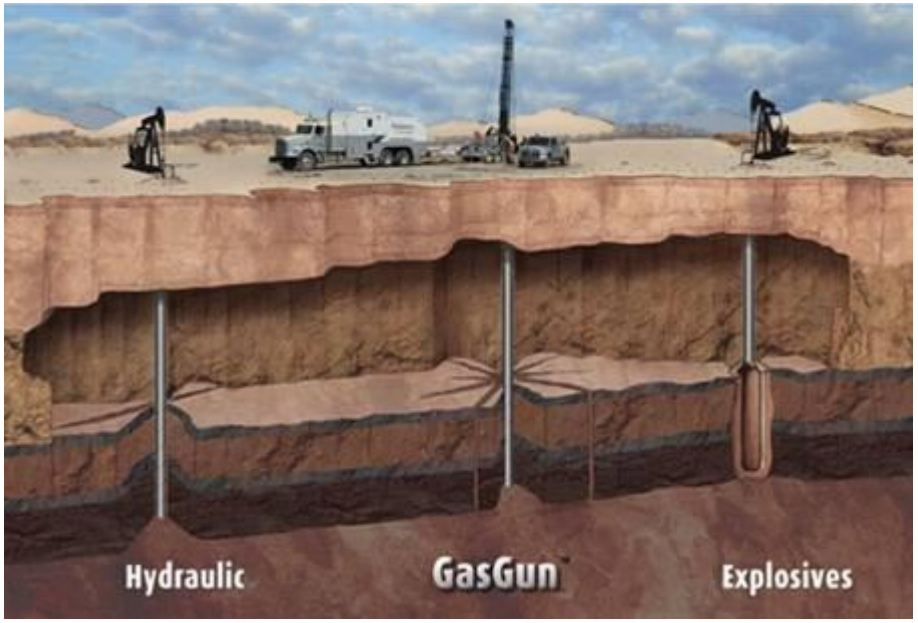


, GasGun with its many radial fractures connects more natural fractures to the well than does hydraulic fracturing.

Stimulation of naturally fractured reservoirs

How does the GasGun compare with hydraulic fracturing?





- *the GasGun is not replacement for large hydraulic fracturing*
- *large hydraulic fracture treatments can create a fracture hundreds, if not thousands, of feet in length*
- *but many small pay zones in depleted or low debit wells cannot justify the expense of these treatments*
- *the GasGun can be a very economical alternative and requires much less equipment for fielding*

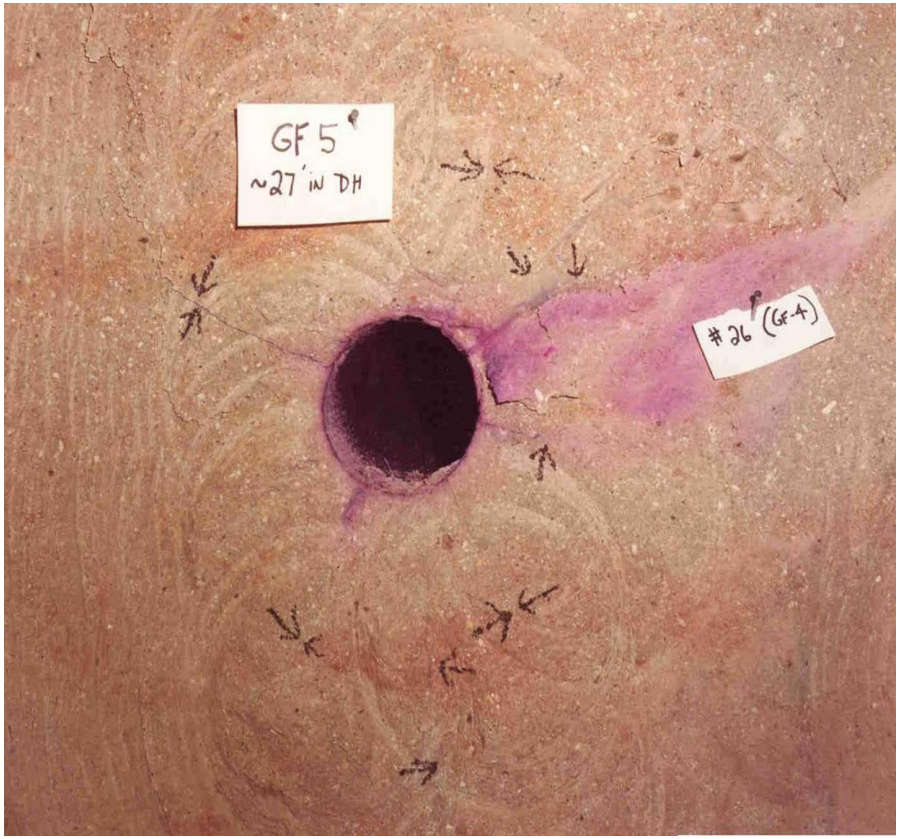
Advantages - GasGun vs. hydraulic fracturing

- *minimal vertical growth out of pay*
- *multiple fractures*
- *entire zone stimulated - no need to “ball off”*
- *minimal formation damage from incompatible fluids*
- *homogeneous permeability for injection wells*
- *minimal on-site equipment needed*
- *much lower cost*

Advantages - GasGun vs. other propellant tools

- *full-bore charge for maximum energy density and gas volume*
- *progressive burning for maximum fracture penetration*
- *lower peak pressures reduce peripheral damage*
- *better propping characteristics*
- *technology proven by independent research*

Advantages;GasGun vs. other propellant tools



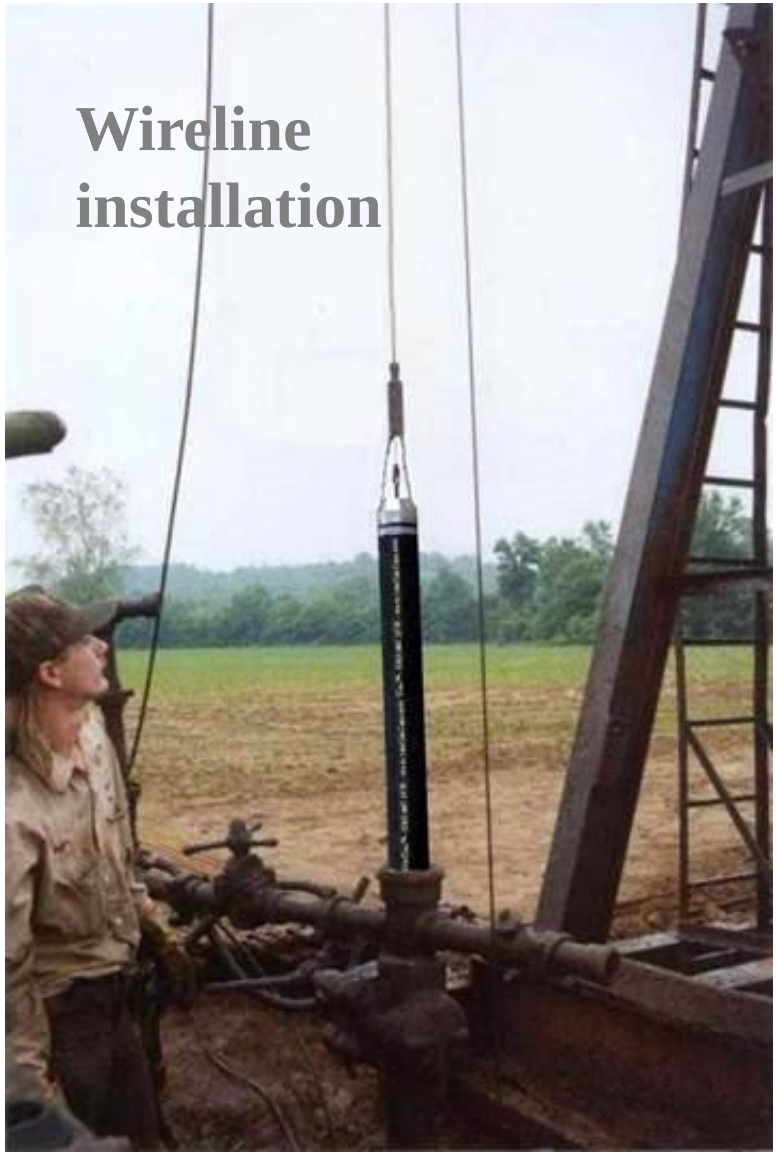
Progressive-GasGun

Regressive-other propellant tools

Study conduced by Sandia National Laboratories

GasGun-field operation

- Wireline conveyed
- Initiated with detonator - similar to perforating gun
- Cased or open hole
- Compatible with lubricator, CCL, sinker bar, etc.
- 100 to 5500 meter fluid tamp
- HSC GasGun is conveyed similar as casing gun
- Can be deployed using TCP technique



Field operation

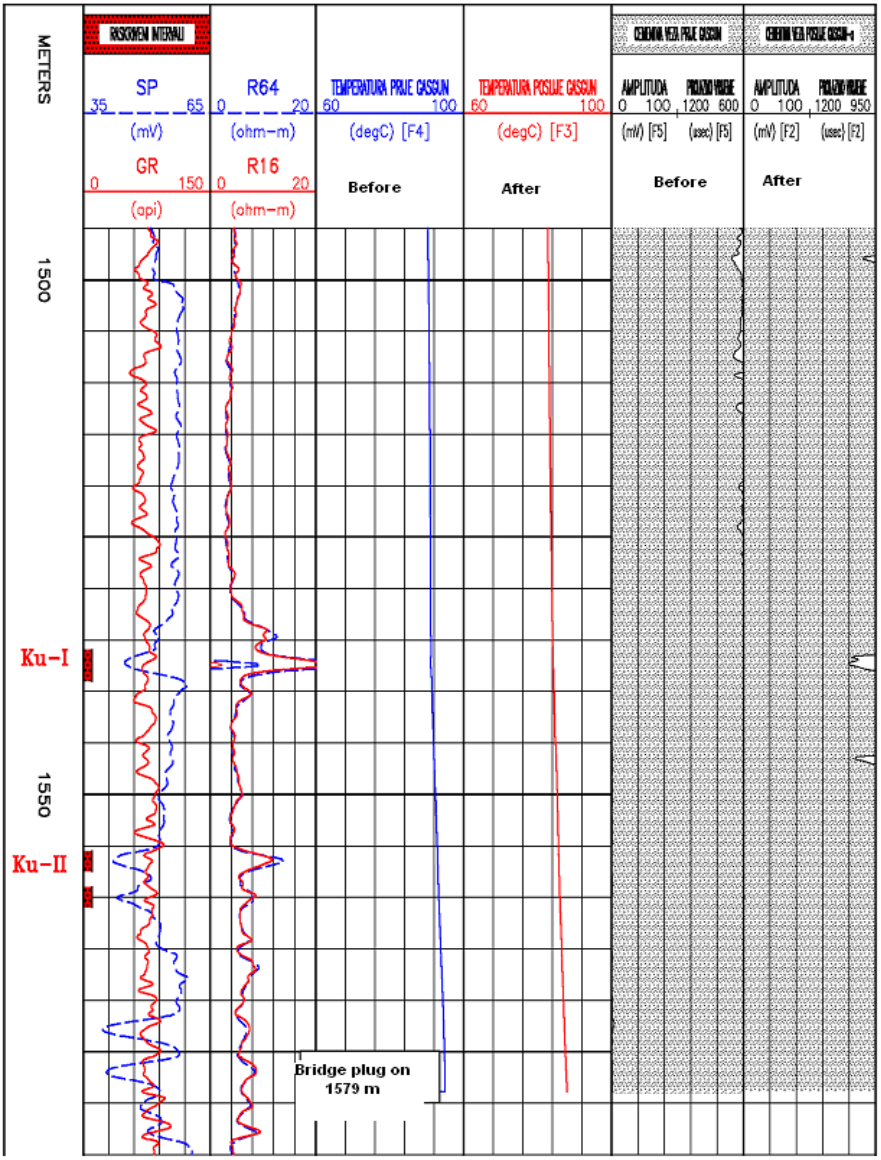
- *The fluid can be anything compatible with the formation such as fresh water, brine, oil, solvent.*
- *The tool is ignited while being suspended at the correct depth.*
- *Pressure control equipment, such as a lubricator, can be used when needed.*
- *Perforated casing must be of good quality and have perforation density at least 13 shots per m with a 12,7 mm entry hole diameter or 18 shots per foot with a 9,5 mm entry hole to allow sufficient area for the high pressure gas to exit the pipe.*

Gas Gun Tool-rubber cylinder or hollow steel carrier

Rubber canister tool

Hollow steel carrier tool-for enhanced pressure and temperature resistance

The analysis of detrimental effects of gas gun activation – cement bond quality

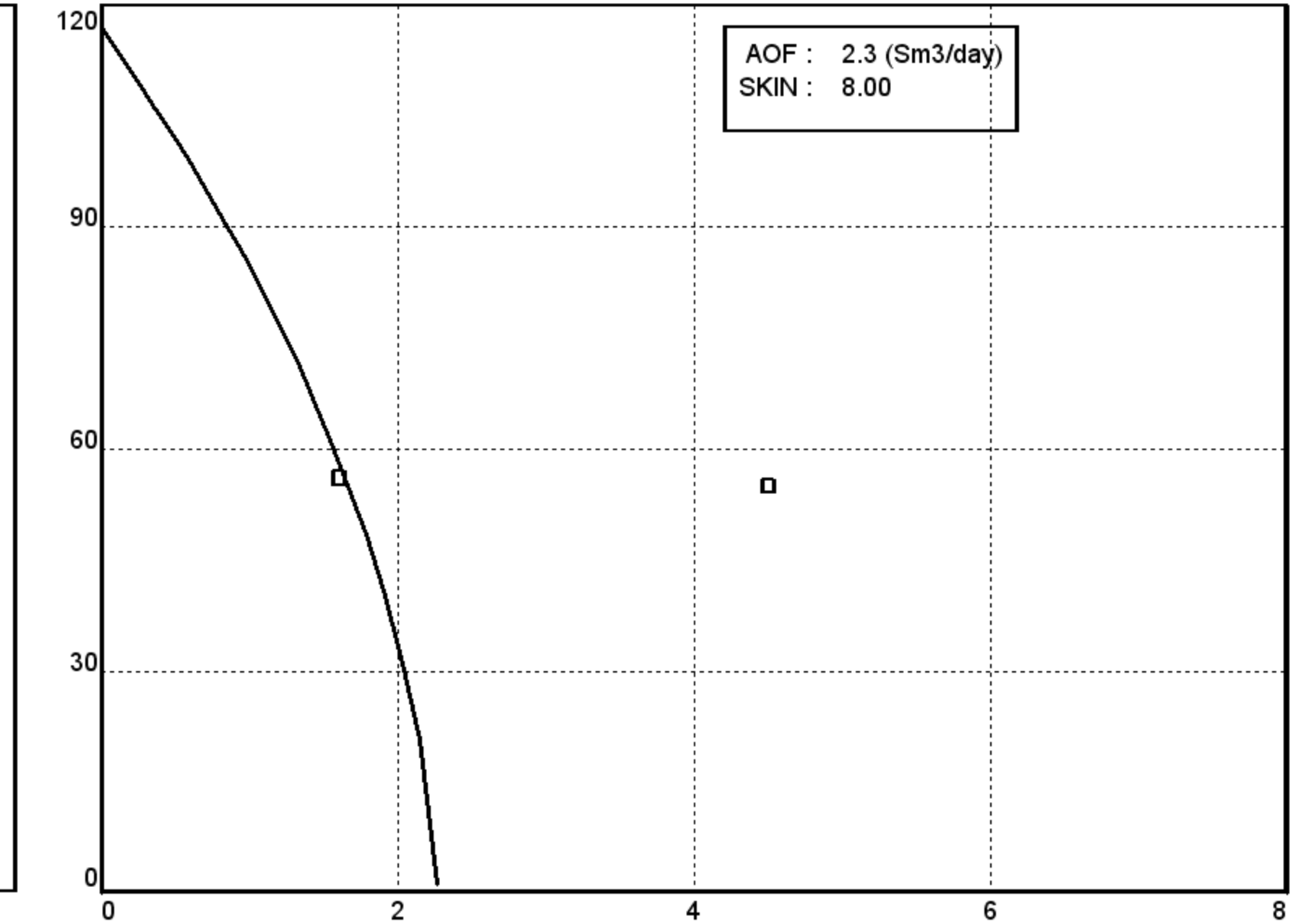


WELL Lip 173-Croatia

Job performed 20. 10. 2004.

- *CBL which had been performed after clearing run showed that there wasn't any sign of change regard to the logging before the stimulation job.*
- *It means that gas gun stimulation didn't cause any changes on cement bond quality*

IPR plot "Darcy (Lip-173 16 May 05 13:44)



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