



# Unconventional perforating for unconventional wells, reservoirs, and formations

## How new perforating technology is producing better wells and reducing surface equipment intensity

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Completing a horizontal well in virtually any of the U.S. shale plays can be an intensive, costly process. Well completions account for up to 60% of the overall well construction cost, including completion equipment, fracturing services, water, chemicals and sand<sup>1</sup>. A subset of the completion process is hydraulic fracturing. In what can be considered the most logistically complex operation conducted throughout the well construction process, a hydraulic fracturing job is a tightly orchestrated mix of equipment, personnel, and consumables—all designed to ensure that the well produces the maximum amount of hydrocarbons, extending profitable production far into the future.

These operations require a staggering amount of equipment. Unconventional shale wells have horizontal lengths that range from 10,000 feet to nearly 20,000 feet and will be completed with up to 100 or more individual stages<sup>2</sup>. Fracturing operations in West Texas routinely require more than 500,000 horsepower hours per well, and each well can consume 2,000 pounds of sand per lateral foot<sup>3</sup>. To top it off, each job requires blenders to mix sand and fluids, along with vast quantities of water, additives, and misc. commodities.

What if the scale of these operations could be reduced by up to 25% without compromising execution, results, and your return on investment (ROI)? What if the equipment on location didn't have to work as hard, extending life cycles and driving down repair and maintenance costs? What if downhole results improved dramatically, with higher-quality casing perforations for improved proppant flow and placement, a better defined and connected fracture network, and ultimately a more productive well?

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## THE ROLE OF PERFORATING

Perforation quality has a direct impact on the future and overall production of a well, its economic life, payout, and ultimately, the value of the field. Perforations create a connection between the formation and the production casing, and provide the path for fracture fluid and proppant to flow in and hydrocarbons to flow out.

Perforation quality can be measured in two ways: 1) the fracture network that is developed in the formation as a result of the perforation; and 2) the quality of the actual hole that is created in the production casing.

## UNDERSTANDING THE FORMATION

Formation fractures propagate along the path of least resistance. Stress in the vertical direction increases with depth, and in deep total vertical depth (TVD) zones like those found in the Permian Basin, overburden stress becomes significant. In horizontal wells (in the lateral section), perforating should occur in the direction of maximum stress (which is up/down) to achieve the best fracture initiation, propagation, and conductive path for hydrocarbon flow<sup>4</sup>.

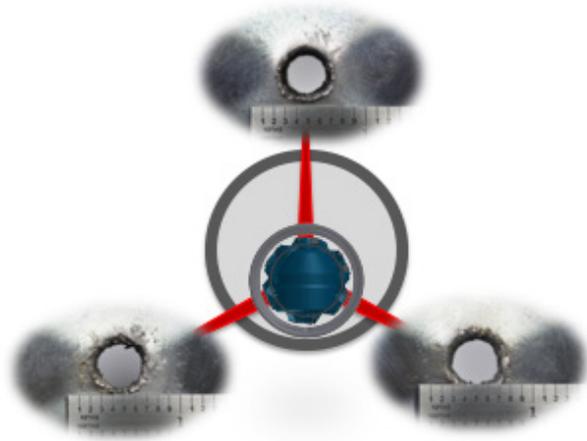
Wells produce best when formation fractures are transverse (perpendicular to the wellbore), beginning at the wellbore face and extending far into the formation. Tortuous fractures begin in a non-transverse direction and tend to re-orient along the maximum stress direction at some distance away from the wellbore. These types of fractures show an increase in average treating pressures, resulting in a greater chance of premature screenout during pumping operations and affecting the connectivity of the fracture network, which can potentially inhibit future production<sup>5</sup>.

## THE IMPORTANCE OF PERFORATION HOLE QUALITY

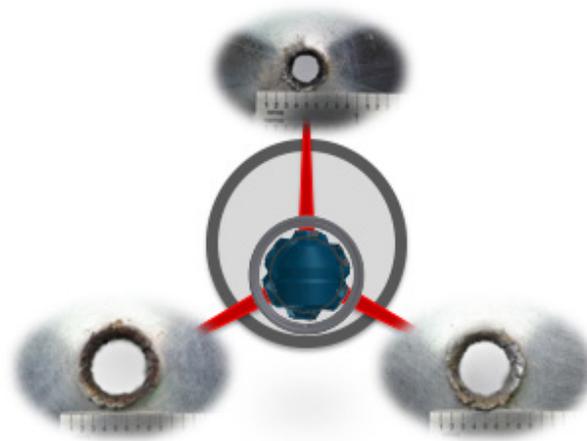
Perforating guns are equipped with multiple charges designed to create casing perforations that run the length of the fracture stage. Successful perforations are measured by the hole diameter, the depth of the perforation into the formation, and the degree of uniformity among the holes, referred to as entry-hole diameters (EHD). Perforation depth is important for increasing the effective wellbore radius and extending the production area into the formation, away from nearby wellbore formation damage resulting from the drilling operation<sup>6</sup>. A perforating job that produces uniform EHDs along the length of the fracture stage is most desirable and following Bernoulli's principle, results in an equal distribution of fracture treating pressures, stimulation fluids, and proppant.

Normally, EHD and uniformity are affected by the perforating gun's position in the casing. In horizontal wellbores, the gun will be positioned on the low side of the casing due to gravity, resulting in varying distances that a perforating charge must travel before it impacts the casing. Centralizing perforating guns is not always practical due to added cost, assembly time, and desired running speed to get to bottom. As a result, shots must travel through different amounts of wellbore fluid, reducing available energy to create perforations in the casing.

Charges directed to the low side of casing travel through minimal wellbore fluid, while charges directed to the high side must travel through more wellbore fluid before reaching the casing wall. This often results in inadequate access to the upper portion of the payzone and reduced production potential.



**Figure 1:**  
*DS Trinity with Fracture™*



**Figure 2:**  
*Conventional gun with conventional charges*

### CONNECTING THE FRACTURE NETWORK

Due to packaging constraints and small diameters, shots in perforating guns have traditionally been placed in a spiral pattern along the length of the gun body. Depending on the gun design, shots may be phased at 60, 90, or 120 degrees, with two or more inches between shots. By staggering the casing perforations, it can be more difficult for individual fractures to connect; thus, reducing the overall effectiveness of the fracture network.

Rock mechanics experts from Shell in combination with engineers from PetroChina recently published research through the American Rock Mechanics Association. Their modeling shows that if perforations were placed in a single plane instead of staggered along the length of the gun, the perforations would have the potential to link up radially and create a transverse fracture directly from the wellbore<sup>7</sup>.

This perforating pattern would drive two benefits: 1) reducing formation breakdown pressure; and 2) improving near-wellbore fracture geometry by reducing tortuosity in the fracture network. Further experimentation revealed that single-plane perforating could lower formation breakdown pressures by as much as 25%.

## NEW SYSTEMS - PROBLEMS SOLVED

As the industry better understands perforating challenges brought on by horizontal wells, solutions to improve perforating performance and increase overall well productivity is also growing. It is now widely believed that single-plane perforation geometry and equal EHD are two important factors in determining how a formation fractures and behaves.

Developed with this purpose in mind, tuned or fracture-optimized charges create uniform EHDs regardless of the perforating gun's position in the wellbore. These charges generate an engineered parallel-shaped jet that forms a hole in the casing that is uniform in size and shape regardless of gun orientation or position within the casing. They are designed to produce a minimum variation in hole size across large amounts of casing fluid and have been shown to lower the risk of nonproductive fracture clusters and stages. Comparative tests have shown that EHDs may vary as much as 40% with standard charges.

This variation can be reduced to approximately 5% or less using tuned charges. Uniform casing entry holes ensure each perforation within the stage achieves the designed treatment pressure, fluid flow, and proppant density. This creates the greatest certainty that fracture clusters will form as designed, optimizing well production. Newer perforating gun designs capitalize on the single-plane perforating research and are driving better-connected fracture networks. Due to limitations on radial space when orienting charges in a single plane, these guns require a smaller charge than conventional guns. Smaller charges sacrifice depth of penetration into the formation, but benefit from uniform EHDs using the fracture-optimized charges. Completion engineers are divided in preference between using charges that deliver the deepest perforation vs. single-plane perforating with its advantages in improving wellbore fracture geometry. This debate promises to be lively and should spark further research and modeling to prove out different theories.



**Figure 3:**  
3-1/2" DS Trinity perforating  
system

## EASIER ON FRAC EQUIPMENT

Single-plane perforating has been shown to reduce average treating pressures while performing fracturing operations by as much as 25%. An unintended positive outcome of this phenomenon is the affect it has on surface fracturing equipment. Reducing treating pressures can mean big savings by optimizing pumping capacity, lowering fuel costs, and reducing wear and tear. In formations where breakdown pressures exceed the design rating of available fracturing equipment, single-plane perforating can lower the risk of a failed fracture stage, reduce the need for additional perforations or sand jetting, and protect against premature screenouts.

## INNOVATION BY DYNAENERGETICS

Recently introduced by DynaEnergetics, the new DS Trinity™ perforating system offers three charges on a single plane using fracture-optimized charges in a compact design. The radially spaced charges are mounted on a gun body between 7 to 8 inches in length (depending on gun body diameter) and create uniform perforation and fracture geometry regardless of gun position in the wellbore. Its compatibility with DynaEnergetics FracTune™ fracture-optimized charges negates the effect of wellbore fluids when perforating, delivering uniform EHDs that allow equal treatment pressure for all perforations, and equal volumes of treating fluid and proppant to pass through.

The DS Trinity system is up to 3.5 times shorter than conventional perforating guns and produces more perforations per stage. Using this system can reduce the required height of rigup cranes and pressure control equipment, driving down well completion costs. Drawing on DynaEnergetics' proven DynaStage™ system, the modular design uses factory-assembled components, lean manufacturing processes, and stringent quality control to streamline wellsite activities and assure performance. Each system is rigorously inspected and function-tested before it is delivered to the customer, reducing rigup and testing time. To reduce HSE risks, the DS Trinity system uses an intrinsically safe plug-and-go detonator technology to eliminate the possibility of accidental detonation while arming.

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## SUMMARY

New methods and technologies are driving well productivity higher while reducing equipment wear and driving down costs. As engineers strive to better understand formation geomechanics and fracture geometries, perforating technology and methods are rapidly evolving. In response to rock mechanics research and modeling, DynaEnergetics has developed the DS Trinity perforating system. Overcoming challenges with gun design and packaging, the DynaEnergetics engineering team produced a unique perforating system that features three charges in a single plane. Single-plane geometry has been shown to reduce formation breakdown pressure and create a fracture network that is better connected for increased well productivity.

In addition, reducing formation breakdown pressure translates to efficiency gains in surface equipment utilized during the fracturing process. With breakdown pressures reduced by as much as 25%, surface equipment receives less wear and tear, and operators save on fuel and maintenance costs.

The DS Trinity system delivers a cost-effective, length-optimized perforating solution that gives operators greater flexibility in well design and completions. Their input and contribution to the development and successful deployment of this technology.

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