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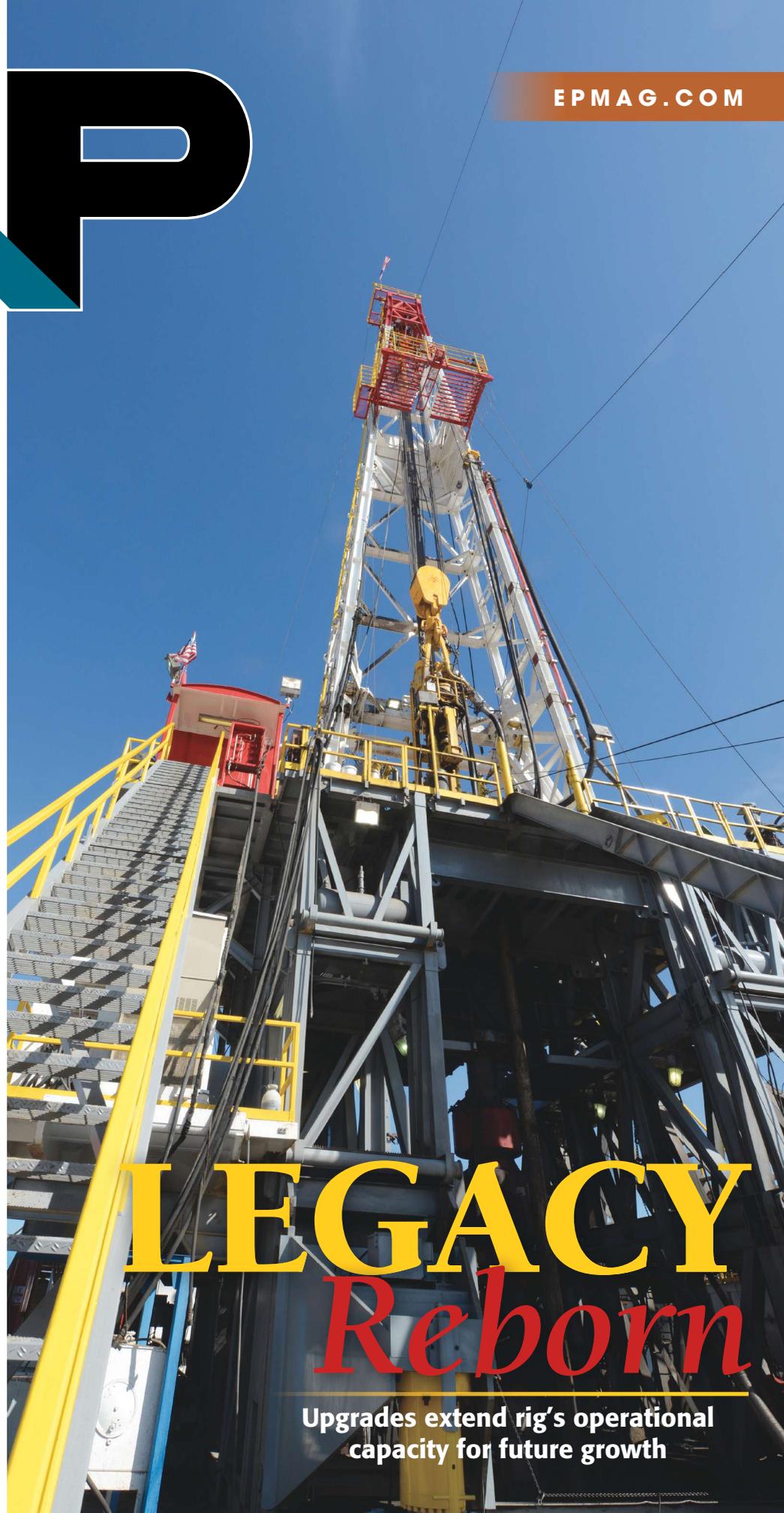
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# Alleviating firing system safety risks and costs

A fully assembled perforating gun system increases efficiency and safety.

**Thilo Scharf, DynaEnergetics**

**T**he need to streamline perforating operations while alleviating the risk of misfires, assembly and downhole time, labor and maintenance costs is a key component to hydraulic fracturing operations, particularly when completing long horizontal wellbores in unconventional shale plays. DynaEnergetics' DynaStage perforating system incorporates technology in the addressable firing system and an improved mechanical design to help improve overall plug-and-perf (PNP) operations. It optimizes perforating operations with fully assembled and ready-to-shoot gun modules delivered to the base or well site.

The fully disposable, maintenance-free system is made more robust by eliminating traditional approaches to selective perforating, detonators, gun hardware and accessory equipment and, with its additional safety features, allows other wellsite operations to run in conjunction with the perforation process.

## System features

The system includes intrinsically safe, integrated switch-detonators, preassembled guns with shaped charges and a composite plug, a firing panel, and a surface tester. Commercialized in 2016, the DynaStage system has targeted two areas to improve efficiency and reduce costs.

The first is safety, for which the system has a simple design that eliminates the risk of inadvertent detonation from stray current or voltage. Surface explosive handling and arming can be conducted in less time and in conjunction with other operations. The design eliminates the need to hold the gun system at shallow subsurface depth during simultaneous operations. Both factors reduce wait times at the well site.

The second targeted area is reliability. The design of the electronic system and simplification of the mechanical field assembly process help to reduce the number of misruns, which increases efficiency and lowers the cost of completions.

## Improved assembly at surface

During the assembly of conventional perforating systems, including mechanical component assembly, arming the system and connecting the gun string to the wireline, there is a risk that resistorized detonators can be initiated with radio frequency energy, stray current or stray voltage on the surface. These traditional detonators can contribute to an increased risk of injury and destruction when connecting the detonator to the gun string and wireline truck.

Safety procedures have been developed to address these risks, and the American Petroleum Institute provides guidelines for safe handling of explosives through Recommended Practice 67. When a traditional gun string with a resistorized detonator is used, all surface operations, including hydraulic fracturing, radio communications, cellphone communications and other well-site activities, are suspended at the start of a perforating run until the gun string is at least 61 m (200 ft) into the well. Operations must be halted again after perforation when the gun is raised to within 61 m of the surface.

The DynaStage system's integrated switch-detonator design replaces all wiring and crimping to eliminate human error and significantly reduces the risk of inadvertent ignition or detonation. Arming a gun is as efficient, safe and reliable as placing a battery in a flashlight. True intrinsically safe microprocessor switch-detonators require no wiring, so they achieve measurably higher reliability than standard separate switch-detonator combinations and are immune to potential hazards that can impact standard selective perforating equipment in use today.

The integrated switch-detonators will either stay safe and operational or fail-safe should any external differential potential occur. They may be damaged by excessive stray current or voltage, but they cannot be initiated except through digitally coded signals sent by the surface firing panel.

Surface test equipment detects any malfunctions before running in hole, and the software allows continuous monitoring of all downhole components until initiation and in between shots. All wellsite operations can continue without interruption, and full selectivity, communication

to all detonators, stage-skipping and gun redundancy are enabled for the most complex completions. Gun length, shot phasing, shot density and charge type are fully customizable with injection-molded gun parts that do not create unwanted debris after perforation.

System features, including the plug-and-go-style detonator and single-use connector subs, minimize assembly time. The time required for changeover from a used assembly to the connection of a new gun system is less than 10 minutes from rigdown to rigup. The DynaEnergetics detonator technology has successfully communicated and initiated on command during more than 500,000 perforating operations without a safety incident.



**The DynaStage system helps wireline companies and operators streamline perforating operations while reducing assembly time maintenance and risk of misfire. (Source: DynaEnergetics)**

### Improved downhole reliability

The system is intended to virtually eliminate misruns by aiming to achieve a 99.9% operating efficiency (one misrun per 1,000 runs). To achieve this goal, the mechanical and electrical assembly of the gun system was redesigned, including changing the way the detonator is assembled within the system. A traditional detonator is assembled into the perforating gun connector sub requiring wiring connections and a port plug with O-ring seals. Wiring connection issues and leaking O-rings are among the most common causes of perforating gun misruns.

With the DynaStage detonator, the wires have been removed and replaced with an injection-molded connector, eliminating crimped wire connections and the associated risks of wiring damage and poor electrical connections. The detonator also was relocated to the gun body, from the tandem arming sub, which allows the use of a much shorter, disposable perforating gun connector sub and eliminates the port plug.

The gun is shipped to the wireline customer fully assembled, except for the detonator. All preshipping assembly operations are performed in the DynaEnergetics gun assembly line, which has been optimized for high-volume assembly, automated inspection and electrical verification of the assembled product. The production line process mitigates the risk of human error typical in the manual redress, cleaning, wiring and assembly of conventional perforating guns. Field assembly only requires inserting the plug-and-go detonator and threading the guns together.

### Success in the field

Since the commercial launch, 500,000 guns have been fired. The production success rate has been one misrun

per 420 runs for a perforating efficiency of 99.41%. DynaEnergetics continues to refine the system components, assembly process and operating procedures with the objective of attaining the 99.9% efficiency rate.

Each perforating stage run with the system reduced completion time by an average of 32 minutes, compared with a conventional system, as a result of the efficiency of surface-level transitions from gun to gun and well to well. Improved downhole reliability also was achieved, with an average decrease in nonproductive time of 2 hours per 100 runs. A significant part of the improved reliability was a reduced need for onsite user interactions that often lead to electrical issues and misruns in conventional wired perforating systems.

The use of the perforating system resulted in fewer days on location and operator cost savings as high as six figures. A Permian Basin operator who used the commercialized DynaStage system has incorporated it into the company's normal completion program.

### Conclusion

The DynaStage system leverages component-level features and a system design approach to produce a perforating system that eliminates many of the causes for misruns, increases simplicity and safety of operations, and delivers higher well productivity. Operators and wireline service companies can optimize their operations with this PNP system because risk and costs are significantly reduced. Multiple perforating and hydraulic fracturing wellsite operations can occur without interruption, and full selectivity, stage-skipping and gun redundancy are enabled to ensure every stage and perforating cluster can be stimulated. **ESP**