



# Multistage Stimulation

Efficiency at every stage

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Schlumberger multistage stimulation systems are designed to stimulate multiple stages efficiently and effectively. These systems—cemented and uncemented—can be used in vertical, deviated, and horizontal wells.

## **Minimize risk**

Schlumberger ensures that effective isolation and contact are achieved as part of a consistent, predictable process. By making sure that stimulation operations proceed efficiently as planned, we help limit the risks inherent in multistage stimulation operations.

All of the products we design and manufacture are subject to a rigorous testing process to ensure repeatable performance downhole. Our products' high level of reliability helps minimize risks to people, the environment, and the reservoir.

## **Increase operational efficiency**

Our portfolio helps you increase efficiency across your operations, saving you time and money. We can reduce or eliminate interventions, optimize the placement of perforation clusters, and minimize the amount

of fracturing fluid required, all to give you more recovery with less waste.

To ensure that we minimize rig time, we provide experienced, knowledgeable people on site and in the office during the planning and execution phases of fracturing operations and during any required interventions.

## **Maximize productivity**

Schlumberger understands that the economic success of wells in unconventional reservoirs depends on the effectiveness of the fracturing treatment. Our engineering services help determine optimal spacing between stages, and our wide choice of systems provides the flexibility to target multiple reservoir sections in sequence. The result is effective fractures with the maximum possible contact.

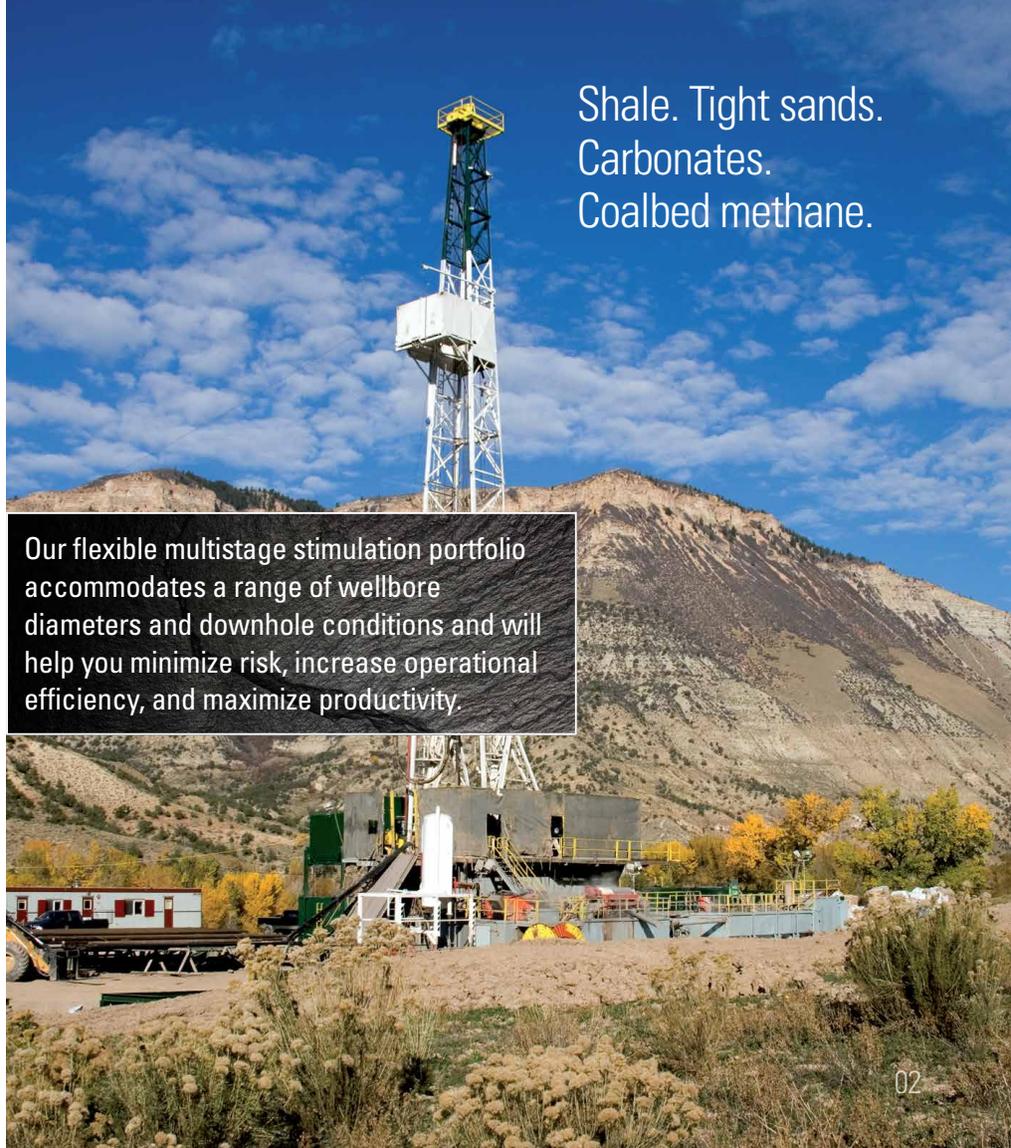
To help you achieve the full production

potential of every well, we also provide a local point of contact to advise on reservoir-specific applications, provide rapid response at the wellsite, and link you to Schlumberger's global experts.



*Falcon\* uncemented multistage stimulation system with ELEMENTAL\* degradable technology frac ball.*

Shale. Tight sands.  
Carbonates.  
Coalbed methane.



Our flexible multistage stimulation portfolio accommodates a range of wellbore diameters and downhole conditions and will help you minimize risk, increase operational efficiency, and maximize productivity.

# Plug-and-Perf Systems

## Copperhead

### Drillable bridge and frac plugs

The Copperhead\* drillable bridge and frac plug and Copperhead Extreme\* drillable bridge and frac plugs are used to isolate stages during multistage stimulation operations in HPHT environments.

- Eliminate presetting and withstand multiple pressure reversals to reduce rig time and costs
- Allow drillout into small, consistently sized cuttings that can be circulated out of the well
- Have external threading at top of plug and internal threading inside base that screw into place and lock to prevent rotational spinning during milling

## Copperhead Big Bore

### Flow-through frac plug

The Copperhead Big Bore\* flow-through frac plug allows fluid to flow freely from below the plug after stimulation and features a high-strength ELEMENTAL degradable ball.

- Minimizes risk and cost of intervention using ELEMENTAL degradable balls

- Reduces completion costs by eliminating the need for coiled tubing
- Eliminates milling interventions in the wellbore after a fracturing job

## Diamondback

### Composite drillable frac plug

The Diamondback\* plug isolates stages during stimulation operations and can be set using wireline, coiled tubing (CT), or jointed pipe.

- Is made of composite material and has special taper design at end of plug that prevents spinning during millout, reducing millout time
- Allows plug to be drilled out quickly into small cuttings and easily circulated out of the well

## Diamondback PT

### Premium torque composite drillable frac plug

The Diamondback PT\* premium torque composite drillable frac plug is designed to isolate zones in vertical, deviated, and horizontal wells.

- Prevents presetting with rigid slips and internal shear ring
- Transmits torque and prevents spinning through antirotation features

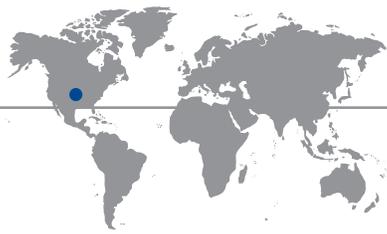
## KickStart

### Rupture disc valve

The KickStart\* rupture disc valve eliminates the need for mechanical intervention to fracture-stimulate the first stage of a plug-and-perf operation and can also be used with the nZone\* multistage fracturing system for cemented applications and nZone ball drop systems.

- Is deployed as a stand-alone tool at the toe of the well for the first-stage stimulation
- Enhances efficiency without intervention or changes to cementing procedures
- Reduces fracture initiation pressures and tortuosity with helical slots, resulting in less hydraulic horse power (HPP) required





### Diamondback Plugs Run In and Mill Out More Than Twice as Fast as Competitor's Plugs

#### Operator seeks best frac plug for multi-zone wells

An operator in Oklahoma had two multizone cased hole wells to fracture in a Woodford Shale field. One well had 11 fracture stages being isolated with 10 of a competitor's composite plug. The second well had 9 fracture stages being isolated with 8 plugs. Because of the Diamondback composite drillable plug's excellent track record, the operator selected it for the second well. Because of the similarities in the two completions, the operator took the opportunity to compare the plugs and decide which one to use in future wells.

The Diamondback plug isolates stages during stimulation operations and can be set using wireline, CT, or jointed pipe. A one-way internal check valve is closed when a ball is dropped from the surface while the zone above the plug is being fractured. Fluids from below the plug, however, can flow freely through it. At the time, Schlumberger had run more than 160

Diamondback plugs since their introduction the previous year, and none had set prematurely. Moreover, for those 160, the average millout time was only 18 minutes, compared with the industry average of 30 minutes.

#### Schlumberger plugs run in and mill out faster than competitor's plug

The competitor's plugs were run in at about 150 ft/min in the horizontal section and 200 ft/min in the vertical section, with an average time of 50 minutes per plug. The 10 competitor plugs set properly and at the desired depths, though one encountered sand at a curve and took more than 90 minutes to release from the wireline setting tool. Millout times of the 10 plugs ranged from 24 to 246 minutes, an average of 85 minutes.

The Diamondback plug's antipreset feature allowed average run-in speeds of 250 ft/min in the horizontal section and a much faster 450 ft/min in the vertical section—twice as fast as

the competitor plugs in the vertical section. The average run-in time per plug was 24 minutes—less than half that of the competitor's.

The Diamondback plug's design and composite material promoted break-up during millout, resulting in smaller, more easily washed-out fragments compared with the competitor's weaved composite plug. Millout time improved dramatically over the competitor's, with times ranging from 13 to 65 minutes, an average of 26.5 minutes—more than three times faster than the competitor plug.

### **Operator selects Diamondback plug for future fracture operations**

Because of the overall savings in time and associated costs and the plug's reliability, the operator selected Diamondback plugs for all of its future fracture operations.



# Dissolvable Plug-and-Perf Systems

## Infinity

### **Dissolvable plug-and-perf system**

The Infinity\* dissolvable plug-and-perf system is a fullbore intervention-less multistage stimulation system that uses degradable seats instead of plugs to isolate zones.

- Eliminates the need for milling out
- Fractures at higher pressures and longer intervals with high-strength, impact-resistant ELEMENTAL degradable technology

## Broadband Sequence

### **Fracturing service**

The BroadBand Sequence\* fracturing service improves well production through the engineered stimulation of zones with increasing fracture initiation pressure.

- Increases efficiency through fewer interventions and reduced NPT
- Stimulates zones using a composite fluid with a proprietary blend of degradable fibers and multimodal particles



# Continuous Pumping Stimulation

## Falcon

### Uncemented multistage stimulation system

The Falcon system uses either hydraulically set mechanical packers or swellable packers to isolate fracture stages during multistage stimulation treatments and production operations in horizontal, deviated, and vertical wells.

- Allows numerous stages to be fractured continuously
- Achieves greater pressure differentials and ball flowback with curved ball seats
- Has engineered delay mechanism that eliminates need for external delay coatings on swell packers
- Has drillable seats and balls for fullbore access and increased production output
- Brings wells into production faster and more efficiently than do conventional plug-and-perf techniques
- Minimizes operation time, costs, and risks
- Eliminates need for interventions

## nZone Ball Drop

### Multistage stimulation system

The nZone ball drop system is designed to complete up to seven stages in horizontal, deviated, and vertical wells without intervention.

- Improves flowback with no concerns about plug debris
- Reduces downtime between fracture stages

## Elemental

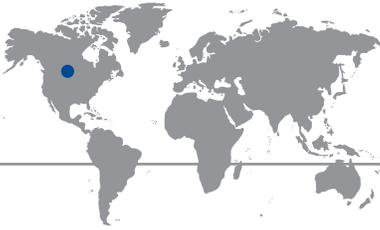
### Degradable technology

ELEMENTAL degradable technology frac balls are designed for cemented and uncemented wells.

- Degrades predictably and fully at bottomhole conditions without the need for chemical additives
- Eliminates the need for interventions to remove frac balls



## Case Studies



### Frac Balls Made with ELEMENTAL Degradable Technology Dissolve in Low-Temperature Wells

#### **Conventional frac balls can fracture, jam, and fail to flow back**

Journey Energy planned to hydraulically fracture seven openhole monobore oil wells, each having from 12 to 25 stages, in the Cardium shale formation in Alberta, Canada. The oil was located in a shallow reservoir surrounded by thick layers of tight shale.

Conventional multistage stimulation involves placing a completion string in the open hole with a series of ball-actuated stages isolated by hydraulically set packers. Composite or other nondegradable frac balls are then pumped from the surface to isolate and selectively access individual zones. When all the stages have been treated, the balls are flushed back to surface to allow production to begin.

With nondegradable balls, production can become obstructed if even one ball deforms

or fractures during treatment because of the increased hydraulic pressure or fails to flow back because of low reservoir pressure. A ball can also become jammed on its seat and choke back production from all treated stages below. These problems require a workover rig to be brought onsite so that the balls and seats can be milled out, adding time, costs, and risks to the project. Moreover, reservoir conditions that can hinder production can also exhibit production profiles similar to that of stuck frac balls, complicating any decision to mill out the balls. Journey Energy wanted to avoid these risks and ensure that production reached its full potential.

#### **Degradable frac balls allow unobstructed production**

Journey Energy opted to use Schlumberger frac balls made using ELEMENTAL degradable technology, together with the Falcon multistage stimulation system for uncemented wells. The

patented aluminum-based alloy is designed to hold its shape during stimulation and then degrade predictably within hours or days after making contact with a well fluid, even in low-temperature formations, which can slow degradation beyond the available time.

The frac ball does not have to degrade completely before flowing back because once its outer diameter is smaller than the seat's inner diameter, the ball passes through to the bottom, where it continues to degrade until it disappears. With a compressive strength comparable to that of mild steel, the balls can withstand differential well pressures up to 10,000 psi [69 MPa] and temperatures up to 300 degF [150 degC] without fracturing or deforming, and they degrade predictably in low bottomhole temperatures. Frac balls made with ELEMENTAL degradable technology never jam or get stuck, so they never need to

be milled, they never restrict the flow path, and they never cause production to be delayed or lost after fracturing. Since their introduction in 2012, these degradable frac balls have been run successfully in more than 500 stimulation stages and have degraded predictably in a wide variety of well depths, temperatures, pressures, and fluids.

### **Eliminating risk of stuck frac balls ensured full production potential**

After the balls were launched and seated, job plots demonstrated clear pressure signatures, indicating that the frac balls had successfully isolated each stage. Further analysis of the differing pressure profiles throughout the stimulation confirmed that each stage remained isolated from the others for the duration of the treatment. The alloy balls performed as expected in the low-temperature wells, successfully isolating and activating

individual zones during stimulation and then degrading predictably and completely after stimulation, all within the time planned and to the pressures and flow rates required. As a result, Journey Energy was assured that the seven wells were producing at their full potential.



# Multistage Stimulation Systems

## Complementary Products and Services

### HiWAY

#### Flow-channel fracturing technique

The HiWAY\* flow-channel fracturing technique removes the link between hydrocarbon flow and proppant conductivity, creating flow channels that result in infinite fracture conductivity.

- Improves production with greater effective contact area
- Reduces well completion time and cost, as well as artificial lift requirement
- Lowers risk of screenout

### MaxCO<sub>3</sub>

#### Degradable diversion acid system

MaxCO<sub>3</sub>\* degradable diversion acid system ensures that the largest possible area of the reservoir is exposed to stimulation fluid, delivering effective diversion that is temporary and nondamaging to the reservoir.

- Eliminates risk of costly cleanout intervention by degrading completely
- Ensures superior zonal coverage by targeting permeability contrasts
- Reduces treatment volume and cleanup time

### Milling Services

Schlumberger offers a range of tools, fluids, and techniques, along with expertise, that enable the efficient removal of packers, plugs, and other downhole obstructions.

- Increases flexibility with a choice of tool sizes and configurations
- Reduces number of separate trips using reliable, high-efficiency tools

### PerfFRAC

#### Selective perforating, fracturing, and stage isolation with ball sealers

The PerfFRAC\* technique offers an efficient way to maximize reservoir contact by enabling individual zones to be selectively perforated, fractured, and stage-isolated in the same run.

- Minimizes time and costs by enabling multiple operations per run
- Reduces interventions by isolating zones without bridge plugs



## StimMORE

### Fiber-laden diversion fluid

The StimMORE\* fiber-laden diversion fluid represents a dynamic, cost-efficient, and operationally simple method of achieving effective fracture diversion in multistage environments.

- Maximizes reservoir contact
- Optimizes treatment volume and reduces completion costs

## Perforating Gun Systems

Schlumberger has developed a wide variety of perforating gun systems, shaped charges, and accessories to meet the diverse technical challenges of stimulating vertical and horizontal wells.

- Ensures optimal performance through in-house design, manufacture, and testing
- Offers versatility in conveyance options

## Case Studies



### BroadBand Sequence Technique Increases Productivity Index More Than 600% in Refractured Shale Well

#### **Suboptimal well production in the Eagle Ford Shale**

Operating in the Eagle Ford Shale, Pioneer Natural Resources has been working with Schlumberger to improve production from horizontal shale wells. New wells are completed in high-pressure, high-temperature (HPHT) areas with fracturing gradients of 0.85–0.95 psi/ft, TVDs of 12,000–13,500 ft, and bottomhole temperatures ranging from 300 to 345 degF. Typical completions are based on the plug-and-perf technique, with four to eight perforation clusters per interval isolated by bridge plugs.

An area of recent interest for the operator is the restimulation of old wells. The operator sought to accelerate and increase the estimated ultimate recovery (EUR) of oil and gas by reestablishing conductivity in old hydraulic fractures and stimulating new reservoir volume. This endeavor is gaining significant traction across

the industry because the number of candidates for refracturing is increasing rapidly as the shale plays continue to age.

A key challenge for refracturing operations is effective stimulation along the length of the wells (4,000–6,000 ft). Since all perforations are open, mechanical aids such as bridge plugs cannot be used.

#### **Effective solution through sequenced fracturing technique**

Pioneer Natural Resources decided to address these challenges with the BroadBand Sequence fracturing technique. The BroadBand Sequence technique is a key enabler for refracturing operations since it delivers temporary isolation of clusters through engineered application of a proprietary, fully degradable composite fluid comprising a blend of degradable particles and fibers.

The candidate well, originally one of the field's best oil producers, had been stimulated two years earlier with multiple fracturing stages. The refracturing operation included 13 fracturing stages, which were completed using an identical amount of proppant from the first stimulation campaign as well as the HiWAY\* flow-channel fracturing technique. Composite pills were pumped between fracturing stages to enable temporary isolation of previously stimulated clusters. A shut-in was applied after placing each composite pill to monitor changes in fracturing gradient.

All 13 refracturing stages were pumped sequentially in 36 hours and without use of mechanical aids such as bridge plugs or inflatable packers.

Initial shut-in pressure (ISIP) measurements captured at the end of each stage showed

progressive increase toward values that are characteristic of previously untreated rock in the area. These features demonstrate the ability of the BroadBand Sequence technique to reinvigorate and isolate depleted areas while enabling stimulation of undepleted areas of the lateral.

#### **PI increase of more than 600%**

After refracturing, the well was put in production using a smaller choke (8/64 in) than the one used prior to restimulation (10/64 in). Results over the first 45 days after restimulation show that, despite the increased restriction, oil and gas production rates doubled while tubing pressure increased fourfold. In addition, the well continues to retrieve fracturing fluid at a rate of 100 bbl/d, which means that the total fluid rate increased threefold.

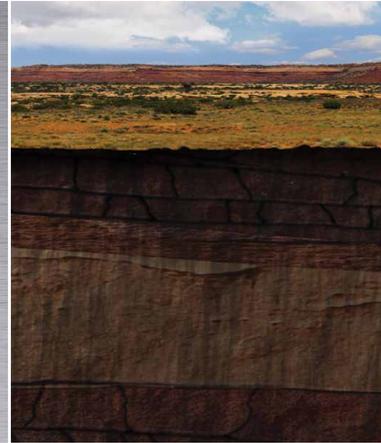
Calculations for the well's productivity index

(PI), which take into account both rates and pressures to normalize production, indicate an increase in PI of more than 600% after the restimulation operation. These outstanding results demonstrate the effectiveness of the BroadBand Sequence fracturing technique to boost oil and gas production from depleted horizontal shale wells.

# Multistage Stimulation

Efficiency at every stage

Schlumberger is committed to leading the industry in innovative approaches to stimulating reservoirs. Our goals are to reduce the costs of your entire drilling and completion process and to maximize recovery by providing products that are simple, flexible, efficient, and reliable.



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