Productivity Enhancement Research Facility (PERF)
The Productivity Enhancement Research Facility (PERF) is the most technologically advanced perforating system laboratory in the industry.
The scientists, engineers, and technicians staffing PERF draw upon a global network of perforating domain expertise with extensive regional knowledge to deliver customized production optimization strategies specific to your reservoir.

The facility is equipped with state-of-the-art testing technologies for superior research, modeling, and simulation. We provide indispensable insight into your well’s reservoir-to-wellbore connection in a laboratory environment prior to field deployment. The resulting fit-for-purpose perforating strategies and shaped charges deliver efficiency, reliability, and enhanced safety over the life of your reservoir.

Schlumberger introduced the industry’s first perforating flow laboratory in 1953. Then as now, operators require the best-possible reservoir-to-well connection, with reduced risk and uncertainty. Today’s understanding of perforating system performance at downhole conditions comes largely from the extensive body of test programs pioneered at our perforating flow laboratory.

Determining the best shaped charges and perforation strategy for your reservoir empowers the production planning process over the life of your well.
To optimize your production assets, you first need to understand your reservoir. We design experiments to match your specific downhole conditions and interpret the results to predict field performance. PERF builds on six decades of active research to control, measure, and diagnose the most critical aspects of the interactions between the perforating system, the wellbore, and the reservoir.

**Backed by integrated perforation research**
- Colocated with the Schlumberger perforating research team
- Analysis of experimental results using comprehensive theoretical and numerical models
- Direct access to the industry’s most advanced understanding of perforating systems and reservoir interactions

The integrated workflow implemented at PERF ensures that the performance of your reservoir is the focus of each stage of perforation design, testing, and validation.
**Reservoir-to-wellbore connection**
Using core samples from your reservoir—or a comparable rock sample—we determine directly how your reservoir will perform when perforated, replicating field well-pressure dynamics.

- **Natural completions**: Confirm perforation skin and productivity.
- **Unconventional resources**: Optimize perforating strategy for hydraulic fracturing.
- **Heterogeneous formations**: Customize perforating for maximum reservoir contact.
- **Sand-prone formations**: Ensure sand-free production for the life of your well.
- **Hostile deepwater environments**: Evaluate perforating techniques for reliable well performance requiring minimal intervention.

*Laboratory test results are used to optimize your stimulation treatment or reservoir-drive injector with the charge, fluid, and perforating gun design answers that testing just in concrete cannot.*
Performance Evaluation to Optimize Your Operations

Simulating reservoir response and reservoir-to-wellbore interactions gives you a deeper understanding of expected perforating system performance.

**Match critical shot-time conditions**
- Understand wellbore dynamics for perforation cleanup.
- Establish pore fluid and core boundary conditions.

**Match flow regime**
- Determine fluid and field rates.
- Assess flow efficiency (well skin, productivity index).
- Evaluate sanding propensity over life of well (depletion stress, water cut).

*The advanced diagnostic techniques used at PERF deliver test results that enable you to see the path reservoir fluids take as they travel toward perforations, enabling you to further optimize your perforation strategy for maximum return on investment.*
Investigate wellbore fluid and reservoir interactions using full-size core samples
- Stimulation (acidizing)
- Sand consolidation treatments
- Well control (nondamaging control fluids while perforating)

From low-rate oil to high-rate gas, and everything in between
- Simulate production flow of oil or gas at realistic downhole rates for accurate system performance validation.
- Investigate water cut to understand how your reservoir responds to a spectrum of fluids and flow rates.
- Employ PERF’s continuous gas delivery system to simulate a wide range of gas flow rates.
- Simulate depletion stress, flow, and water cut to see if sanding might be a concern later in your well’s life.

The continuous gas delivery system at PERF simulates gas flow rates up to 300 MMcf/d.
**Downhole simulation vessels**
- Perforate real rock (core from your reservoir or analog outcrop) at downhole stress conditions.
- Replicate field well pressure dynamics.
- Measure perforation flow efficiency and expected well skin in the field.
- Obtain comparable results qualified to API RP 19B Section II and Section IV.

The simulation of your reservoir’s performance in a laboratory setting is at the center of every test program conducted in PERF. We start by modeling the field perforating operation, then use this model to design your specific laboratory test program. The test results are translated back to your reservoir in the context of your specific objectives.
Industry’s Largest Polyaxial Stress Frame for Testing Perforating Systems, 3D Reservoir Inflow, and Hydraulic Fracturing

- Shoot a full perforating system in the industry’s largest polyaxial stress frame.
- Investigate realistic 3D inflow and perforation-to-perforation interactions to better understand field well performance.
- Realistically simulate the downhole stress field with three independent stresses to progress beyond perforating for studying hydraulic fracture initiation.

A 3D reconstruction reveals inflow and perforation behavior after shooting a full perforating system in PERI’s polyaxial stress frame.

The industry’s largest polyaxial stress frame makes it possible to test perforating systems from charge detonation through flowback and measure flow under realistic well conditions, including the stress field specific to your well for wellbore, pore, and vertical and horizontal stresses.
Engineered perforating system boosts productivity across 6,200 ft in offshore HPHT gas condensate wells

Case Studies

Formation damage limits production in hostile environment
An operator producing in an HPHT gas condensate field in the North Sea wanted to optimize well deliverability via an engineered perforating strategy. Existing high-temperature shaped charge technologies, however, have historically been unreliable in adequately bypassing drilling-induced damage.

The ideal approach would achieve reservoir contact, perforate long intervals, sufficiently bypass formation damage, and improve productivity index (PI) while remaining within strict safety and barrier requirements and minimizing skin.

The operator collaborated with Schlumberger at the Productivity Enhancement Research Facility (PERF) to develop and customize a solution that would meet the productivity objectives without compromising safety standards.

Customized perforating system bypasses damage
Focus was placed on enhancing penetration as well as optimizing wellbore dynamics by using underbalance to ensure clean perforations. SPAN Rock* stressed-rock perforating analysis was used to calculate setup pressures for optimal cleanup and to predict expected shock loads on the bottomhole assembly and coiled tubing.

Evaluating the results of SPAN Rock analysis also determined that PowerJet Nova* HNS shaped charges would bypass the drilling damage. These high-temperature-rated charges improve penetration in stressed rock by 25% compared with previous-generation charges and provide up to 50% more formation contact.

High-speed pressure gauges positioned below the guns recovered downhole pressure data from each perforation run; results confirmed that SPAN Rock analysis accurately simulated the actual dynamic underbalance that was achieved at the perforations.

*PowerJet Nova and SPAN Rock are registered trademarks of Schlumberger.
Extensive laboratory testing combined with offset field history demonstrated that perforating in a base oil would be least damaging to the formation while eliminating challenges associated with cleaning up alternative solids-laden fluids.

To remove the long gun strings from the live wells with a potential 6,000-psi surface pressure, two barriers were instituted. A lubricator valve, set above the subsurface safety valve, was successfully run on each well as the primary isolation barrier. A 5.125-in-ID CIRP* completion insertion and removal under pressure system, complete with remotely activated 15,000-psi hydraulic gate valves installed above the tree, would ensure successful gun retrieval should the downhole barrier be compromised and surface pressure was present.

*Downhole gauges confirmed that the measured peak dynamic underbalance correlated with the pressure simulated prejob through SPAN Rock analysis. The rapid drop in pressure removed skin damage, creating cleaner perforating and improving the productivity index.
In-depth design and testing of a customized completion fluid and unique perforation strategy enable Statoil to optimize well productivity in the North Sea

Optimize perforation performance in overbalance environments
To perforate long horizontal North Sea wells, Statoil sought a safer, more efficient technique that would not compromise well performance in the process. An overbalanced shoot-and-pull technique using conventional completion fluids would have resulted in unclean perforations, leaving the operator with low productivity. However, with a completion fluid customized to meet specific reservoir needs, Statoil could continue using the shoot-and-pull technique while obtaining optimal productivity.

Design field-specific technique and fluid
To address Statoil’s specific needs in this North Sea scenario, a custom completion fluid was designed with the operator’s reservoir characteristics in mind. Additionally, a proposed perforating system and dynamic underbalance technique were designed and tested to further optimize production. Both the fluid and the technique were evaluated at the Productivity Enhancement Research Facility (PERF) near Houston using the same perforating gun technology and dynamic underbalance that were used in the field. Prior to deployment, studies from the PERF laboratory demonstrated that the combination of a customized perforating strategy and fluid system could deliver superior well performance in challenging conditions.

“Testing conducted in the PERF laboratory helped achieve high well productivity after overbalanced perforating.”
Statoil
Enhance productivity and efficiency
After safely and efficiently perforating several wells in its program with the proven, optimized technique developed at PERF, Statoil recorded excellent productivity in the field. According to the operator, the development of a unique perforating fluid designed specifically for long horizontal wells played an important role in the overall perforating strategy. In addition to improving the productivity of Statoil’s completions program, the customized fluid and dynamic underbalanced perforating technique contributed to the cost-effective operation.

Additional reading:


Statoil was able to enhance production in long horizontal North Sea wells with a customized completion fluid and dynamic underbalance technique that were proved through laboratory testing prior to field deployment.
Multiple factors impede effective production
An HPHT gas field in the northern portion of China’s onshore Tarim basin lies in a tight sand reservoir at a depth of 6,000–7,500 m [19,685–24,606 ft] with pressures from 15,229 to 20,305 psi and temperatures up to 170 degC. With high compressive strength (17,405 psi), low porosity (5%–8%), and low permeability (<10 mD), most wells in the reservoir require stimulation to improve productivity.

Stimulation concept verified by laboratory modeling
To overcome challenging reservoir conditions PetroChina and Schlumberger used the stimulated reservoir volume (SRV) concept. In this new method multiple short clusters are perforated throughout the entire reservoir section and large volumes of slickwater (low proppant concentrations) are pumped at a high rate with fibers for diversion. A wireline-conveyed 2.25-in perforator using 15,000-psi pressure control equipment was selected to accommodate a 68-mm [2.68-in] restriction in the downhole safety valve and operate in the completion of 4½-in tubing and a packer set above the pay zone, which is lined with 5½-in high-strength TP140V casing (12.09-mm [0.48-in] wall thickness).

Because perforation entrance hole size and penetration depth are critical, particularly with the relatively small perforating gun for the casing size, a two-step laboratory program was designed and executed at the Productivity Enhancement Research Facility (PERF). First, screening tests assessed perforation hole diameter in the casing at ambient surface conditions. Then, two laboratory
tests were conducted at downhole pressure and temperature to confirm perforation casing hole diameter and penetration depth into a stressed sandstone core. The results indicated that perforation performance at downhole conditions would enable successful stimulation operations and confirmed predictions made with SPAN Rock analysis.

**Production increased threefold following perforation**

The perforation operation was conducted successfully in a total of three runs made using an addressable-switch firing system with 12 guns (six stages total). The multistage stimulation was then executed and resulted in a 300% production rate increase for the well compared with PetroChina’s nearby wells.

<table>
<thead>
<tr>
<th>Test Number</th>
<th>Core ID</th>
<th>Core Average UCS, psi</th>
<th>Gun-to-Casing Clearance, in</th>
<th>Casing Hole Diameter, in</th>
<th>Residual Rock Penetration Depth, in</th>
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<tbody>
<tr>
<td>Test 1</td>
<td>NG7-17</td>
<td>14,718</td>
<td>0</td>
<td>0.22 × 0.24</td>
<td>3.7</td>
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<tr>
<td>Test 2</td>
<td>NG7-16</td>
<td>14,981</td>
<td>2.302</td>
<td>0.13 × 0.13</td>
<td>2.4</td>
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</tbody>
</table>

*Test 1 (0° phased) split core and casing assembly.*

*Test 2 (180° phased) split core and casing assembly.*
## Schlumberger Productivity Enhancement Research Facility (PERF)

### Integrated field operations expertise
Access a global network of geography-specific perforating domain expertise with extensive regional knowledge to aid in the design and execution of test programs with the greatest relevance to real-world field operations. PERF engineers are accustomed to tailoring optimized solutions for specific basins and reservoir types.

### PERF Testing Parameter Capabilities

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Range</th>
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</thead>
<tbody>
<tr>
<td>Overburden stress, psi</td>
<td>0–30,000</td>
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<tr>
<td>Reservoir pressure, psi</td>
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<tr>
<td>Wellbore pressure, psi</td>
<td>0–30,000</td>
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<td>Temperature, degF</td>
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<td>Flow rate (liquid) per perforation, bbl/d</td>
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<tr>
<td>Flow rate (gas) per perforation, MMcf/d</td>
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<td>Core diameter, in</td>
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<tr>
<td>Core length, in</td>
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<tr>
<td>HSD* gun system size, in</td>
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