In April 2007, GEODynamics introduced a new class of Reactive™ perforating shaped charge that delivers a step change improvement in perforation tunnel geometry and performance. The CONNEX™ perforating product generates a secondary reaction in the perforation tunnel thanks to proprietary liner metallurgy and charge design. CONNEX™ perforating technology was developed under license from QinetiQ with the vision and support of Shell.

CONNEX™ Perforating delivers debris-free tunnels with no crushed zone, even in low-quality rock and with no need for significant underbalance during perforating. Depth of penetration and casing entry hole diameter are comparable to leading conventional deep penetrating charges. Because the external profiles of CONNEX™ charges are identical to conventional products, they can be deployed in existing hardware, following standard operating procedures.

The CONNEX™ family of products is the first to be entirely developed and optimized for flow performance, using all-natural rock targets. Testing in GEODynamics’ flow laboratory under representative stress and pressure conditions shows perforations shot with CONNEX™ charges deliver more than 30% greater flow than those shot with leading conventional charges.

...debris-free tunnels with no crushed zone...
...more than 30% greater flow...

So How Does It Work?

When a CONNEX™ Perforating charge is fired, it initially behaves exactly like a conventional shaped charge. The main explosive load detonates, evolving a huge volume of gas and generating tremendous pressure. As the detonation wave advances through the main body of the charge it collapses the conical metal liner toward its axis, producing a high velocity jet of particles moving at over 20,000 ft/sec.

Along the axis of the cone, particle collision pressures as high as 15 million psi are generated. The particle jet pushes aside and plastically deforms the gun body, wellbore casing, cement, and formation. Rock grains are pulverized and displaced radially, forming the perforation tunnel. Finely crushed rock together with mud, cement, and charge debris is forced into the pore throats of the surrounding rock, leading to a ‘crushed’ or ‘altered’ zone of reduced permeability.

Whereas perforation with conventional charges depends on flow from the undamaged matrix to the wellbore to remove the crushed zone and any debris that may be obstructing the tunnel, CONNEX™ Perforating introduces a secondary Reactive™ effect that makes flow unnecessary. A carefully controlled bimetallic combination within the powdered metal liner reacts under the tremendous pressures of detonation and liner collapse. This Hume-Rothery reaction is highly exothermic and takes place in the perforation tunnel microseconds after it has formed. The energy released supercharges the near-tunnel region, creating a surge of flow into the wellbore. This flow removes material from the entire tunnel length, including the impermeable but relatively weak crushed zone. Since every tunnel is subjected to this secondary reaction they are all cleaned out, irrespective of differences in rock quality or local pressure conditions.
The photographs below provide a side-by-side comparison of perforation tunnels created with conventional and CONNEX™ products. Figures 7 and 8 show tests shot under moderate confining stress. Figures 9 and 10 show tests shot under higher confining stress. All tests were carried out with 25g HMX deep penetrating shaped charges and Berea sandstone targets. In both cases, the CONNEX™ tunnel delivered a productivity ratio more than 30% greater than the conventional equivalent.
Six Things to Remember about CONNEX™ Perforating

- Clean tunnels without having to apply significant drawdown
- Clean tunnels even in poor or heterogeneous formations
- Reactive™ effect in every tunnel means all tunnels clean up
- >30% increase in productivity compared to conventional charges
- Drops into conventional equipment, wireline or TCP
- The first in a new class of perforators optimized for flow
### CHARGE SPECIFICATION

<table>
<thead>
<tr>
<th>CONNEX Charge</th>
<th>Perforating Properties</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>XLS eXtra Low Swell</td>
<td>Connex perforating products are rewriting the perforating book by delivering unprecedented tunnel performance without the need for expensive underbalanced or cleanup operations.</td>
<td>The CONNEX™ perforating product generates a secondary reaction in the perforation tunnel thanks to proprietary liner metallurgy and charge design. The technology was developed under license from QinetiQ with the vision and support of Shell. CONNEX™ Perforating delivers debris-free tunnels with no crushed zone, even in low quality rock and with no need for significant underbalance when perforating. Depth of penetration is comparable to leading deep-penetrating charges. Since the external profiles of CONNEX™ charges are identical to conventional products, they can be deployed in existing hardware, following standard operating procedures. The CONNEX™ family of products is the first to be entirely developed and optimized for flow performance, using all-natural rock targets. Testing in GEODynamics’ flow laboratory under representative stress and pressure conditions shows perforations shot with CONNEX™ charges can deliver more than 40% greater flow than those shot with leading conventional charges.</td>
</tr>
<tr>
<td>XEH eXtra Entry Hole</td>
<td>System qualified for shooting dry</td>
<td></td>
</tr>
<tr>
<td>D System must be shot in fluid</td>
<td>System qualified for shooting dry</td>
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**FIRING HEADS**

**Pressure Activated Firing Head (LP)**

The Pressure Activated Firing Head (LP) is used where pressure firing is required, including horizontal wells, well stimulation or as a backup firing system.

**Mechanical Impact Firing Head**

The Mechanical Impact Firing Head is designed for applications where there is insufficient hydrostatic well pressure to utilize the safety impact firing systems. However, this Firing Head will operate in hydrostatic pressures up to 20,000 psi.

**Redundant Annulus Pressure Firing System**

The Redundant Annulus Pressure Firing Head was designed to allow underbalance perforating for shoot and pull applications. This tool uses differential pressure across the packer to actuate the firing mechanism. Utilizing the Owen’s Packer Bypass System.

**Coiled Tubing Safety Impact Firing Head**

The Safety Impact Firing Head is designed to run perforating guns, jet cutters or severing tools on coil tubing. The system is actuated by, dropping a ball and pressuring up the tubing. Once the ball is seated, a predetermined pressure is applied to operate on the precision shear pins, after shearing the firing pin strikes the detonator causing the gun to fire.

**Pressure Activated Time Delay Firing Head**

The Pressure Activated Time Delayed Firing Head, permits underbalance perforating through the use of a pressure actuated firing head employing a time delay fuse. The use of the time delay allows for time to bleed the actuating pressure off the tubing, to achieve the desired underbalance prior to firing the guns.

**Mechanical Firing Head**

The Mechanical Firing Head is an economical TCP Firing Head which allows detonation of the gun system by releasing a Slim Nose Drop Bar into the tubing from surface. The Firing Pin is held in the bore of the Firing Head with a Shear Pin which is severed upon impact of the Slim Nose Drop Bar, allowing the Firing Pin to travel downward. The percussion transmitted to the Initiator causes detonation which is transferred to the Gun System.

**Mechanical Safety Impact Firing Head (HP)**

The Mechanical Safety Impact Firing Head is designed to be the primary firing system on all Wide Nose Drop Bar TCP operations. Designed to meet API RP-67 safety recommendations, the Mechanical Safety Impact Firing Heads require both the drop bar action as well as a minimum hydrostatic to fire. Two models are utilized to cover the pressure ranges normally anticipated in TCP operations.
TCP ACCESSORIES

**Automatic Gun Release**

2-3/8" & 2-7/8" EUE The Automatic Gun Release is run when it is desirable to drop the gun upon firing. This tool is designed to fit onto the top sub of the gun. A short section of detonating cord runs through the center of the tool below the percussion detonator. Several Owen Firing Heads can be threaded into the top of this tool for detonation of the gun system. The gun can be activated by either:

**Mechanical Gun Release, Shift Up**

The Mechanical Gun Release, Shift Up is designed as a medium duty separation tool for use in TCP operations where it is desirable to drop the discharged gun system. The guns may be released using a standard Model B Shifting tool. After the guns have been released, a tapered re-entry guide remains on the tubing for production purposes. The shifting sleeve bore size is the minimum I.D. after the tool has been shifted.

**Vertical Shock Absorber, 3-1/2" O.D**

The 3-1/2" Vertical Shock Absorber is designed to run between the Packer and TCP guns. The purpose of the VSA is to protect delicate electronic gauges and mechanical tools from the severe shocks associated with the detonation of the TCP guns.

**Radioactive Marker Sub**

The Radioactive (RA) Marker Sub is run in a TCP string above the Firing Head or Packer and is used for accurate depth control. A small radioactive pellet is inserted into the cavity of the sub and can be readily detected by wireline gamma ray logging tools. The gamma ray log done inside the tubing can be compared to the open hole logs with the location of the RA Marker superimposed. This gives the exact location of the Marker with respect to the formation of interest, so gun placement may be done extremely accurately as a comparison to pipe tally calculations.

**Combination Fill/Flow Nipple**

barrier of the Fill/Flow Sub, along with a restricted ID through the tool which acts as an integral No-Go feature. This tool may be used as a Combination Fill/Flow and No-Go and may be placed below a gun release in the TCP string.

**Surge Tool, Underbalance Sub**

The Under-Balance Sub may be run in a TCP string to achieve a differential pressure between the formation and tubing string to establish an under-balance condition for perforating. This tool uses a thick glass disk sealed inside the housing as a pressure barrier.

**Digital Shot Detection System**

Digital Shot Detection System (DSDS) enables the user to monitor downhole acoustics on the tubular. The system is particularly well suited for monitoring the firing of Tubing Conveyed Perforating Guns.
TCP APPLICATIONS

Closed-Chamber Surge-and-Test Application
TCP string is used to provide a controlled surge volume by allowing the well to flow through the surge chamber. The surge chamber is initially run empty and then opened to the formation by the lower tubing isolation valve.

Dual String Multizone Selective Completion Application
In a permanent completion, the completion string, including all downhole hardware and guns, is conveyed into the well on the production tubing spaced so that the guns are opposite multiple zones of interest after the packers are set.

Downhole Temperature Versus Expected Time Exposure
Downhole temperature and expected time exposure are among the most important parameters to consider when planning a TCP operation.

Reperforation with Packer Set between Existing Perforations Application
In this application a well may be reprobated or a new zone perforated with open perforations in the well.

Stab-In Completion Application
In a permanent completion, the packer and seal bore assembly are set on wireline, and the guns are conveyed on the production tubing and stung into the packer.

Sucker Rod Pump TCP Firing Systems
Sucker rod pump installations prevent creating an underbalance with conventional tubing-conveyed perforating TCP techniques.

Single-Trip TCP-Acid Frac-DST Application
Using this string, a well may be perforated, acid fractured and tested through a DST string on a single trip into the well.

Sting-Through Completion Application
In a permanent completion, the packer and seal bore assembly are set on wireline, and the guns are conveyed on the production tubing and stung into the packer.

Single-Trip Perforate and Gravel-Pack Application
A well may be perforated and gravel packed on a single trip into the well. The underbalance is created by circulating a lighter fluid through the packer bypass. After firing, the guns automatically drop, allowing the packing operation to proceed.

Single-Trip Selective Firing, Commingled Production Application
With this string, a well may be selectively perforated on a single trip.

TWC Tubing Wireline-Conveyed Perforating System
Deep, hot wells often have a long section of liner. The packer is set in the casing section above the liner hanger, and the production tubing is run a few feet inside the top of the liner. This type of installation prevents conventional conveyance of tubing-conveyed perforating TCP guns.