

# The Propellant Technology Development Group and the licensees

The Propellant Technology Development Group's goal is to integrate the perforation, well stimulation, well production, computer modeling, and high-speed data collection technologies. Each of the individual companies had been working on components of the technology, and when Marathon Oil Company took the lead in forming the group, the joint expertise and resources proved successful in developing this technology.

Propellant Technology Development Group personnel represent a broad base of knowledge, experience, and expertise. The group has access to the combined resources of the individual participating companies.

The group's credentials include individuals with:

- \* Over 20 mechanical oilfield tool patents
- \* Eight individuals with 12 plus years of propellant manufacturing/operations experience
- \* Completion engineers with over 20 years of experience
- \* Shaped charge design engineers with 30 years of experience
- \* Geophysicist with a PhD in rock mechanics from MIT with 35 years of experience
- \* Individuals assisting the United Nations' explosives shipping and testing organizations
- \* Over 50 combined years of military experience in high-shock measurements
- \* Total of over 300 years of oil field experience for the core team members



## Marathon Oil Company

Test Wells, Producing Wells  
Perforating, Completion Expertise  
Legal/Patent Expertise



## HTH Technical Services, Inc.

Propellant Manufacturing  
Propellant Field Experience  
Recorder Field Experience



## Owen Oil Tools

Shaped Charge Manufacturing  
Hardware Manufacturing  
Shipping/Distribution  
Design Expertise



## John F. Schatz

### Research & Consulting, Inc.

Computer Simulation Expertise  
Rock Mechanics Expertise  
Propellant Design Experience



## Instrumentation and Engineering Services

High Speed Recorder  
Hardware Manufacturing  
Shipping/Distribution  
Design Expertise

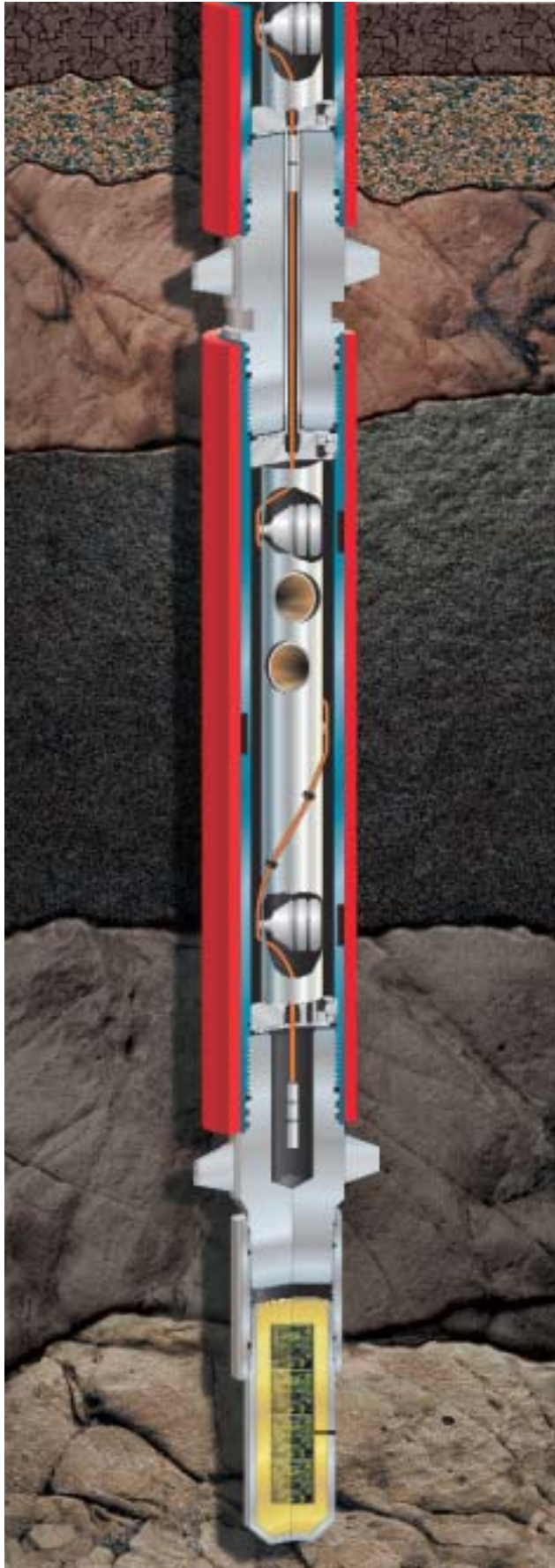
## COMPUTALOG

Wireline Services

## Computalog

Wireline Service Company  
Propellant Field Experience

*Propellant Technology Development Group companies and their resources.*



## Licensees of the StimGun™ assembly and related technologies

There are at least nine companies licensed with the StimGun™ assembly and related technologies. These licenses range from worldwide tubing-conveyed perforation (TCP) and wireline with integrated major service companies to single country wireline licenses.

The Propellant Technology Development Group views its association with its licensees as a team effort. This approach has resulted in the rapid development and worldwide commercialization of the StimGun technology while minimizing the past reputation of propellant stimulation products for misapplication, misuse, and poor design.

License agreements for the StimGun body of technology are available from the Propellant Technology Development Group through Marathon Oil Company. ✨



# Introduction to the StimGun family of products

In the right application and with the right tool, propellants work. However, all propellant-based products are not the same. The StimGun family of propellant-based products offers the industry the first fully integrated, technology-based, and thoroughly tested tools designed to dynamically clean up and stimulate the near-wellbore area. These stimulations are not only cost-effective, but in many instances may be the only available solution for elimination of certain near-wellbore problems. This technology is used both as a primary stimulation and in conjunction with other stimulation technologies such as hydraulic fracturing.

To date, several thousand wells have been successfully treated. The key to our success has been in development of an “engineered process” for the optimization of stimulation design. The process integrates computer modeling, high-speed data acquisition, testing, and data interpretation. The result is the ability to select propellant tools and treatment procedures that ensure the customer that each specific job has been thoroughly

evaluated, the applicability of the technology has been assessed, potential problems have been minimized, and when complete, results can be quantitatively evaluated.

Perhaps the easiest way for us to introduce the technology is to review a few of our successes. The remainder of articles in this publication present in detail the who, why, and how of the StimGun family of products. ✨



*The StimGun™ assembly received Hart's Petroleum Engineering International Special Meritorious Engineering Award for Engineering Innovation. The Propellant Development Technology Group was honored to receive this prestigious award at the Offshore Technology Conference in 1997. The entry was submitted in the Completions and Perforating category and was recognized as one of the year's best new engineering innovations in the industry's efforts to improve well completions.*

StimGun™ Assembly	StimTube™ Tool	Well Stimulation Tool (WST)
<b>Problem:</b> Hydraulic fractures had inefficient proppant placement.	<b>Problem:</b> Well was perforated, but did not flow.	<b>Problem:</b> Operator was unable to initiate hydraulic fracture treatment due to a lack of breakdown
<b>Location:</b> West Texas	<b>Location:</b> Gulf of Thailand	<b>Location:</b> Western Canada
<b>Solution:</b> Perforate with StimGun™ assembly	<b>Solution:</b> Treat with 5 ft (1.5 m) StimTube™ tool centered on 11 ft (3.3 m) perforated interval.	<b>Solution:</b> Treat with 6 ft (2 m) WST centered on 10 ft (3 m) perforated interval
<b>Results:</b> Proppant was placed over the entire zone, as verified by radioactive tracer analysis.	<b>Result:</b> The well flowed at 1 mmcf/day (30 E3m <sup>3</sup> /d).	<b>Result:</b> Hydraulic fracture initiated and went away successfully with no discernible breakdown pressure.

*Examples of case history successes for perforation breakdown and near-wellbore stimulation.*



# Tools, components, and industry usage

*Brent Kirschner, Owen Oil Tools*

The StimGun family of products currently consists of three unique tool configurations – the StimGun™ assembly, the StimTube™ tool and the Well Stimulation Tool (WST). These three products allow for maximum stimulation design flexibility for a wide range of well configurations. With each of these products, production/injection enhancement is accomplished through perforation breakdown and near-wellbore stimulation.

The StimGun technology is best understood as an engineered job design process that integrates the use of the products with PulsFrac™ computer modeling and data acquisition using the high-speed gauge. Unlike approaches used by others, the StimGun technology takes into account well fluids, well mechanicals, and rock properties to select the optimum tool for each specific application.

## StimGun family of products



**StimGun™ assembly**



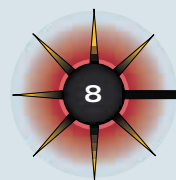
**StimTube™ tool**



**Well stimulation tool (WST) and hardware**



**High-speed/high-shock downhole memory gauge**





## The StimGun™ assembly

The StimGun™ assembly has two major components – a conventional hollow steel perforating gun and a sleeve of special propellant material surrounding the gun. The perforating gun is fired in the wellbore as normal, and as a result of the perforating process the sleeve is ignited. The sleeve, which is a proprietary oxidizer, and binder combination burns quickly and produces a burst of high-pressure gas. This high-pressure gas enters the perforation and creates fractures resulting in an improved flow path from the formation to the wellbore. The sleeves are available for hollow carrier

perforating gun systems from 2 $\frac{3}{8}$  in. (60.3 mm) through 7 in. (177.8 mm) outer diameter (OD). The StimGun™ assembly can be lowered into the well on wireline, tubing or drill pipe, or with coiled tubing.

## Industry Usage

As of December 2001, over 30,000 ft (9140 m) of the StimGun™ assembly have been run. This represents thousands of successful completions. These include onshore-offshore oil, gas, and injector wells around the world. The StimGun™ assembly is a field-proven method of perforating and stimulating in one run.

## StimGun™ assembly components



**Propellant sleeve** – Cast tube of a proprietary oxidizer/resin binder material, similar in appearance to plastic pipe, that simply slides over the perforating guns. The “propellant-like” material (actually classified as an oxidizer) is ignited by the perforating events. Usually a minimum of four shots per foot is required to adequately ignite the sleeve. However, 6 spf (20 spm) are generally recommended. Maximum temperature rating is 330°F (160°C). The sleeves are impervious to all current well fluids.



**Centralizing rings** – Used to position and secure the sleeves to the outside of the perforating gun. In addition to securing the sleeves, the rings are available over-sized (typically sleeve OD +  $\frac{1}{4}$ "/6.4 mm) to protect the sleeves from contact with the casing.

**Finned tandem/bull nose subs** – Subs centralize the assembly and protect the sleeves – while resulting in minimum flow restriction. Typically gun OD +  $\frac{1}{2}$ " (12.7 mm)



**Perforating guns** – Typically hollow steel carrier guns are recommended. Sleeves are currently available for the following gun OD sizes: 2 $\frac{3}{8}$ ", 2 $\frac{1}{2}$ ", 2 $\frac{3}{4}$ ", 2 $\frac{7}{8}$ ", 3", 3 $\frac{1}{8}$ ", 3 $\frac{3}{8}$ ", 4", 4 $\frac{1}{2}$ ", 4 $\frac{7}{8}$ ", 5 $\frac{1}{8}$ ", & 7" (60.3 mm, 63.5 mm, 69.9 mm, 73 mm, 79.4 mm, 85.7 mm, 101.6 mm, 130.2 mm & 177.8 mm).



**High-speed/high-shock downhole memory gauge** – Data acquisition at rates up to 100,000 points per second (user programmable for high, intermediate, and low speeds). Sensors available include pressure, temperature, acceleration – high-G for shock measurement and acceleration, low-G for tool velocity calculation. Maximum memory = one million data points. Sizes available (OD) = 1 $\frac{1}{16}$ " & 2" (42.9 mm & 50.8 mm). Maximum temperature rate = 255°F (125°C).



## The StimTube™ tool

The StimTube™ tool consists of a molded cylinder of propellant-like oxidizing material surrounding an internal steel support tube containing detonating cord. The StimTube™ tool provides efficient, cost effective remediation to existing perforated or open-hole intervals. The StimTube™ tool is available in a variety of sizes including 1½ in., 1⅞ in., 2 in., 2½ in., and 3 in. (38.1 mm, 42.9 mm, 50.8 mm, 63.5 mm and 76.2 mm). The StimTube™ tool is run into the wellbore, typically on wireline, and positioned across existing perforations. The conventional detonating

cord is then initiated causing the oxidizer to ignite. Similar to the StimGun™, the StimTube's proprietary propellant burns quickly and produces a burst of high-pressure gas.

## Industry Usage

As of December 2001, over 12,000 ft (3660 m) of the StimTube™ assembly have been run. Applications are primarily through-tubing pre-hydraulic fracture treatment and stimulation of damaged wells, where wellbore restrictions do not allow for the use of the StimGun™ assembly.

## StimTube™ tool components



**The StimTube™** – A cast cylindrical rod of proprietary oxidizer/resin material with an embedded steel support tube, ignited with 40 grain detonating cord. Available sizes – Outside Diameters – 1½", 1⅞", 2", 2½", and 3" (38.1 mm, 42.9 mm, 50.8 mm and 76.2 mm); lengths – 1', 2', 3', and 4' (.3 m, .6 m, .9 m and 1.2 m). Maximum temperature rating = 340°F (170°C). Impervious to all well fluids.



**Firing head** – Used to connect the detonator to the detonating cord and to connect the tools to the wireline or coiled tubing.



**Connecting subs** – Used to assemble multiple StimTube™ tools and to minimize tool contact with the casing. Generally, maximum recommended total length per run of StimTube™ tool for wireline applications is 15' (4.6 m). Longer lengths can be run on continuous tubing.



**Bull nose sub** – Used to terminate the assembly and protect the propellant and detonating cord end seal.



**High-speed/high-shock downhole memory gauge** – Typically run just below the wireline cable head.



## Well Stimulation Tool (WST)

The WST is a “stick” tool consisting of a cast cylindrical rod of a proprietary oxidizer/resin material with a central ignition system. It is primarily used in perforated or open hole wells with no inner diameter restrictions.

## Industry Usage

As of December 2001, over 15,000 ft (4570 m) of the WST has been run. This product has an extremely reliable ignition system and a verified burn repeatability. The WST is primarily used as a perforation breakdown tool and as a horizontal well stimulation tool.

## Well Stimulation Tool components



**WST available sizes** – ODs 1½", 1⅞", 2 in., 2½ in., and 3 in. (38.1 mm, 42.9 mm, 50.8 mm, 63.5 mm and 76.2 mm); lengths – 1', 2 ft, 3 ft, and 4 ft (.3 m, .6 m, .9 m and 1.2 m). It is ignited with 40, 60, or 80 grain detonating cord, however 40 is typically recommended. Maximum temperature rating – 250°F (120°C). Impervious to all well fluids except methanol.



**Steel carriers** – Similar to a spent perforating gun except with typically 24-1" holes per foot. It is available in several ODs depending the specific WST used.



**Connecting subs** – Used to assembly multiple WSTs. Generally, maximum recommended total length per run of WST for wire line applications is 12 ft (3.7 m). Lengths of over 1000 ft (305 m) can run on tubing.

**Bull nose sub** – Used to terminate the assembly.

**Firing head** – Used to connect the detonator to the detonating cord, and to connect the tools to the wire line or tubing.



**High-speed/high-shock downhole memory gauge** – Typically connected below the bull nose sub.

# Safety and regulatory compliance

David Boston, Owen Compliance Services, Inc.

Joe Haney, HTH Technical Services, Inc.

**P**roduct safety and regulatory compliance are of paramount importance to the Propellant Technology Development Group. The StimGun family of products have all been thoroughly tested to ensure that they are manufactured, transported, stored, and handled in a manner that meets worldwide regulatory requirements and does not endanger people, property, or the environment.

Beginning in the product design phase, issues of product safety and risk management were addressed. The chemical oxidizer used in these products was selected based on low sensitivity, high stability, and good performance. The binder used was selected based on chemical compatibility, stability, and fuel content. Prior to start-up of manufacturing, a preliminary hazard assessment was completed. Additionally, the products have been tested and classified per UN Model Regulations and the US Department of Transportation (DOT) regulations. The chemical compatibility of the propellant with various well fluids was



**Figure 1** – Surface Test – StimGun™ assembly, 2½ in. (73 mm) Perforating Gun, 6 spf (20 spm), no ignition of StimGun sleeve observed.

**...products have been tested and classified per UN Model Regulations and the US Department of Transportation (DOT) regulations**

evaluated as well as the effect of rapid low-to-high pressure cycling. As part of the risk management assessment, all products were tested for ignition potential at surface conditions. The results of the testing have also been used to identify any possible

intrinsic hazards for handling of the products by the end-user.

## Testing and classification of StimGun products

The testing of the StimGun product family has been ongoing since 1996. Owen Compliance Services, Inc. (OCS) performed a hazard assessment review and witnessed the initial product testing. Based on this initial testing, the products were classified as oxidizers.\* This product classification was later reconfirmed by testing conducted by Natural Resources Canada (NRC), through its Canadian Explosives Research Laboratory (CERL).

## Additional product safety testing

Owen Oil Tools Inc. has conducted several “explosive” tests on the products, as follows.

### StimGun™ assembly

Multiple surface tests were performed. An example is shown in Figure 1. The most important result is that perforating guns will not ignite the StimGun™ assembly sleeves at the surface.

\* The StimGun family of products are DOT classified as oxidizers (5.1) and not as propellants. For classification purposes, propellants are equivalent of explosives. Therefore throughout this publication, when the term “propellant” is used with regard to StimGun products, it should technically be interpreted in DOT terms to mean “oxidizer, mixture, solid.”



**Figure 2** – (a) View of the StimTube™ tool after detonating cord wrapped around the exterior of the tool was ignited – note that essentially none of the tool was ignited by the detonating cord. (b) View of the StimTube™ tool after detonating cord was run through the central ignition tube and ignited. The ignition of the detonating cord resulted in fragmentation of the tool and minor ignition of some of the fragments.

### StimTube™ tool

Multiple surface tests were conducted. Detonating cord wrapped around the StimTube™ tool will not ignite the oxidizer material (Figure 2a). Detonating cord run through the full length of the central igniter tube will fragment and only partially ignite the oxidizer mixture (Figure 2b).

### Well Stimulation Tool

At surface, without confining pressure, detonating cord will not ignite the oxidizer mixture.

### Additional tests of propellant mixtures

A harsh environment test at 20,000 psi (138 MPa) and 400°F (204°C) generated no reaction. Multiple rapid pressure cycling tests from atmospheric to 5000 psi (35 MPa) and back generated no reaction. Fluid compatibility tests with propellant mixtures used in the StimGun™ assemblies

and all StimTube™ tools indicated no reaction with hydrochloric acid, nitric acid, xylene, and alcohol. Mixtures used in the WST and certain obsolete StimGun™ assemblies are affected by water or alcohol absorption.

### Conclusions

The hazard assessment testing for the UN and DOT classification and for product safety of the StimGun family of products has been rigorous. These products can be safely transported with all domestic and international transport regulations. Guidelines for safe handling and use have been established. Sensitivities have been determined.

As with all dangerous goods, there is a potential for error and/or abuse. Training is required for all personnel involved with the manufacture, transportation, storage, and end use of the products. ✨



Nitroglycerin and other explosives came into general use as stimulants in 1867 and prevailed until the late 1940s when explosive-based stimulation was replaced by hydraulic fracturing.

