For over a decade The GasGun Inc. has been providing low cost stimulation solutions to oil and gas well operators.
What the GasGun Can Do for Your Wells...

- Create multiple radial fractures extending up to 50 feet from the wellbore.

- Minimal vertical fracture growth out of zone avoids problems often associated with hydraulic fracturing and acidizing.

- Remove wellbore damage caused by perforators, drilling fines, cement, acids, mud cake, scale, polymer gel, etc.

- Improve effectiveness of acidizing by fracturing first with the GasGun, allowing acid to etch new channels into formation.

- Enhance production in naturally fractured reservoirs by intersecting more fractures.

- Reduce costs of hydraulic fracturing by breaking down the formation first with the GasGun. Treating pressures are often dramatically reduced.

- Increase injection rates in waterfloods, waste disposal, and gas storage wells.
What is the GasGun?

The GasGun is a solid-propellant well-stimulation device based on proprietary ballistic technology from the U.S. military. It incorporates the most advanced design on the market with the use of progressively burning propellants that have been proven by independent research to be many times more effective in creating fractures and increasing formation permeability.

For over a decade The GasGun Inc. has been providing low cost stimulation solutions to oil and gas well operators. Our third-generation patented design, introduced in 2004, vastly improved the tool’s performance and fieldability. Its unrivaled success in the field has increased demand rapidly with thousands being fielded throughout the U.S., Canada, Europe, Africa, and the Middle East.
The GasGun generates high pressure gases at a rate that creates a fracturing behavior dramatically different from either hydraulic fracturing or explosives. The goal is to tailor the pressure-time profile to produce multiple fractures which provide optimum nearbore drainage.
Over the last 40 years oilfield service providers have performed tens of thousands of propellant stimulations for oil and gas companies all across the globe. Despite their widespread use, propellant stimulations account for a small part of the overall fracture stimulation market, and their applications have not been well understood by most operators. Historically, propellant tools have been applied in wells as either a pre-treatment to hydraulic fracturing or in wells where hydraulic fracturing is uneconomical. With advancements in the safety, reliability and design of propellant tools along with the accumulated knowledge from decades of use, oil and gas companies are finding new applications for this maturing technology.

Background
Oil and gas wells have been stimulated with high explosives since the late 1800s. This form of stimulation is often referred to as “well shooting”. Problems of wellbore damage, safety hazards and unpredictable results have reduced the relative number of wells stimulated with classic high explosives, and this method has largely been replaced by the use of propellants.

The solid propellants used in these stimulations deflagrate rather than detonate. Unlike explosives, the burn front in these materials travels slower than the sound speed, and the burn rate can be tailored to fit a wide range of applications. Pressure/time behavior of propellants differ from explosives in that peak pressures are lower and burn times are longer. The approximate values of peak pressure and duration noted for the intermediate pressure pulse of Figure 1 are for the GasGun®, which is one of the propellant stimulation devices commercially available today.

Common applications
Early success with the GasGun in the Appalachian and Illinois Basins provided the impetus to expand the service throughout the USA and international markets, with over 5,000 stimulations being conducted over the last decade. As is true with many emerging technologies, the majority of these stimulations have been performed for small independent operators in the USA. Due to its low cost and minimal onsite equipment these operators have found the GasGun to be an economical method of stimulating marginally producing wells. In recent years, the large independent oil and gas companies have begun to recognize the merits of propellant stimulation technology and have been applying it in a wide range of applications with regularity.

In specific applications, propellant stimulation technology has some distinct advantages over other stimulation methods. This has resulted in the routine use of propellant tools, and some of the most common applications for the technology will now be described.
Close water contacts

When designed properly, propellant tools create multiple radial fractures extending from the wellbore. This fracture pattern is illustrated above the GasGun heading in Figure 2. This provides superior nearbore permeability. These multiple fractures are created in a matter of milliseconds, which allows the vertical growth of the fractures to be controlled. As a result, operators can avoid problems often associated with hydraulic fracturing and acidising where fractures can grow vertically into neighbouring water zones. There are hundreds of cases where propellant tools have been the only stimulation solution an operator has in wells with close water contacts.

Cement invasion

Another very common application for the GasGun is for wells that have formation damage as a result of cement invasion. This commonly occurs after cement squeeze jobs or when setting casing during the initial completion of a well. Many operators will simply perforate the well to try and establish communication with the reservoir. Many times this is unsuccessful because the perforations are not able to penetrate deep enough into the formation to bypass the damage, and as a result the well will need to be stimulated. Hydraulic fracturing is commonly chosen, but this is a very costly method of removing nearbore damage. Acidising is another option, but it can be difficult to control and can channel out of the pay zone. Propellant stimulations are a very efficient way to remove this type of formation damage because they are focused in the pay zone and can reach tens of feet past the perforation tunnels. In most cases this is all that is necessary to restore communication with the reservoir.

Injection wells

Injection wells have historically been one of the most successful applications for propellant stimulation tools.

Regardless of whether the injection well is used for a waterflood or waste disposal, performance can be significantly enhanced by this technology.

Over time injection wells often become damaged by the fluids being injected into the reservoir. This increases injection pressure requirements and reduces the amount of flow. Injection pressures can rise to the point where an operator can no longer inject fluids at all because of mandated pressure limits. A stimulation becomes necessary in order to break past the damage and restore flow. Because the damage is often restricted to the nearbore region of a well, a propellant stimulation is typically all that is needed to reduce pressures and improve injection rates.

Pre-frac treatment

In some wells, propellant stimulation tools are used in advance of a hydraulic fracturing treatment. Some reservoirs can be very difficult to break down during hydraulic fracturing. This can further be exacerbated by the fact that perforators crush and compact rock, which leads to the creation of skin in the perforation tunnels. As a result, breakdown pressures can exceed the capabilities of the downhole and surface equipment. It can also lead to premature screenouts in the wellbore. A very simple and economical solution to this problem is to shoot a propellant tool in advance of the hydraulic fracture. In some situations this can be the difference between running a successful fracture treatment or none at all.

Another reason for running a propellant tool prior to a hydraulic fracture is to preferentially break down certain sections of a reservoir. When fracturing long perforated intervals it can be difficult to get all the perforations stimulated effectively. Using a propellant tool in sections that are known to be more difficult to break down will allow for a more homogeneous stimulation of the entire reservoir.
Developing applications

As the GasGun has gained acceptance larger oil and gas companies with more sophisticated completions have found new uses for the technology. These newer applications include formation evaluation, gas storage wells and remote locations. While these applications represent a relatively small portion of the total propellant stimulations performed, they are growing in popularity.

Formation evaluation

Formation evaluation has become increasing important to operators trying to optimise their fracturing programmes. Obtaining accurate production test results from each proposed reservoir gives the completions engineer the information they need to evaluate the potential of each zone and design the frac job accordingly. In order to achieve accurate data it is critical that operators are well connected to the reservoir. Many operators achieve this by pumping into the formation to break down the perforation tunnel damage. This works well in many cases, but it can be time consuming, expensive and detrimental to formations that are water sensitive. Running a propellant tool instead of pumping in provides similar benefits, but often at a reduced cost and it is compatible with all formation types.

Case One - A large independent operator with a field in West Texas has a very active drilling programme with several new well completions each week. The target formation is a sandstone with several intervals ranging from 4000-6000 ft deep. These are all gas wells, and they require significant fracturing in order to be commercially viable. The operator completes each stage by running a conventional hydraulic fracture treatment with a mixture of different sands for proppant. It had been experiencing difficulties with the flowback of each stage because the reservoir would not give back the injected fluid. The result was suboptimal gas production.

The operator wanted to experiment with running CO2 fracture stimulations to try and eliminate the flowback problems. Each zone would need to be individually production tested prior to stimulation. The operator did not want to run the risk of pumping into each zone with water to break the perforations down for fear that it would further damage the water sensitive formation. It decided to use the GasGun to get past all the nearbore damage and establish good connectivity with the reservoir.

The operator was able to test, stimulate and flowback each zone successfully. For several months after the stimulation the well performed better than neighbouring wells that had been conventionally fractured. As a result the operator revamped its fracturing programme and continues to use the tool to evaluate its reservoirs prior to stimulation.

Case Two - A large independent operator with a significant acreage position in the Marcellus Shale drilled some vertical test wells in the field so that it could monitor the pressure in the reservoir over time. It wanted to make sure that the well completion left as little skin as possible in order to get precise measurements of virgin reservoir pressure. After perforating the shale it monitored pressure for several weeks and knew fairly quickly that it did not have good connectivity with the reservoir.

The operator assumed that there must be skin damage in the perforation tunnels. It considered pumping into the formation with fluid, but was concerned that it would skew the pressure measurements because it would artificially charge the reservoir. It decided to reperforate using reactive shape charges, which are designed to break up and remove debris in the perforation tunnels leaving as little skin as possible. Unfortunately after this reperforation effort it did not see any change in the reservoir pressure and believed that there must still be some damage further out from the wellbore.

The operator then decided to stimulate the formation using the GasGun in order to bypass the damage. The day after the stimulation it ran pressure gauges again and found that it now had the connectivity it was looking for. At the date of writing, the operator has been monitoring the reservoir for six months and continues to get unobstructed pressure measurements. The operator has since shot another test well with the GasGun in a different part of the field and experienced the same positive response.
Gas storage wells

As discussed earlier, injection wells are typically one of the best applications for propellant stimulation technology. While gas storage wells are not injection wells in the classic sense, it is important to maintain their deliverability, which means keeping the formation damage to a minimum. Good communication with the reservoir allows a gas storage well operator to inject and withdraw with optimal efficiency.

Case one - A gas storage well operator in the Northeastern US was experiencing problems with injection and withdrawal of gas in several of its wells. It was believed that the formation had been damaged by the repeated injection and withdrawal cycle over several years.

Hydraulic fracturing was cost prohibitive so the operator decided to test the GasGun in three gas storage wells. Two of these wells were cased hole completions and the third was open hole. It shot 20 ft of zone in each of the three wells and then put them back into the injection cycle.

The operator was pleased with the initial results from the stimulation, but more time is needed to properly evaluate the injection and withdrawal rates.

Remote locations

The use of propellant stimulation tools in very remote locations is not a common occurrence, but when it does occur it really highlights the ease and efficiency of this type of stimulation. Hydraulic fracturing requires so much equipment that it can either be too expensive or simply impossible to conduct in a remote area.

Case one - The town of Wainwright is a Native community of approximately 500 residents in Northwest Alaska. A picture of the town can be seen in Figure 3. The only means of power generation in this small town is to transport approximately 500,000 gal./y of diesel by barge. The burning of diesel fuel for power generation represents a significant expense and sense of dependence for this small community.

In June 2007, in a co-operative effort among the US Geological Survey, Bureau of Land Management, Arctic Slope Regional Cooperation, North Slope Borough, and the Olgoonik Corporation a 1600 ft continuous core hole was drilled and tested to determine if coalbeds that underlie the community contain sufficient methane to serve as a viable and economic alternative energy source. A picture of the drilling rig can be seen in Figure 4.

Initial results from the well indicated that enough methane gas was present in the subpermafrost coal seams to serve as a power source for this small community. It was also determined that methane could be produced without the need for extensive reservoir stimulation.

After several more years of testing and somewhat disappointing long term production results, it was decided that the test well was in need of some form of stimulation. Due to the remote location of the well and equipment constraints the GasGun proved to be the most viable solution to its stimulation needs.

In May 2010, a 6 ft GasGun was air freighted to the town of Wainwright. In late June the GasGun was shot from a skid mounted wireline unit. After several weeks a gravel pack was installed and the well was production tested. After the treatment the well dewatering rates doubled and gas production has been increasing steadily.

Conclusion

Propellant stimulation tools represent a growing and important part of the overall oil and gas well stimulation market. They provide an economical alternative to other forms of stimulation and in some cases they represent the only solution to an operator’s stimulation needs. They have garnered the acceptance of the smallest of operators with just a few wells to the largest of the independents. With the ever growing list of applications, propellant tools will continue to be a viable stimulation option for oil and gas companies in the future.
Oil and gas wells have been stimulated with high explosives since the late 1800s. It appears however, that the term ‘well shooting’ originated many years before, in the days when a water well was sometimes rejuvenated by shooting a rifle down the well. Nowadays, classic high explosives, such as nitroglycerine or gelatin, are rarely used to stimulate oil and gas wells due to problems of wellbore damage, safety hazards and unpredictable results. Extensive research on solid propellants that deflagrate rather than detonate have led to safe and much more effective options.

In the last 50 years, hydraulic fracturing has been the predominant method of well stimulation. Sophisticated techniques, software, equipment, fracturing fluids and proppant have been developed to optimise the hydraulic fracturing process. However, hydraulic fracturing has disadvantages including a lack of control over the vertical fracture growth and the high cost of treatment.

**Fundamentals**

Figure 1 displays generalised pressure-time profiles for three stimulation methods. Hydraulic fracturing is conducted by isolating a specific zone or formation in the wellbore and applying hydraulic pressure sufficient to overcome the compressive stresses surrounding the borehole. Quasistatic pressure is applied until tensile stresses are created and breakdown occurs. Hydraulic fracturing creates a single bi-wing fracture oriented perpendicular to the least principal in situ stress.

At the other extreme of the pressure-time regime of Figure 1 is the profile for high explosives. High explosives detonate and create
a shockwave. Pressures created are extremely high but last only a few microseconds. Due to inertial effects, tensile stresses are not produced and instead, extreme compressive stresses enlarge the wellbore by crushing and compacting the rock. The enlarged wellbore is left with a zone of residual compressive stress. These residual stresses and compacted rock can actually reduce permeability near the wellbore. Extensive cavings often fill the wellbore with debris that require days, even weeks, to clean up. The use of high explosives is limited to openhole completions.

Between these two extremes, solid propellants can generate a pressure pulse that creates a fracturing behaviour that is dramatically different from either hydraulic fracturing or explosives. Solid propellants do not actually detonate; they deflagrate. Deflagration is a burning process that takes place without any outside source of oxygen and creates large quantities of high pressure gas at a rapid rate. Propellants offer a very wide range of burn durations, from milliseconds to seconds, and not all will produce the desired fracturing behaviour.

The goal is to tailor the pressure-time profile so that it is slow enough to load the rock in tension, avoiding the inertial effects that create extreme compressive stresses in explosive loading; and rapid enough so that a single fracture cannot take all of the high pressure gas being produced. If the burn rate is high enough, pressures reach levels sufficient to put other parts of the wellbore in tension, creating multiple fractures that propagate in directions not governed by the earth’s in situ stress state. This provides the desired benefits of optimum nearbore drainage and fracture propagation that is contained to the zone of interest. The required pulse duration is approximately 10 000 times longer than...
for explosives and 10 000 times shorter than for hydraulic fracturing. The fracture patterns resulting from the three pressure profiles of Figure 1 are depicted in Figure 2.

Some of the effective applications of these stimulations are summarised as follows:

- Remove skin and damage from perforators, drilling fines, scale, mud cake, cement, etc.
- Improve effectiveness of acidising.
- Prepare well for hydraulic fracturing.
- Increase injection rates in waterfloods, waste disposal and gas storage wells.
- Stimulate naturally fractured reservoirs.

### A solid propellant tool

The approximate values of peak pressure and duration noted for the intermediate pressure pulse of Figure 1 are for the GasGun®, which is one of several propellant stimulation devices commercially available today. The pressure profile of the GasGun has been shown to achieve the multiple fracturing behaviour described above from research conducted at Sandia National Laboratories in the 1970s. Depending on well conditions, peak pressures can range from 10 000 to 50 000 psi, and burn times vary from 5 to 30 milliseconds.

In contrast, there are at least three propellant stimulation devices currently being marketed that have burn times in the order of seconds rather than tens of milliseconds. These tools are basically solid propellant rocket motors and will only produce a single hydraulic-like fracture that can wander out of the pay zone, following the path of least resistance. They will not produce the desirable pattern of multiple fractures. Another drawback of these slow burning devices involves the high level of energy lost uphole.

The Sandia research included full scale experiments conducted in a tunnel complex at the Nevada Test Site, and direct observations of the fracturing were made by mining out the borehole after stimulation (Figure 3). Based on these findings, coupled with refinements made to the tool and extensive empirical evidence, GasGun fractures are believed to radiate 10 to 50 ft from the wellbore, depending on depth and rock properties.

The GasGun propellant is similar to that used in large bore military guns. While the concept of using solid propellants to stimulate oil and gas wells is not entirely new, the propellant incorporates a new design with progressively burning propellants. Progressive burning means that the rate at which the propellant burns increases with time, producing gas faster as the material is consumed. This feature is accomplished with multi-perforated propellant grains that increase their surface area as the propellant burns (Figure 4).

Progressive burning propellants are more effective at controlling peak pressures, thus allowing more propellant energy to be delivered to the formation without causing casing damage. It also creates longer fractures by producing more gas late in the process when crack volumes are the greatest. In the Sandia research cited previously, a multi perforated propellant was 300 times more effective in enhancing formation permeability than a standard reggressively burning propellant in a direct side by side comparison.

### Propellant stimulations compared to hydraulic fracturing

Solid propellant stimulations will never replace hydraulic fracturing. Large hydraulic fracture treatments can create a fracture hundreds of feet in length, which may be necessary to produce reservoirs with extremely low permeability. But many small pay zones in marginal wells cannot justify the expense of these treatments. A propellant stimulation can be an economical alternative, requiring less onsite equipment, and can in some cases replace small hydraulic fracture treatments.

For example, in December 2005, a major Canadian producer decided to test the GasGun against traditional stage frac in shallow gas wells of the Basal Belly River formation. They stimulated five wells with the GasGun and six using 5 t sand frac. The operator then conducted a pressure transient analysis on each well. Results are presented in Table 1.

As stated previously, hydraulic fracturing creates a single bi-wing fracture oriented perpendicular to the least principal in situ stress. Unfortunately, the fracture can propagate vertically as well as laterally seeking the path of least resistance. Many hydraulic fractures have been known to break out of the producing formation and into aquifers and thief zones. While the fractures produced by the GasGun are more limited in length, vertical fracture growth will be no more than 1 - 3 ft above or below the treated zone. The advantages of GasGun stimulations over hydraulic fracturing are summarised as follows:

- Minimal vertical growth out of pay.
- Multiple fractures.
- Selected zones stimulated without the need to set packers or ball off.
- Minimal formation damage from incompatible fluids.
- Homogeneous permeability for injection wells.
- Minimal onsite equipment needed.
- Much lower cost.

### Fielding

The propellant is conveyed to the formation in a high strength hollow steel carrier under a minimum fluid column of 300 ft that tamps the charge and assures that the energy is restricted to the pay zone. Simple calculations based on Newtonian mechanics (F = ma) show that a typical GasGun pressure pulse will lose less than 1.5% of its energy when fielded under a 300 ft water column.

It is the mass of the fluid column and the short duration of the pressure pulse, tens of milliseconds, that prevents the fluid column from moving more than a few inches during the fracturing process. High pressure gas is forced into the perforation tunnels immediately adjacent to the tool and not into other open zones above or below. This allows the operator to selectively treat zones of interest. There is no need to set packers to isolate the treatment zone as would be the case for hydraulic fracturing in wells with multiple open intervals.

The same cannot be said for propellant stimulations based on rocket motor technology. The relatively long duration pressure pulse will significantly raise the fluid column and allow gases to enter other zones. Also, energy losses uphole can reach 50% or more in these stimulations.
The fluid tamp over the GasGun tool can be anything compatible with the formation such as fresh water, brine, oil or solvent. The tool is usually fielded by wireline but can also be tubing conveyed. The tool is ignited while being suspended at the correct depth. Pressure control equipment, such as a lubricator, can be used when needed. Typically little or no cleanup is required, and the well can usually be put back on production immediately after the stimulation.

Case studies
The following two case studies demonstrate the advantages of solid propellant stimulations over traditional explosive and hydraulic fracture stimulations.

Bradford sand waterflood
In November 2006, four injection wells in Cattaraugus County, New York, were stimulated - two with the GasGun and two with nitroglycerine. The wells are part of a large waterflood and were completed openhole in the Bradford sandstone formation at 1600 ft. Prior to stimulation, injection rates were zero in all four wells. Approximately 130 ft of formation was treated in each well.

The wells stimulated with nitro involved significant cleanout expenses and achieved injection rates of 15 bpd of water. In contrast, the wells treated with the GasGun had no cleanout expenses and achieved injection rates of 60 and 90 bpd of water. Based on these results, all the injection wells and many of the producing wells in the field were stimulated with the GasGun, with similar success.

Arbuckle dolomite
Stimulating oil wells in the Arbuckle dolomite of Kansas presents special challenges. This formation is known to lie just above vast quantities of water. Hydraulic fracturing and even light acidising commonly results in vertical fracture migration into the water bearing zone. As a result, many operators have adopted a strategy of using the GasGun to create a fracture network that does not migrate out of zone, followed with a light acid treatment that usually goes on vacuum. Oil production typically increases with little or no change in the percentage of water production. Nearly 200 Arbuckle wells have been treated with this method and economic success has been achieved in approximately 75% with an average three to tenfold increase in production.

Conclusions
Solid propellants have a wide range of burning characteristics and can produce large quantities of high pressure gas. If burn times are selected in the proper range, the resulting behaviour of multiple radiating fractures confined to the treatment zone has many distinct advantages over conventional hydraulic fracturing.

In the last 10 years, over 4000 GasGun propellant stimulations have been performed in the USA, Canada, Europe, Africa and the Middle East. Well depths have ranged from 200 - 15 000 ft. Some of the most successful treatments have been in formations that are known to produce large volumes of water when hydraulically fractured. Examples include the Arbuckle formation in Kansas, the Aux Vases, Cypress, and Tar Springs formations in the Illinois basin. Successful stimulations have been achieved in many lithologies including sandstone, limestone, dolomite, shale, coal, chert, chalk, marlstone and diatomite.

References
THE TECHNOLOGY BEHIND USING a gun to blast open a well has come a long way in the past hundred years or so.

Oil and gas wells have been stimulated using high-energy explosives since the late 1800s, while well shooting is believed to have been done long before that, back when water wells were sometimes brought back to life by firing a rifle down the well.

The technology has been evolving ever since. Part of that evolution is the GasGun, a radial fracturing tool that users say can be an effective and economical method of fracturing formations. Its roots can be traced back to the Second World War in that the propellant it shoots out is similar to what was used in large-bore guns like howitzers.

The propellant itself is top-secret because it, along with the carrier design, is patented. Adam Schmidt, chief operating officer of GasGun Inc., will reveal is that it’s military-grade, large-bore gun ammunition.

Compatible with both open and cased hole completions, the propellant consists of perforated grains that are progressive-burn-
Call it a low explosive. It generates high-pressure gas at a rapid rate that is tailored to the formation’s characteristics. The rate is fast enough to create multiple fractures radiating 10 to 50 feet from the wellbore, but not so rapid as to pulverize and compact the rock — which is the danger of using classic high explosives such as nitroglycerine.

Usually fielded by wireline using a casing collar locator, the GasGun is ignited while suspended out of the producing zone. “The tool is either wireline- or tubing-conveyed into position just the same as a perforating gun,” explains Colin Haynes, technical sales manager for Sebring Energy Inc., the exclusive supplier of GasGun in Canada. “However, it does not create holes in the casing, therefore it is run in the well after the well is perforated and placed on depth, exactly where the perforations exist.”

A minimum 100-metre cushion of any fluid is then placed above the GasGun, keeping the gas generated directly at the perforated zone. The tool is then detonated and gas is generated inside the carrier at an extremely high rate.

The gas exits the carrier and goes into the wellbore where it enters all the perforating tunnels and creates the radial fractures. The spent carrier is returned to surface where it can be reused.

The star-shaped pattern of multiple fractures removes wellbore damage or blockage and increases the formation permeability near the wellbore.

Hydraulic fracturing, on the other hand, creates a single fracture which, unfortunately, can propagate vertically as well as laterally, seeking the path of least resistance. Many hydraulic fractures have been known to break out of the producing formation and into aquifers and thief zones.

While the fractures produced by the GasGun are more limited in length, gas pressures overpower the in-situ state of stress, creating fractures with minimal vertical growth. As a result, GasGun fractures are much less likely to wander out of the producing zone.

John van Schyndel, operations manager for Sebring Energy Inc., says he’s used the tool twice, the first application being four or five years ago on a relatively shallow well of about 600 metres at Wandering River near Lac La Biche in northeast Alberta, when he was with BXL Energy Ltd.

The GasGun was called in to service after the well didn’t live up to its potential based on a drillstem test, producing only 350 to 400 thousand cubic feet (mcf) of gas per day after the test said it should have output of 900 mcf per day.

Van Schyndel was reluctant to frac it, though, because of underlying water in the reservoir that was fairly close to the intended zone. “We felt if we got really aggressive we could frac into that water,” he says.

GasGun stimulation brought production to 700 mcf per day. “We were quite happy with the outcome of that,” he says.

Van Schyndel says the GasGun was very easy to use and provided significant cost savings compared to traditional hydraulic fracturing. He estimated the GasGun treatment cost $6,000 to $8,000 whereas even a small hydraulic fracture would run about $20,000 to $35,000.

Subsequent use of it a few years later, for Espoir Exploration Ltd., wasn’t successful in changing the character of the well at all, he says. He allowed that may have been because of the well’s greater depth — 1 200 to 1 300 metres — or due to the fact there was in-situ bitumen in the reservoir.

But he says he’d definitely use it again. “For this type of technology one out of two’s probably not bad odds.” He suggested it might be useful as a pre-fracture treatment before committing to the much greater expense of a hydraulic fracture.

That’s exactly why Geoff Ready tried it out in central Alberta, when he was working for Morpheus Energy Corporation. The chemical engineer, who’s now vice-president of Tandem Energy Corporation, applied the GasGun on a tight formation that had a history of not responding to conventional fracturing.

It worked well, he says, estimating it saved the company $15,000 to $20,000 on horsepower costs that would have been spent on a hydraulic frac. “It’s money well spent.”

Six months later he used it on another well after a conventional frac left some tools downhole, forcing Morpheus to kill the well by pumping water down the hole. The tools were retrieved but the water damaged the well so that it wouldn’t flow.

“After we GasGunned it the well was back to what it was before we had the problems,” says Ready. “It basically got us past the damage we had artificially created in the hole. It was a cheap try at recovering the well and it worked out extremely well.”

He says the GasGun doesn’t replace a hydraulic fracture but it comes in handy when you’re using it as a pre-frac tool and he sees no reason why it wouldn’t work on oil wells, too.

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In This Issue:

◆ Totally New GasGun™ Design Solves Debris Problems ....................... 2

◆ GasGun™ Being Used As Formation Evaluation Tool .............................. 3

◆ Not All Propellant Stimulations Are Created Equal .............................. 3

◆ Recent Field Results... 4
New GasGun™ Design Solves Debris Problems

Additional benefits include more consistent results, higher pressure and temperature specs, and improved fielding accuracy and efficiency

After two years of research, design, and testing, we are proud to announce that the GasGun has been totally redesigned. The new design has eliminated debris problems associated with the old expendable rubber-canister, has nearly eliminated all wireline damage and cases of being stuck in the well, improves the propellant burning process for a more uniform stimulation, and provides greater pressure and temperature capabilities.

Over the last few years, we have had extensive feedback from operators who are very pleased with the performance of the GasGun and its ability to stimulate their production and injection wells but who have often struggled with the rubber and plastic debris left downhole after the treatment. The challenge was to find a way to enclose the same highly energetic solid propellant in a sealed carrier that does not impede the rapid expansion of the propellant gases and is completely retrievable.

The schematic shows how this feat was accomplished. The new design uses a custom ported 3¾” O.D. high-strength hollow-steel carrier. The ports are sealed with thin plastic port plugs which provide pressure and temperature ratings of up to 4000 psi and 280°F. When the tool is ignited, the port plugs blow out and the propellant gases exit the portholes. The plastic plugs break apart in the wellbore preventing them from getting stuck around the carrier. The entire carrier is retrieved from the well and is reusable. U.S. and Canadian patents on this design are pending.

Since the new design is based on a standard 3¾” perforating gun carrier, it is completely compatible with standard casing collar locators (CCL) and other typical oil field equipment. The ability to use a CCL with the GasGun makes it easy to locate the tool precisely, which is essential to a successful stimulation. This also means that the new design can be tubing conveyed when necessary, and plans are being made to stimulate two horizontal wells using a standard pressure-activated firing head.

We have fielded over two hundred of these new tools over the last few months with outstanding results. We have run junk baskets with gage rings to look for debris, but have found none. Wireline operators love the new design; they tell us that it is very easy to run and that they almost never have any damage to wireline or other equipment. As a result, on-site efficiency has been greatly improved, and operators are able to get their wells on production quickly, saving both time and money. Best of all, operators are reporting production increases that are better than ever. This is likely a result of improvements we made to the ignition system that produces a more uniform and consistent propellant burn.

If you have not yet tried the new GasGun, or if you had problems in the past, you owe it to yourself to take another look at this innovative and economical stimulation method. Our prices have not changed. Please call us to discuss your particular needs.

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Thank You...

We would like to offer our sincere thanks to the many well owners who have stuck with us over the years, even when GasGun treatments did not always go perfectly, and who have shared their production results and ideas for improvements. We also owe a debt of gratitude to the many individuals at our wireline partners who have worked many hours under tough field conditions to bring the GasGun technology to this industry. Their persistence, feedback, and suggestions on our various designs have proved essential in perfecting this device. We couldn't have done this without their help.
GasGun™ Being Used As Formation Evaluation Tool

Most operators use the GasGun as a direct stimulation tool for their production and injection wells. It has been used to stimulate low permeability reservoirs and to overcome wellbore damage caused by cement, acids, drilling fines, and perforators. In many cases, operators follow a GasGun treatment with acid, using the fractures created as a pathway to get the acid into the zone of interest. In some cases, operators use the GasGun as a pre-treatment for hydraulic fracturing since treating pressure are often dramatically reduced.

Recently, some operators have been reporting that they are using a GasGun stimulation as a tool for evaluating the potential production of a particular formation. Since GasGun fractures are known to reach out past near-bore damage, production data after stimulation can tell the operator if further treatments are justified. If significant production increases are achieved after a GasGun stimulation, some operators will decide to invest in, say, a hydraulic fracture treatment or possibly in horizontal drilling. If, on the other hand, production does not increase significantly, they may decide not to spend additional money on that formation.

The GasGun is an economical stimulation method, and operators continue to demonstrate great creativity in its applications. We are indebted to the many operators who have shared this kind of information with us and have allowed us to pass the ideas along to our other customers.

Not All Propellant Stimulation Are Created Equal

An operator who has fielded 27 of our new GasGun tools in 14 wells in East Texas this year decided to try using another propellant stimulation device for comparison purposes. Even though their success rate with the GasGun was 70%, by their estimation, they were planning on treating a great many more wells and felt that the information was worth the price for future planning. The competitor’s product that was selected is marketed and fielded by a major wireline service company. After stimulating four wells with the competitor’s device with no success, the operator decided that all remaining wells in this field would be stimulated with the GasGun. For more detailed information on these stimulations, look in the “Recent Field Results” section of this newsletter for the Woodbine sandstone.

TOOL SPECS:
Diameter: 3 3/8 inches (86 mm)
Length: 1 – 20 feet (0.5–6 meters)
Max Temperature: 280 °F (138 °C)
Max Pressure: 4000 psi (276 bars)

* 20 feet is the maximum length that can be fielded in a single run.
Recent Field Results

State: Oklahoma
Formation: Fortuna sandstone
Prior Production: 8 BOPD
After Stimulation: 40 BOPD
After 2 months: 30 BOPD

In December 2004, an oil well in Caddo County, Oklahoma, was stimulated with a 4 foot GasGun. This well is a cased hole completion in the Fortuna sandstone formation at a depth of 2042 feet. Oil production immediately increased from 8 to 40 BOPD and continued at that level for 30 days. Production decreased to 30 BOPD for the next 60 days and has leveled off at 10 BOPD.

State: Ohio
Formation: Rose Run sandstone
Prior Production: 0.75 BOPD
After Stimulation: 8 BOPD

In April 2005, a well in Perry County, Ohio, was stimulated with a 10 foot GasGun. This well is a cased hole completion in the Rose Run sandstone formation at a depth of 5297 feet. The operator suspected the formation was glazed due to a downhole fire and was producing just ¾ BOPD. After the GasGun stimulation the well produced 8 BOPD.

State: Texas
Formation: Woodbine sandstone
Prior Production: 0 (wells pump off)
After Stimulation: 9 of 13 are now able to produce

Starting in March 2005, a series of 13 wells in Titus County, Texas, were stimulated with the GasGun. These wells are all cased hole completions in the Woodbine sandstone formation at an average depth of 3500 feet. The operator has more than 100 wells in the area, most of which have been shut-in since the mid-1990’s. The operator chose to make the GasGun and another competing propellant stimulation tool a part of their re-completion program. Prior to any stimulation the wells would just pump-off very quickly making them uneconomical to operate. 9 of the 13 wells treated with the GasGun have allowed the operator to keep the wells on pump and they are “very pleased” with the wells’ level of production. The operator also tried a competing propellant stimulation tool in 4 wells out of the same field and had no improvement in production from any of those treatments.

State: Kentucky
Formation: Knox dolomite
Prior Production: 0 BOPD
After Stimulation: 33 BOPD
After one month: 20 BOPD

In October 2004, a well in Adair County, Kentucky, was stimulated with a 12 foot GasGun. This well was completed open hole in the Knox dolomite formation at a depth of 1388 feet. The well was drilled in 1994 and originally produced 90 BOPD, but then went to water. The operator did a cement squeeze to shut off the water, but was unable to get the well to produce again. They decided to try a GasGun to help them break past the suspected cement invasion into the formation. Immediately after the GasGun treatment the well went from 0 to 33 BOPD. After one month, production leveled off at 20 BOPD.

State: Oklahoma
Formation: Bartlesville sandstone
Prior Production: 3 BOPD & 25 MCF/D
After Stimulation: 15 BOPD & 100 MCF/D

In July 2004, a well in Creek County, Oklahoma, was stimulated with a 2 foot GasGun. This well is a cased hole completion in the Bartlesville sandstone formation at a depth of 2310 feet. After the GasGun stimulation and a small 4000 lb frac, the well’s production increased from 3 BOPD and 25 MCF to 15 BOPD and 100 MCF.

State: Kansas
Formation: Arbuckle dolomite
Prior Production: 1-2 BOPD
After Stimulation: 40 BOPD
Sustained: 8 BOPD

In May 2004, a well in Barber County, Kansas, was stimulated with a 10 foot GasGun. This well is a cased hole completion in the Arbuckle dolomite formation at a depth of 3369 feet. Prior oil production was 1-2 BOPD. For a few days after the GasGun stimulation the well had some flush production of 40 BOPD. The well then leveled off at 8 BOPD.

Country: Croatia, Europe
Formation: Sandstone
Formation Depth: 1539-1559 Meters
Prior Production: 1 m³/d (6.3 BOPD)
After Stimulation: 4.2 m³/d (26.4 BOPD)
After two months: 2.9 m³/d (18 BOPD)

In October 2004, a well located in Croatia was stimulated with multiple GasGuns. This well is a cased hole completion with 3 sandstone intervals that were re-perforated and stimulated with the GasGun. A 2 meter (6.6 feet) GasGun was shot at a depth of 1559 meters (5115 feet), a second 2 meter was shot at 1555.5 meters (5103 feet), and finally a 3 meter (10 feet) was shot at 1539 meters (5049 feet). Prior to the GasGun stimulations the well was producing approximately 1 m³/day (6.3 BOPD). Immediately after the stimulation, the well produced 4.2 m³/day (26.4 BOPD). The well’s production stabilized at 2.9 m³/day (18 BOPD). Analysis showed that total remaining recoverable oil prior to the GasGun would have been approximately 400 m³ (2516 bbl). After the GasGun, remaining recoverable oil is expected to be 3800 m³ (23,900 bbl).

State: Oklahoma
Formation: Dutcher sandstone
Prior Production: 3 BOPD @ 150psi
After Stimulation: 13 BOPD @ 600psi

In June 2005, a new well in Seminole County, Oklahoma, was stimulated with a 4 foot GasGun. This well is a cased hole completion in the Dutcher sandstone formation at a depth of 2686 feet. The initial production of 3 BOPD at 150 psi was unsatisfactory to the operator. They decided to try a GasGun followed by a small acid job. After the treatment the well came in at 13 BOPD at 600 psi.


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GasGun® Stimulation vs. Traditional Stage Frac

In December 2005, a major Canadian producer decided to test the GasGun against traditional stage fracs in twelve shallow gas wells of the Basal Belly River formation in Alberta, Canada. They stimulated six wells with the GasGun and six with 5 tonne sand fracs. The operator then conducted a pressure transient analysis on each well. Results of this analysis show the calculated parameters to be remarkably similar between these two methods and that the effectiveness of the stimulations to be roughly equivalent. The producer chose the GasGun over hydraulic fracturing for the rest of the field because it is considerably less expensive.

<table>
<thead>
<tr>
<th>Well #</th>
<th>BHP (kPa)</th>
<th>Skin Factor</th>
<th>XF (m)</th>
<th>eff. K (mD)</th>
<th>kH (mD.m)</th>
<th>Production (MCF/D)</th>
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<tr>
<td>Well #6</td>
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<tr>
<td>Average</td>
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</tbody>
</table>

* Averages for GasGun data excludes Well #1 on the basis of it being anomalous when compared with the others

Xf is fracture half length in meters
Eff K is the effective permeability in millidarcies
kH is the perm from the PTA results multiplied by the height of the pay zone
**GasGun® Field Results**

Table of Contents

<table>
<thead>
<tr>
<th>State</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arkansas</td>
<td>1</td>
</tr>
<tr>
<td>Illinois</td>
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<tr>
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<td>West Virginia</td>
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*More extensive field results can be found on our website at [www.TheGasGun.com](http://www.TheGasGun.com)*
Formation: Pettit Limestone (new well)
Formation Depth: 3400'
Prior Production: 0 BOPD
After Stimulation: 8 BOPD
Sustained: 8 BOPD

In November 2007, a new well in Columbia County, Arkansas, was stimulated with a 4 foot GasGun. This is a cased hole completion in a Pettit limestone formation at a depth of 3400 feet. A sustained production of 8 BOPD was achieved after the GasGun stimulation. The sustained oil production from this well beat the operator's expectations.

Formation: Pettit Limestone (new well)
Formation Depth: NA
Prior Production: 0 BOPD
After Stimulation: 50 BOPD
Sustained: 50 BOPD

In October 2007, a new well in Columbia County, Arkansas, was stimulated with a 3 foot GasGun. This is a cased hole completion in a Pettit limestone formation. The operator has the well throttled back at a sustained production of 50 BOPD. The sustained oil production from this well was far beyond the operator's expectations.
**Formation: Robinson Sandstone**  
**Formation Depth:** 892’  
**Prior Production:** 0.5 BOPD  
**After Stimulation:** 18 BOPD

In October 2006, a well in Lawrence County, Illinois, was stimulated with a 4 foot GasGun. The well was completed open hole in the Robinson sandstone formation at a depth of 892 feet. Oil production went from 0.5 BOPD to 18 BOPD after the GasGun stimulation.

**Formation: Aux Vases Sandstone**  
**Formation Depth:** 3180’  
**Prior Production:** 10 BOPD  
**After Stimulation:** 45 BOPD

In July 2003, a new well in White County, Illinois, was stimulated with a 4 foot GasGun. This well is a cased hole completion in the Aux Vases sandstone formation at a depth of 3180 feet. The well was reportedly making 10 BOPD naturally. After the GasGun treatment, production increased to 45 BOPD.

**Formation: Benoist Sandstone**  
**Formation Depth:** 1436’  
**Prior Production:** 0.5 BOPD  
**After Stimulation:** 4.5 BOPD  
**After 4 months:** 4.5 BOPD

In November 2000, a well in Clinton County, Illinois, was stimulated with a 4 foot GasGun. The well was completed open hole in the Benoist sandstone formation at a depth of 1436 feet. Oil production increased from 0.5 to 4.5 BOPD. We received a report 4 months later stating that production was still holding at 4.5 BOPD.
**Formation: Aux Vases Sandstone**  
Formation Depth: 3224’  
Prior Production: 2-4 BOPD  
After Stimulation: 54 BOPD  
Sustained: 8-12 BOPD  

In June 2000, a well in Hamilton County, Illinois, was stimulated with a 6 foot GasGun. This well was completed open hole in the Aux Vases formation at a depth of 3224 feet. A water-bearing zone is known to exist just below this oil layer, and hydraulic fracturing would likely “bring in the ocean.” Immediately following the GasGun stimulation, oil production increased from 3 to 54 BOPD with a modest amount of water. This data helps confirm the fact that GasGun fractures stay in the zone treated. Production has been sustained at 10 BOPD.

**Formation: Trenton Limestone**  
Formation Depth: 2350’  
Prior Production: 1 BOPD  
After Stimulation: 18 BOPD  
After 1 week: 8 BOPD  
After 3 months: 5 BOPD  

In May 2000, an old well, drilled in 1903 in Clark County, Illinois, was stimulated with two 10-foot GasGuns. This well was completed open hole in the Trenton formation at a depth of 2350 feet. Oil production, which had been 1-1.5 BOPD, went to 18 BOPD initially, 8 BOPD for about a week and after 3 months leveled off at 5 BOPD.

**Formation: Tar Springs Sandstone**  
Formation Depth: 2422’  
Prior Production: None (Recompletion)  
After Stimulation: 30 BOPD & 45 BWPD  
After three weeks: 5-6 BOPD & 5-6 BWPD  

In February 2000, a well in White County, Illinois, was stimulated with an 8 foot GasGun. This well was recompleted in the Tar Springs formation at a depth of 2422 feet. This formation is particularly close to water and is known to "bring in the ocean" when fraced. Immediate production after stimulation was 30 BOPD and 45 BWPD and, after three weeks, was 5-6 BOPD and 5-6 BWPD.
**Illinois**

**Formation: Cypress Sandstone (Injection Well)**  
**Formation Depth: 2508’**  
**Prior Injection Pressure: 1600 psi**  
**After Stimulation: 800 psi**

In November 1999, an injection well in Wabash County, Illinois, was stimulated with a GasGun. The well was completed in the Cypress formation at a depth of 2508 feet and had been previously acidized and hydraulically fractured in an effort to lower injection pressures. After each treatment, injection pressures would drop from 1600 psi to 800 psi, but would rise back to 1600 psi after just 2 months. A 6 foot GasGun was used, and again the pressure dropped from 1600 psi to 800 psi, but this time the improvement was long lasting. As of March 13, 2001, 16 months later, the injection pressure is still at 800 psi. (Note: All GasGun stimulations performed to date in injection wells have provided positive results.)

**Formation: Aux Vases Sandstone**  
**Formation Depth: 3200’**  
**Prior Production: 0 BOPD**  
**After Stimulation: 1000 BOPD**  
**After two weeks: 40 BOPD**  
**After three weeks: 6 BOPD**

One of our most dramatic stimulations occurred in early August 1999 in White County, Illinois. The well was completed open hole in the Aux Vases formation at 3200 feet and had no natural production. Hydraulic fracturing was attempted, but it apparently screened out. An acid treatment was also unsuccessful. With absolutely no production realized, a 4 foot GasGun was tried. The well immediately began to flow at the surface at a rate of 40 barrels per hour, or nearly 1000 BOPD. It continued at that rate for several days. Eventually the well was put on a pump, and after two weeks was producing 40 BOPD. After three weeks the well was down to 6 BOPD, and the operator decided to try another hydraulic fracture. This time the hydraulic fracture treatment was successful.

**Formation: Pennsylvania Sandstone**  
**Formation Depth: 3 wells at 530’**  
**Prior Production: 1 BOPD**  
**After Stimulation: 5-6 BOPD**  
**Sustained: 4-5 BOPD**

In late May 1998, three shallow (530’) wells in Madison County, Illinois, responded well to GasGun stimulations. These wells were shot with nitroglycerine and produced for a time, but were later plugged with cement. The cement was drilled out in the 80’s. Some wells received some acid treatment, without much response. Each of the three wells produced about 1 BOPD. All three wells were shot with the GasGun and production in each increased to 5 to 6 BOPD plus some gas. After several months of pumping, sustained production was 4 to 5 BOPD.
Indiana

**Formation: Renault Limestone**  
**Formation Depth:** 583'  
**Prior Production:** 0.6 BOPD  
**After Stimulation:** 6 BOPD

In August 2002, a well in Daviess County, Indiana, was stimulated with a 4 foot GasGun. This well is a cased hole completion in the Renault limestone formation at a depth of 583 feet. Production increased from 0.6 to 6 BOPD.

![Renault Limestone](image)

**Formation: Cypress Sandstone**  
**Formation Depth:** 2431'  
**Prior Production:** 1.5 BOPD  
**After Stimulation:** 6 BOPD

In June 2000, a well in Posey County, Indiana, was stimulated with a 6 foot GasGun. This well is a cased hole completion in the Cypress sandstone formation at a depth of 2431 feet. Production increased from 1.5 to 6 BOPD.

![Cypress Sandstone](image)

**Formation: Palestine Sandstone**  
**Formation Depth:** 1848'  
**Prior Production:** 0 BOPD  
**After Stimulation:** 12-15 BOPD

In May 2000, a well in Posey County, Indiana, with no production whatsoever was readied for abandonment. An attempt to recover the casing failed. Instead of proceeding with abandonment efforts the well was stimulated with a 6 foot GasGun in a last ditch effort. The cased hole tool was placed at a depth of 1848 feet in the Palestine sandstone formation. Production of 12-15 BOPD was achieved.

![Palestine Sandstone](image)
Indiana

**Formation: Cypress Sandstone**
*Formation Depth: 2425’*
*Prior Production: 1 BOPD*
*After Stimulation: 18 BOPD*
*After 2 months: 15 BOPD*

In January 2000, another oil well in Posey County, Indiana, was stimulated with an 8 foot GasGun. This well is a cased hole completion in the Cypress sandstone formation at a depth of 2425 feet. Production increased from 1 to 18 BOPD, but also made 200 BWPD. The well was later hydraulically fractured, and since the GasGun had already broken down the formation it took only 900 psi pressure rather than the usual 1400 psi for this location.

**Formation: Tar Springs Sandstone**
*Formation Depth: 2206’*
*Prior Production: 0 BOPD*
*After Stimulation: 40 BOPD*
*After 4 months: 5-8 BOPD*

In October 1999, an oil well in Posey County, Indiana, was stimulated with a 4 foot GasGun. This well is a cased hole completion in the Tar Springs sandstone formation at a depth of 2206 feet. There had not been any production from this well prior to the stimulation, and the well produced 40 BOPD and no water after the stimulation. The lack of any water production is significant since hydraulic fracturing in this location typically results in large amounts of water. After four months, production leveled off at 5-8 BOPD.

**Formation: Hardinsburg sandstone**
*Formation Depth: 1766’*
*Prior Production: 1.5 BOPD*
*After Stimulation: 8 BOPD*
*Sustained: 8 BOPD*

In October 1999, an oil well in Vanderburgh County, Indiana, was stimulated with a 6’ GasGun. This well was completed open hole in the Hardinsburg sandstone formation at a depth of 1766 feet and had been previously shot with nitro. Production increased from 1.5 to 8 BOPD after the treatment and held steady at that level for four months.
Formation: Mississippi Chert  
Formation Depth: 4696'  
Prior Production: None (new well)  
After Stimulation: 450 MCF/D  

In February 2007, a new well in Edwards County, Kansas, was stimulated with a 10 foot GasGun. This well is a cased hole completion in the Mississippi chert formation at a depth of 4696 feet. Gas production came in at 450 MCF/D after the GasGun stimulation and there was no water production. The operator was very pleased with the results and has since shot several more wells.

Formation: Arbuckle Dolomite  
Formation Depth: NA  
Prior Production: None (new well)  
After Stimulation: 12 BOPD  

In September 2006, a new well in Ellsworth County, Kansas, was stimulated with a 6 foot GasGun. This well is a cased hole completion in the Arbuckle dolomite formation. After the well was logged, the engineer recommended to the operator that it be plugged. The operator completed the well anyway and tried to do a 500 gallon acid treatment. They couldn't get the formation to take the acid so they then decided to try the GasGun. After the GasGun, the operator was able to get the acid into the formation and production came in at 12 BOPD.

Formation: Viola Limestone  
Formation Depth: 2453'  
Prior Production: 1 BOPD & 6 BWPD  
After Stimulation: 4 BOPD & 27 BWPD  

In December 2005, a well in Butler County, Kansas, was stimulated with a 10 foot GasGun. This well is a cased hole completion in the Viola limestone formation at a depth of 2453 feet. Oil production increased from 1 BOPD to 4 BOPD and water production increased from 6 BWPD to 27 BWPD.
Kansas

**Formation: Arbuckle Dolomite**
**Formation Depth: 3369’**
**Prior Production: 1-2 BOPD**
**After Stimulation: 40 BOPD**
**Sustained: 8 BOPD**

In May 2004, a well in Barber County, Kansas, was stimulated with a 10 foot GasGun. This well is a cased hole completion in the Arbuckle dolomite formation at a depth of 3369 feet. Prior oil production was 1-2 BOPD. For a few days after the GasGun stimulation the well had some flush production at a rate of 40 BOPD. The well then leveled off at 8 BOPD.

<table>
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<tr>
<th>Prior Production</th>
<th>After GasGun</th>
<th>Sustained</th>
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<tbody>
<tr>
<td>1.5</td>
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<td>8</td>
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</tbody>
</table>

**Formation: Lansing-Kansas City Limestone**
**Formation Depth: 3078’**
**Prior Production: 4 BOPD**
**After Stimulation: 13 BOPD**
**After 2 months: 8.35 BOPD**

In December 2003, a well located in Osborne County, Kansas, was stimulated with an 8 foot GasGun. This is a cased hole completion in the Lansing-Kansas City limestone formation at a depth of 3078 feet. The well was producing approximately 4 BOPD prior to the GasGun shot. Immediately after the stimulation production increased to 13 BOPD and after two months settled in at 8.35 BOPD.

<table>
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<td>4</td>
<td>13</td>
<td>8.35</td>
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**Formation: Arbuckle Dolomite**
**Formation Depth: 2337’**
**Prior Production: None (New well)**
**After Stimulation: 25 BOPD**
**Sustained: 15 BOPD**

In December 2001, a new well in Butler County, Kansas, was stimulated with an 8 foot GasGun. This well is a cased hole completion in the Arbuckle dolomite formation at a depth of 2337 feet. Immediately after the stimulation production came in at 25 BOPD and quickly leveled of at 15 BOPD. One month later the well was still producing 15 BOPD.

<table>
<thead>
<tr>
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<th>After GasGun</th>
<th>After One Month</th>
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<tbody>
<tr>
<td>0</td>
<td>25</td>
<td>15</td>
</tr>
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</table>
Formation: Arbuckle dolomite  
Formation Depth: 3433'  
Prior Production: 1 BOPD  
After Stimulation: 6 BOPD  
Sustained: 6 BOPD  

In September 2001, a well in Barton County, Kansas, was stimulated with a 6 foot GasGun. This well is a cased hole completion in the Arbuckle formation at a depth of 3433 feet. In similar wells, acid treatments were frequently unsuccessful; excess pressure would invariably break into water. Production went from 1 to 6 BOPD after the GasGun treatment. This operator has successfully treated numerous other Arbuckle wells with the GasGun and has achieved consistent results.

Formation: Mississippi Chert  
Formation Depth: 4274'  
Prior Production: 1.7 BOPD & 20 BWPD  
After Stimulation: 17 BOPD & 85 BWPD  
After 2 weeks: 17 BOPD & 85 BWPD  

In August 2001, a well in Hodgeman County, Kansas, was stimulated with a 6 foot GasGun. This well is a cased hole completion in the Mississippi formation at a depth of 4274 feet. Production went from 1.7 to 17 BOPD after the GasGun treatment. This operator has successfully treated several other Mississippi chert wells with the GasGun and has achieved consistent results.

Formation: Arbuckle Dolomite  
Formation Depth: 3 wells at 2390'  
Prior Production: 8.7 BOPD combined  
After Stimulation: 30 BOPD combined  
Sustained: 30 BOPD combined  

In April 2001, three oil wells in Butler County, Kansas, were stimulated with GasGun tools of various sizes. These wells are both cased and open hole completions in tight sections of the Arbuckle formation at depths of approximately 2390 feet. In similar wells, acid treatments were frequently unsuccessful; excess pressure would invariably break into water. After the GasGun stimulations, low-pressure acid treatments were successful. Over a period of two months, the combined production of the three wells rose from 8.7 to 30 BOPD.
Formation: Knox Dolomite
Formation Depth: 1388'
Prior Production: 0 BOPD
After Stimulation: 33 BOPD
After one month: 20 BOPD

In October 2004, a well in Adair County, Kentucky, was stimulated with a 12 foot GasGun. This well was completed open hole in the Knox dolomite formation at a depth of 1388 feet. The well was drilled in 1994 and originally produced 90 BOPD, but then went to water. The operator did a cement squeeze to shut off the water, but was unable to get the well to produce again. They decided to try a GasGun to help them break past the suspected cement invasion into the formation. Immediately after the GasGun treatment the well went from 0 to 33 BOPD. After one month, production leveled off at 20 BOPD.

Formation: O’Hara Limestone
Formation Depth: 1716'
Prior Production: New well (No Natural Production)
After Stimulation: 24 BOPD
After Acid Treatment: 48 BOPD

In October 2001, a new well in McClean County, Kentucky, was stimulated with a 4 foot GasGun. This well is located near older producing wells. The well was swabbed down prior to the stimulation, and there was no natural production. This well is a cased hole completion in the O’Hara formation at a depth of 1716 feet. After the GasGun stimulation, the well was making 24 BOPD. A few days later the well was acidized and production increased to 48 BOPD.

Formation: Bethel sandstone
Formation Depth: 1861'
Prior Production: None (New well)
After Stimulation: 20 BOPD
After 2 months: 5 BOPD

In December 2000, a new well in Muhlenburg County, Kentucky, was stimulated with a 6 foot GasGun. This well is a cased hole completion in the Bethel formation at a depth of 1861 feet. The well was perforated and acidized with no production realized. After the GasGun stimulation, the well was making 20 BOPD. Two months later, production was 5 BOPD.
**Formation: Benoist Sandstone**  
**Formation Depth: 1766’**  
**Prior Production: None (New well)**  
**After Stimulation: 30 BOPD**

In August 2000, a new well in Muhlenberg County, Kentucky, was stimulated with a 6 foot GasGun. This well is a cased hole completion in the Benoist formation at a depth of 1766 feet. After 4 weeks production was recorded at 30 BOPD.

![Benoist Sandstone](image)

**Formation: Rosiclare Sandstone**  
**Formation Depth: 1790’**  
**Prior Production: None (New well)**  
**After Stimulation: Flowed at surface**  
**Sustained: 30 BOPD**

In July 2000, a new well in Muhlenberg County, Kentucky, was stimulated with a 4 foot GasGun. This well is a cased hole completion in the Rosiclare formation at a depth of 1790 feet. After stimulation the well began to flow at the surface. After 4 weeks the well was making 20 BOPD, and after 6 weeks it was making 30 BOPD.

![Roscilare Sandstone](image)

**Formation: Corniferous Dolomite**  
**Formation Depth: 1183’**  
**Prior Production: 5 MCF/D**  
**After Stimulation: 60 MCF/D for 8 months**  
**Sustained: 30 MCF/D**

In March 2000, a well in Wolfe County, Kentucky, was stimulated with a 10 foot GasGun. This well is a cased hole completion in the Corniferous formation at a depth of 1183 feet and was suspected to have cement invasion. Production increased from 5 MCF/D to 60 MCF/D for 8 months. After 9 months, production leveled off at 30 MCF/D.

![Corniferous Dolomite](image)
**Mississippi**

**Formation: Tuscaloosa Massive Sandstone**  
**Formation Depth: 8513’**  
**Prior Production: 100 BOPD**  
**After Stimulation: 150 BOPD**  
**Sustained: 150 BOPD**

In December 2006, a well in Jones County, Mississippi, was stimulated with a 10 foot GasGun. This is a cased hole completion in a Tuscaloosa sandstone formation at a depth of 8513 feet. After the GasGun stimulation, production increased by 50% going from 100 BOPD to 150 BOPD. Oil production was still at 150 BOPD a year later.

**Tuscaloosa Massive Sandstone**

<table>
<thead>
<tr>
<th></th>
<th>Prior Production</th>
<th>After GasGun</th>
<th>Sustained</th>
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<tr>
<td>Barrels of Oil per Day</td>
<td>100</td>
<td>150</td>
<td>150</td>
</tr>
</tbody>
</table>

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**Formation: Upper Tuscaloosa Sandstone**  
**Formation Depth: 8204’**  
**Prior Production: 40 BOPD**  
**After Stimulation: 80 BOPD**  
**Sustained: 80 BOPD**

In October 2006, a well in Jones County, Mississippi, was stimulated with a 4 foot GasGun. This is a cased hole completion in a Tuscaloosa sandstone formation at a depth of 8204 feet. After the GasGun stimulation, production increased from 40 BOPD to 80 BOPD. Oil production was still at 80 BOPD a year later.

**Upper Tuscaloosa Sandstone**

<table>
<thead>
<tr>
<th></th>
<th>Prior Production</th>
<th>After GasGun</th>
<th>Sustained</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barrels of Oil per Day</td>
<td>40</td>
<td>80</td>
<td>80</td>
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</table>
In November 2006, an injection well in Cattaraugus County, New York, was stimulated with the GasGun. The well is part of a large waterflood field and was completed open hole in the Bradford sandstone formation at an approximate depth of 1600 feet. Prior to the stimulation the operator could not inject any fluid at all. 130 feet of the Bradford sand was stimulated with the GasGun. The operator was immediately able to inject an average of 90 BWPD. After several months the well was still holding at its post stimulation rates. For comparison, the operator tried to stimulate two similar wells with nitroglycerine. After the nitro shots they could only inject a maximum of 15 BWPD and had significant well clean out expenses. Based on these results the operator went on to stimulate all the injection wells and many of the producing wells in the field with the GasGun. To date, over 500 GasGuns have been shot in this particular field.

In November 2006, an injection well in Cattaraugus County, New York, was stimulated with the GasGun. The well was completed open hole in the Bradford formation at an approximate depth of 1800 feet. Prior to the stimulation the operator could not inject any fluid at all. 120 feet of zone was stimulated with the GasGun. They were immediately able to inject an average of 60 BWPD. After several months the well was still holding at its post stimulation rates.
**Formation: Beekmantown Dolomite**  
**Formation Depth:** 3745'  
**Prior Production:** 35 MCF/D  
**After Stimulation:** 140 MCF/D  
**Sustained:** 100 MCF/D

In March 1999, we stimulated an open hole Beekmantown dolomite well at 3745 feet in Ross County, Ohio. This well was drilled about six months previously, and production had fallen to 35 MCF/D with a casing head pressure of 150 psi. Immediately after shooting an 8 foot GasGun, this well began making 140 MCF/D at a casing head pressure of 650 psi. After two weeks, the production leveled off at 100 MCF/D.

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**Formation: Oriskany Sandstone**  
**Formation Depth:** 1567'  
**Prior Production:** 10 MCF/D  
**After Stimulation:** 160 MCF/D

In September 1998, a gas well in Lake County, Ohio, was stimulated with a 6 foot GasGun. This well was completed open hole in the Oriskany sand at a depth of 1567 feet. The well had been produced since 1985, and production had fallen from 40 MCF/D to 10 MCF/D. The GasGun stimulation was successful in increasing gas production to 160 MCF/D.

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**Formation: Rose Run Sandstone**  
**Formation Depth:** 4230'  
**Prior Production:** 3-5 BOPD  
**After Stimulation:** 40 BOPD  
**Sustained:** 18 BOPD

In June 1998 we stimulated an open hole Rose Run sand at 4230' in Hocking County, Ohio. The well had been making 3 to 5 BOPD, but initial flows when the well was drilled in February and logs suggested that this well should perform much better. There was evidence that the well had been damaged when it had been killed with 120 BBL of unfiltered brine. The well was stimulated with an 8 foot GasGun and began making 40 BOPD. Production level was sustained at 18 BOPD.
Formation: Viola Limestone
Formation Depth: 4227'
Prior Production: 8 BOPD
After Stimulation: 26 BOPD
Sustained: 26 BOPD

In July 2007, a well in Pottawatomie County, Oklahoma, was stimulated with three 4 foot GasGuns. This well is a cased hole completion in the Viola limestone formation at a depth of 4227 feet. This is an old well, and the operator suspected he had cement invasion in the formation. Oil production increase from 8 BOPD to 26 BOPD after the GasGun treatment.

Formation: Senora Sandstone
Formation Depth: 588'
Prior Production: None (new well)
After Stimulation: 250 MCF/D

In November 2006, a new well in Hughes County, Oklahoma, was stimulated with a 6 foot GasGun. This well is a cased hole completion in the Senora sandstone formation at a depth of 588 feet. After the GasGun stimulation, the well came in at 250 MCF/D. The operator has since throttled the well back to 50 MCF/D and is very pleased with the results.

Formation: Prue Sandstone
Formation Depth: 2890'
Prior Production: None (new well)
After Stimulation: 80 BOPD & 30 MCF/D

In June 2006, a new well in Creek County, Oklahoma, was stimulated with two 10 foot GasGuns. This well is a cased hole completion in the Prue sandstone formation at a depth of 2890 feet. After the GasGun treatment, the operator did a small frac job, which was accomplished with a 30% reduction in treating pressure. When the well was put on production it was making 80 BOPD and 30 MCF/D. The operator believes most of the improvement in production was a result of the GasGun.
Formación: Dutcher Sandstone  
Depths: 2686'

Producción Anterior: 3 BOPD @ 150psi  
Producción Después de la Estimulación: 13 BOPD @ 600psi

En junio de 2005, un nuevo pozo en Creek County, Oklahoma, fue estimulado con un GasGun de 4 pies. Este pozo es una perforación de unión en la formación Dutcher sandstone a una profundidad de 2686 pies. La producción inicial de 3 BOPD a 150 psi fue insatisfactoria para el operador. Decidieron tratar el pozo con un GasGun seguido de un pequeño tratamiento con ácido. Después del tratamiento, el pozo inició la producción con 13 BOPD a 600 psi.

Formación: Fortuna Sandstone  
Depths: 2042'

Producción Anterior: 8 BOPD  
Producción Después de la Estimulación: 40 BOPD  
Producción Después de 2 meses: 30 BOPD

En diciembre de 2004, un pozo de petróleo en el condado de Caddo, Oklahoma, fue estimulado con un GasGun de 4 pies. Este pozo es una perforación de unión en la formación Fortuna sandstone a una profundidad de 2042 pies. La producción de petróleo se incrementó inmediatamente de 8 a 40 BOPD y continuó a ese nivel durante 30 días. La producción disminuyó a 30 BOPD durante los siguientes 60 días y luego se estabilizó en 10 BOPD.

Formación: Cleveland Sandstone  
Depths: 1288'

Producción Anterior: 3 BOPD  
Producción Después de la Estimulación: 16 BOPD  
Sostenido: 20 BOPD

En junio de 2004, un pozo en Osage County, Oklahoma, fue estimulado con un GasGun de 10 pies. Este pozo es una perforación de unión en la formación Cleveland sandstone a una profundidad de 1288 pies. La producción de petróleo aumentó de 3 BOPD antes de la estimulación a 16 BOPD inmediatamente después. La producción continuó a aumentar a 20 BOPD tres días después.
**Oklahoma**

**Formation: Misener Sandstone**
Formation Depth: 5946'
Prior Production: 2.5 BOPD
After Stimulation: 134 BOPD
After 2 weeks: 80 BOPD

In June 2002, a well in Grant County, Oklahoma, was stimulated with a 4 foot GasGun. This well is a cased hole completion in the Misener formation at a depth of 5946 feet. This well was drilled in 1996 with the completed formation only 2 feet from water. The customer initially tried to stimulate the formation with a diesel frac, but was unable to break it down. Immediately after the GasGun stimulation, it produced 134 BOPD. The well produced 1200 BBL in the first 12 days and has leveled out at 80 BOPD.

**Formations: Booch Sandstone**
Formation Depth: 3111'
Prior Production: None (recompletion)
After Stimulation: 19 BOPD
After 3 months: 10 BOPD

In April 2002, a well in Seminole County, Oklahoma, was stimulated with a 6 foot GasGun. This is a cased hole well which was recompleted in the Booch formation at a depth of 3111 feet. Immediately after the stimulation production came in at 19 BOPD. Three months later production was reported to have leveled off at 10 BOPD. This production surpassed the customer's expectations.

**Formation: Cromwell Sandstone (waste disposal)**
Formation Depth: 3184'
Prior to stimulation: well producing water
After Stimulation: well on heavy vacuum
Sustained: well still on heavy vacuum

In February 2002, a waste disposal well in Hughes County, Oklahoma, was stimulated with two 10-foot GasGuns. This well is a cased hole completion in the Cromwell formation at a depth of 3184 feet. Before the shot, the well was producing water and required significant injection pressure in order to take any fluid. Immediately after the GasGun shots, the well went on a very heavy vacuum. As of the date of this writing (9 months later), the well is still on heavy vacuum. The customer has disposed of as much as 1200 BWPD and could take much more if he needed it to.

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**Graphs:**

**Misener Sandstone**
- Prior: 2.5 BOPD
- After: 134 BOPD
- After 2 weeks: 80 BOPD

**Booch Sandstone**
- Prior: None (recompletion)
- After GasGun: 19 BOPD
- After 3 Months: 10 BOPD

**Cromwell Sandstone (waste disposal)**
- Prior Production: well producing water
- After Stimulation: well on heavy vacuum
- Sustained: well still on heavy vacuum
Pennsylvania

Formation: Gordon Sandstone (Injection Wells)
Formation Depth: 2 wells at approx. 2450’
Prior Injection: 0 BWPD @ 1200 psi
After Stimulation: 150 - 200 BWPD @ 1200 psi
Sustained: 150 - 200 BWPD @ 1200 psi

In March 2007, two injection wells in Washington County, Pennsylvania, were stimulated with the GasGun. The wells were completed open hole in the Gordon formation at an approximate depth of 2450 feet. Prior to the stimulation the operator could not inject any fluid at all at 1200 psi. After the GasGun, they were immediately able to inject an average of 150 - 200 BWPD at 1200 psi. Several months later the wells were still holding at their post-stimulation injection rates.

Formation: Gordon Sandstone (Injection Well)
Formation Depth: 2360’
Prior Injection: 70 BWPD @ 1200 psi
After Stimulation: 300 BWPD @ 1200 psi
Sustained: 300 BWPD @ 1200 psi

In February 2007, an injection well in Washington County, Pennsylvania was stimulated with a 6 foot GasGun. This well is a cased hole completion in the Gordon formation at a depth of 2360 feet. Prior to the stimulation the operator could inject 70 BWPD at 1200 psi. After the GasGun, they were immediately able to inject 300 BWPD at the same pressure. After several months the injection rate was still holding at 300 BWPD.

Formation: Lockport Dolomite
Formation Depth: 5208’
Prior Production: 65 MCF/D
After Stimulation: 120 MCF/D
Sustained: 120 MCF/D

In August 2002, a well in Mercer County, Pennsylvania, was stimulated with a 10 foot GasGun. The well was completed open hole in the Lockport dolomite formation at a depth of 5208 feet. Prior to the stimulation the well was making 65 MCF/D. After the GasGun, the well showed no increase in production for nearly 3 months. The operator then noticed that the well pressure began to build, and the flow started to increase. Within about a week’s time the well settled in 120 MCF/D. The operator believes that too much fluid was put in the well during the workover, and that ultimately it took some time to get that fluid off the formation.
Formation: Canyon Sandstone  
Formation Depth: 2962’  
Prior Production: None (new well)  
After Stimulation: 190 MCF/D  

In November 2007, a new well in Sutton County, Texas, was stimulated with two 4 foot GasGuns and a 10 foot GasGun. This well is a cased hole completion in the Canyon sandstone formation at a depth of 2962 feet. After the three GasGun shots, the well came in making 190 MCF/D. The operator was very pleased with the results of the stimulation.

Formation: San Andres Dolomite  
Formation Depth: 1460’  
Prior Production: 0 BOPD  
After Stimulation: 42 BOPD & 70 BWPD  
Sustained: 30 BOPD & 2 BWPD  

In October 2005, a well in Crockett County, Texas, was stimulated with two 10 foot GasGuns. This is a cased hole well which was recompleted by drilling out an old bridge plug, and then reperforating the San Andres formation at a depth of 1460 feet. There was no show of oil after the perforating was completed. The operator felt he needed to use the GasGun to get deeper into the formation. Immediately after the stimulation, production came in at 15 BOPD and 70 BWPD. On the second day it made 38 BOPD & 14 BWPD. On the third day it made 42 BOPD and 2.5 BWPD. Oil production remained steady at 40 BOPD for a month and then the operator decided to throttle it back to 30 BOPD.

Formation: Flippen Limestone  
Formation Depth: 2352’  
Prior Production: 3 BOPD  
After Stimulation: 8 BOPD & 30 MCF/D  

In January 2004, a well in Taylor County, Texas was stimulated with a 6 foot GasGun. This well is an open hole completion in the Flippen sandstone formation at a depth of 2352 feet. After the GasGun stimulation, production went from 3 BOPD and 1 BWPD to 8 BOPD, 1 BWPD, and 30 MCF/D.
**Texas**

**Formation: Devonian Limestone**  
**Formation Depth: 9798’**  
**Prior Production: 29 BOPD**  
**After Stimulation: 82 BOPD**

In November 2002, a well in Crane County, Texas, was stimulated with a 12 foot GasGun. This well was completed open hole in a Devonian lime at a depth of 9798 feet. The well had some paraffin problems, and its production, which started out at 135 BOPD, had slowly fallen to 29 BOPD. After the GasGun stimulation, production came in at 82 BOPD.

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**Formation: Not Available**  
**Formation Depth: 714’**  
**Prior Production: None (new well)**  
**After Stimulation: 12 BOPD & 60 BWPD**

In August 2002, a shallow well in Montague County, Texas, was stimulated with an 8 foot GasGun. This well is a cased hole completion with the treated interval at a depth of 714 feet. The operator has several hundred wells in the area and frequently stimulates them with a small hydraulic fracture treatment. The frac treatments typically bring the wells in at 2 BOPD and 200 BWPD. Production after the GasGun stimulation was 12 BOPD and 60 BWPD.

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**Formation: Devonian Limestone**  
**Formation Depth: 7500’**  
**Prior Production: 38 BOPD & 37 MCF/D**  
**After Stimulation: 100 BOPD & 55 MCF/D**  
**Sustained: 55 BOPD & 55 MCF/D**

In May 2002, a new well in Crane County, Texas, was stimulated with two 10 foot GasGuns. This is an open hole well which was completed in a Devonian formation at a depth of approximately 7500 feet. Oil production went from 38 to 100 BOPD, and gas production went from 37 to 55 MCF/D after the GasGun treatment. Prior to the stimulation, the operator did some production modeling based on six 20 foot long fractures extending out from the wellbore. Based on this modeling they anticipated initial production to increase to 68 BOPD. The operator was very pleased to see actual results come in better than they expected.
West Virginia

**Formation: Devonian Sandstone**  
**Formation Depth:** 2987'  
**Prior Production:** 5 BOPD  
**After Stimulation:** 40 BOPD  
**Sustained:** 40 BOPD

In July 2007, a well in Harrison County, West Virginia, was stimulated with a 3 foot GasGun. This is a cased hole completion in a Devonian sandstone formation at a depth of 2987 feet. Production increased from 5 BOPD to 40 BOPD. After 6 months, production was still holding at post stimulation levels.

![Devonian Sandstone Production](image1)

**Formation: Devonian Sandstone**  
**Formation Depth:** 2963'  
**Prior Production:** 5 BOPD  
**After Stimulation:** 15 BOPD  
**Sustained:** 15 BOPD

In July 2007, a well in Harrison County, West Virginia, was stimulated with a 3 foot GasGun. This is a cased hole completion in a Devonian sandstone formation at a depth of 2963 feet. Production increased from 5 BOPD to 15 BOPD. After 6 months, production was still holding at post stimulation levels.

![Devonian Sandstone Production](image2)

**Formation: Gordon Sandstone (Injection Wells)**  
**Formation Depth:** 3 wells at 3500'  
**Prior Injection:** 0-50 BWPD  
**After Stimulation:** 100 - 150 BWPD  
**Sustained:** 100 - 150 BWPD

In May 2007, three injection wells in Wetzel County, West Virginia, were stimulated with the GasGun. These wells were completed open hole in a Devonian sandstone formation at an approximate depth of 3500 feet. Before the stimulations, injection rates ranged between 0 to 50 BWPD. After the GasGun stimulations, the injection rates increased in all 3 wells and now range from 100 to 150 BWPD. After 6 months, injection rates were still holding at their post stimulation levels.

![Gordon Sandstone Injection](image3)