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results have reduced the relative number of wells stimulated with classic high explosives, and this method has largely been replaced by the use of propellants.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 increasingly important to operators trying to optimize their fracturing programs. 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 program 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 neighboring wells that had been conventionally fractured. As a result the operator revamped its fracturing program 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 it had 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 contained 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 Gun 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.