PRACTICAL APPLICATIONS OF
DYNAMIC GAS PULSE LOADING WELL STIMULATION TECHNIQUES

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ABSTRACT

In recent years there has been a great deal of interest in the use of propellants to generate high pressure gas pulses for fracturing hydrocarbon bearing formations. Much of the R & D effort in these Dynamic Gas Pulse Loading (DGPL) techniques has centered around their ability to induce multiple radial fractures in naturally fractured reservoirs, thereby greatly increasing the probability of intersecting fractures. Servo-Dynamics, Inc. has taken a somewhat broader approach to DGPL and through several thousand practical field applications, has also shown the process to be a valuable aid in the workover and completion of conventional cased-hole wells. By inducing multiple fractures with very limited vertical growth, DGPL has proven to be very effective in the breakdown of tight zones, overcoming skin damage, and stimulation of zones near water, among other things.

In most applications success rates of over 90% have been achieved, at times permitting the production of zones which otherwise could not have been completed. Following a review of the state-of-the-art this paper presents the basic principals underlying DGPL stimulation, its strengths and weaknesses, and documents its effectiveness in various applications through case histories. Finally, basic guidelines are presented for evaluating if a well could benefit from a DGPL treatment.

INTRODUCTION

The petroleum industry has been stimulating wells for over a century in an attempt to increase well productivity. Among the many techniques that were available for well stimulation were those involving high energy explosives such as TNT and Nitroglycerin. However, problems of wellbore damage, safety and unpredictable results greatly reduced the relative number of wells stimulated using high energy explosives[1]. Research was directed towards improving already established stimulation techniques such as hydraulic fracturing and acidizing. Industry has found, however, that these conventional stimulation techniques were not always applicable due to the harmful side effects of certain stimulation fluids that could react negatively with the formation, causing clays or other fines to swell or migrate, reducing the formations effective permeability or porosity. Operators determined that the use of expensive stimulation methods were not always necessary. The benefits of low cost stimulation techniques involving chemical energy sources became more apparent, inspiring some to continue research in this area.

New light was shed in the late 1950's on chemical energy sources with the introduction of the Dynamic Gas Pulse Loading technique by Henry Mohaupt, who has also been credited with the invention of the armour piercing lined shaped charge. The principal was introduced in 1947 as the jet process; which is the universally accepted method of perforating today. The DGPL technique, given the name **STRESSFRAC®**, is the registered trademark for Servo-Dynamics, Inc.

This DGPL treatment may be characterized as a wireline run, high pressure/low volume CO_2 treatment. Over a thousand practical field applications have shown the process to be a valuable aid in the workover and completion of conventional cased hole wells. Of the 620 intervals stimulated by Servo-Dynamics, Inc. in 1985 2% were in open hole completions in naturally fractured reservoirs. Operators utilizing this DGPL technique have been extremely satisfied. About 70% of the wells treated represented or resulted in repeat business.

Areas of application and the concept of DGPL is further described in this paper.

DGPL - A Dynamic Gas Pulse Loading (DGPL) Technique

DGPL is a propellant-actuated gas generating stimulation technique designed to function as a multiple fracture and fracture propagation device for both standard cased and open hole completions. Unlike other stimulation techniques, the DGPL system does not follow the path of least resistance. Rather, its unique ability to generate controlled high pressure gases rapidly across the zone of interest ensures that the entire interval has been stimulated. The process must be augmented by the use of a fluid head that acts as a gas tamping device and provides fluid coupling between the CO_2 gas generated and the zone of interest.

The DGPL process incorporates the pressure load generated by the CO_2 gas such that:

1. the peak radial stress is below the flow stress of the rock
2. the peak hoop stress is above the tensile strength of the rock
3. the initial loading rate is large enough to initiate multiple fractures
4. the duration of the pulse and gases generated by the propellant is sufficient to drive the fractures created until the pressure drops essentially to lithostatic conditions
5. The working pressures are below well-damage levels for casing or crushing levels for strata.

The pressures required to propagate a fracture are extremely close to the in-situ pressures as seen during a hydraulic frac treatment; the hydraulic frac treatment being conducted at pressures slightly higher than the minimum in-situ fracture stress. Usually a time scale requiring hundreds of seconds is involved. This results in a pair of wing type fractures usually oriented perpendicular to the least principal stress. Whereas DGPL creates multiple fractures at much greater pressures than the minimum in-situ stresses in a fraction of a second. While the fractures do not extend past the near wellbore area they may link the well to natural factures which normally would not be intercepted by a standard completion technique. Well tests show that an efficient drainage channel in the fracture is created, despite the absence of a propping agent. This is due to the extremely rapid loading rate of DGPL accompanied by a high velocity gas erosion of the fracture zone (placer action).

As a matter of interest, Fig. 1 summarizes the damage induced by standard perforation techniques. Usually acid washes are used to help clear up the blocked perforations, but operators who have had the opportunity to use the DGPL system are finding the perforation efficiency is much higher than offered by an acid cleanup treatment.[2]

Fig. 2 shows the domain of the hydraulic and DGPL process in terms of the in-situ conditions. The casing strength is added to the figure to show the range available for DGPL up to "normal" casing strengths. Explosive-induced stresses would fall off the graph to the right of the casing strength limit. Experience indicates that cemented casings exhibit higher casing strengths. Many wells have been treated at pressures such that ΔS in Figure 2 was equal to the "safe" casing stress without any noticeable damage.[2]

Advantages Of A DGPL Well Stimulation Technique

The DGPL System can be used in a number of well problem areas. Whether the system is used solely on its own or to complement other stimulation techniques, wellbore area stimulation can be assured. The increased perforation efficiency from a DGPL application will apply to the following problem areas often encountered.

The DGPL System Offers:

Improved Perforating Efficiency:

Significant advantages as a pre-frac or pre-acid treatment conditioning tool for tight formations. Following a DGPL application conventional stimulation techniques have shown substantial increases in feed rate and lowering of injection pressures, all a function of the improved perforation efficiency.

Formation Breakdown:

Over 90% of the wells treated have exhibited significant reduction or elimination of formation breakdown pressures for subsequent conventional stimulation treatments.

Skin Damage:

The fractures from the DGPL application penetrate and substantially reduce the effects of any skin damage caused by mud, cement invasion, workovers, or well-killing fluids and scale from the precipitation of deposits from source water. Pressure build-up tests run on both oil and gas wells before and after the DGPL stimulation show substantial decreases in the skin factor. Reductions by an order of magnitude may be expected in heavily damaged wells.

Absence of Casing or Cement Damage:

Numerous casing and cement evaluation logs have shown that there are no detrimental effects to the casing or cement bond from a DGPL treatment, provided there is a good bond present above and below the zone when the treatment is performed.

Treatment of Thief Zones or Close Oil/Water Contacts:

In the controlled elevated gas regime associated with the DGPL process. The mechanism of formation fracture initiation does not lead to the fractures created by DGPL to follow the path of least resistance as invariably occurs with other conventional stimulation techniques. The multiple fractures are predominantly horizontal in direction with limited vertical growth; providing an excellent stimulation technique for wells exhibiting close oil/water contacts or thief zones.

Selective Stimulation:

The selective nature of the DGPL process results in gases generated to be applied across the zone of interest. This allows stimulation of additional zones above or below the original zone of interest without the need of isolation devices.

Analytical Applications:

DGPL has been found to be a low cost effective method of zone evaluation. Data obtained from the DGPL treatment assists in the decision making process as to what, if any, further completion work may be necessary. Such a situation may occur in a new well where the zone of interest has been drill-stem-tested with negative results, however,if nearby wells are productive; should it be cased and tested further or abandoned.

Non-Damaging:

The DGPL treatment generates a non-damaging CO_2 gas medium which is generally compatible with all formation types.

Injection Wells:

Low cost makes the DGPL process a viable and effective treatment technique for stimulating injection wells by improving perforation efficiency to give an improved injection profile across the interval of interest.

Safety:

The DGPL tool is very stable and safe. It does not require the heavy equipment on surface needed for many completion practices, thus eliminating the hazards associated with such practices. The entire DGPL tool and assembly are contained within the wellbore.

Situations may arise where other conventional stimulation techniques may not be applicable due to the nature of the well problem. The DGPL treatment has been used successfully in a few of these areas:

- treatment of formations that have screened out due to an insufficient feed rate resulting from decreased perforation efficiency.

- treatment of formations where the operator is unable to establish a feed rate into the zone of interest.

- cement squeezes, successful in restricting fluid flow from an undesirable zone, may have lowered or completely shut off production from the desired zone of interest. Reperforating is insufficient and acid may contact the undesireable zone as seen in repeated cement squeeze situations.

Areas Limiting The DGPL Application:

Fines:

Areas exhibiting a continuous, high migration of fines will show an initial improvement from a DGPL stimulation. However this improvement will diminish in direct relation to the rate of fines migration and buildup.

Unconsolidated Sandstones:

Any fractures resulting from the DGPL process will be subject to the integrity of the formation and its ability to heal itself. Generally, unconsolidated formations tend to heal themselves rapidly, eliminating any benefit which may have been derived. The only benefit in this type of application is its use as a perforation or slotted liner cleaner.

Tight Formations Not Exhibiting Natural Fracturing:

Removal of skin damage and high breakdown pressures would be the only advantage derived from The DGPL Process. These formations require high volume, low rate hydraulic fracturing.

Compatibility Problems:

The DGPL Process can be used as part of an overall workover strategy in the treatment of wells exhibiting damage due to emulsions or other compatibility problems.

WELLBORE CONFIGURATION NECESSARY FOR PROPER DGPL APPLICATION:

Certain wellbore conditions must exist before a DGPL stimulation can be considered. These conditions are based on data accumulated from controlled experimentation and experience resulting from actual field applications.

- the casing must be perforated with a shot-density of at least 4 shots per foot, preferably oriented at 90^{0} to optimize the performance of the DGPL treatment.

- a good cement bond should exist between the casing and the formation. This will ensure that there are no detrimental effects to the casing.

- a minimum of 500 psi is necessary in the wellbore when running the DGPL . In the event that a formation is not capable of supporting the required fluid head or is very sensitive to any fluid type, special tools requiring a minimum hydrostatic of 150 psi can be made available.

FIELD APPLICATION AND SERVICE

When an operator contemplates using The DGPL Process on a well, it is recommended that all well data be readily available for review. The information is necessary to ensure that the well is a suitable candidate and that a program is carefully engineered to fit the overall completion or rework procedure.

The operator is offered two alternatives for running the DGPL into his well;

1. The DGPL tool can be run through tubing, although tubing size will restrict the size of the tool that can be run. This may affect the overall effectiveness of the stimulation, depending on wellbore conditions.

2. The recent introduction of a retrievable carrier has added dexterity to The DGPL System. The carrier supplies additional containment of the energy created, making the system more efficient.

Another advantage to running the DGPL with the carrier is a special pressure gauge housed inside the carrier assembly which allows the measurement of the peak-pressure load generated by the process.

The DGPL tool (Fig. 3) consists of an aluminum or polycarbonate housing (housing removed when using carrier system), loaded with a solid fuel propellant. Through the centre of the tool runs an ignition tube necessary for actuating the propellant. The tool is lowered into the wellbore on an electric wireline. It is then logged into position with the use of a casing collar locator (CCL). Once satisfied that the tool has been properly positioned, an electric current is sent from the surface, igniting the tool. The ensuing chemical reaction generates the desired high pressure low volume CO_2 gases.

CASE HISTORIES

Several thousand wells have been successfully treated using The DGPL Process. The wells presented in this report were taken from a few producing regions across North America. The wells represent the successful application of the DGPL system to specific problem well types.

FIELD: East Texas
FORMATION: Rodessa Limestone with 5 md permeability and 14% porosity.
SOLUTION: **STRESSFRAC**
RESULTS: Previous injection rate 300 bbls/day at 150 psi
After
STRESSFRAC: 400 bbls/day at 30 psi

FIELD: Davey (Central Alberta)
FORMATION: Basal Belly River Sandstone with 10 md permeability and 7% porosity.
PROBLEM: Migrating fines causing perforation plugging.
SOLUTION: **STRESSFRAC**

RESULTS: Prior production - 9.5 BOPD
After
STRESSFRAC: 25 BOPD
After
One Year: 22 BOPD

FIELD: Rangely (Western Colorado)
FORMATION: Weber Sandstone
PROBLEM: Prior acid work had destroyed most of the 7" casing and problem was compounded by serious scale build-up across the zone. Need to isolate and treat six best intervals across the zone to break through scale.
SOLUTION: **STRESSFRAC**
RESULTS: Prior production: 1600 bbls/day, 99% water, 1% oil
After
STRESSFRAC: 3900 bbls/day, 98% water, 2% oil

FIELD: Powder River Basin (Wyoming)
FORMATION: Minnelusa Sandstone with 15 md permeability and 11% porosity.
PROBLEM: Near wellbore damage and close oil/water contact.
SOLUTION: **STRESSFRAC**
RESULTS: Prior production - 19 BOPD - Swab test
After
STRESSFRAC: 96 BOPD - Swab test
Well was then put on pump;
After one week - 50 BOPD - no water
one month - 60 BOPD - no water
two months - 75 BOPD - no water

GENERALIZATION AND CONCLUSIONS

The Dynamic Gas Pulse Loading technique is a valuable completion aid with a wide variety of field applications. In most areas of application the DGPL technique is meant to be used as a complement to, rather than as a substitute, for conventional completion techniques. Each application must be carefully engineered to fit the overall completion or workover procedure or the chances for a successful treatment may diminish. With its non-damaging medium, low cost and wide range of applications, the DGPL technique is an attractive alternate stimulation technique for both major and independent operators.

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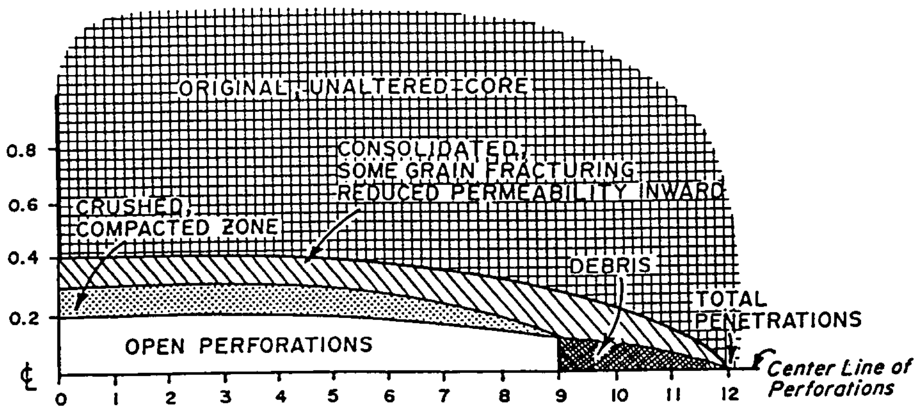

Figure 1

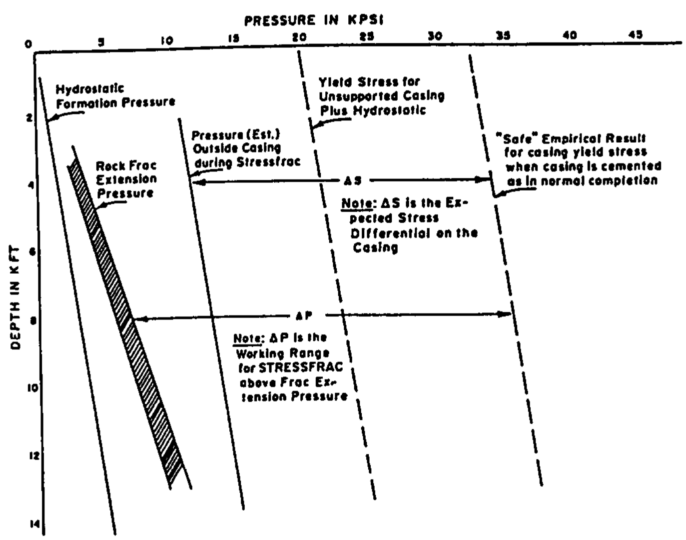

Figure 2

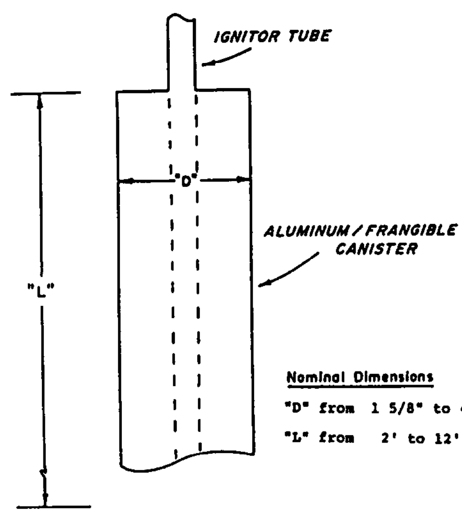

Figure 3—Stressfrac tool configuration