PRACTICAL APPLICATIONS FOR OVERBALANCED PERFORATING AND SURGING

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ABSTRACT

Extreme overbalanced perforating and surging has been used in many types of reservoirs as a completion method since the June, 1990. This method of completion is not a panacea for the petroleum industry, but it does address many of the problems associated with low pressure and/or low permeability reservoirs. This paper will present some of the more practical applications for today's completion practices. The cases presented include skin removal, massive hydraulic fracture replacement, and treatment volume reductions. The possible application of this process for coal seam wells will also be discussed.

INTRODUCTION

Operators have accepted underbalanced perforating as the standard completion practice for maximizing perforation productivity. Unfortunately, most operators are working in older reservoirs where the bottomhole pressure has been depleted through production. In gas reservoirs the problem that more often needs to be addressed is the low permeability. In both situations there is typically less pressure in the reservoir than is required to effectively underbalance surge all the perforations clean. The common "solution" to poor completion efficiency is a breakdown treatment with acid or water, sometimes incorporating ball sealers, to improve the flow path to the wellbore from the reservoir. Once again, pressure and permeability variations will compromise the effectiveness of the breakdown. If the breakdown pressure could be applied in a more rapid manner and at a pressure higher than the rock fracture gradient then it could be a more effective tool for optimizing production. These are the premise that lead to the application of overbalanced pressure.[1]

The application of the extreme overbalance pressure for perforating or surging is a simple process. In a perforating application (Fig. 1), the gun is positioned prior to pressuring the wellbore. The fluid level is adjusted to a predetermined level, and then the additional pressure required is applied using a compressible gas. With this configuration the pressure may be applied to the entire system, or it can be contained to the tubing by using a vent assembly. The guns are fired after the pressure has reached the predetermined level. This will apply for tubing conveyed or wireline conveyed perforating guns. The surge application is similar except the pressure must be contained in the tubing string until a frangible disk is broken or sheared.

Through repeated use of extreme overbalanced perforating and surging in an area a set of guidelines have been developed. The minimum desired overbalanced gradient is 1.3 psi/ft. Typically the pressure limits of the tubulars (casing and tubing) and downhole equipment are used to determine the actual job pressure. Nitrogen is the preferred gas used to "energize" the system. The amount of work that can be done is directly proportional to the nitrogen volume. The liquid volume in the casing and tubing is limited to 1000' or less. This limit will allow for less energy to be expended in the form of friction pressure which means there is more pressure available to displace the fluid. These guidelines are considered "rules of thumb" and not absolutes. There will always be unique cases that require exception to the rules.

SKIN REMOVAL

The first application of extreme overbalance perforating was in the Strawn Sand in Coke County, Texas. The production interval varied from 15-70' over a gross interval ranging from 15-150' at a depth of approximately 6000'. The porosity in the pay averaged 20%. The reservoir pressure ranged from 1400 to 2200 psi. Permeability varied greatly from .06 md to 1.2 md.

The conventional optimized completion before using overbalanced perforating consisted of the following:

1. Perforating with a casing gun with 1000-1500 psi underbalance.
2. Run tubing and swab test to evaluate.
3. Breakdown interval with lease crude, swab and evaluate.
4. Fracture stimulate with 125-200 bbls gelled oil and 5-10000 lbs sand.
5. Swab test well or put on rod pump to recover load oil and evaluate.

The entire process would take 15-18 days before the well was producing formation hydrocarbons. Typically, the producer would begin as a low volume oil well producing at 5-10 BOPD with 100 MCFD gas or less, and would eventually become a gas well producing at rates of about 300 MCFD.

The new optimized completion eliminated several of the interim steps, and was truly an optimized procedure. The wells were no longer perforated underbalanced. This was decided because of the unpredictability of the reservoir pressure. This also reduced the time that had been required to swab down the casing to achieve the underbalance into the wellbore. All of the intermediate steps that called for testing were eliminated. This testing had proven to be nothing but wasted effort. Almost all of the wells needed to be treated for skin damage. Tubing conveyed perforating guns were used to further reduce the time required to complete the wells. In many cases the cost of the TCP was the same as the wireline conveyed casing guns. All of these changes resulted in less time and money being spent on a well, and put production on line as much as two weeks earlier.

The new procedure was as follows:

1. Circulate the hole with lease crude.
2. Run TCP on packer and tubing.
3. Perforate the well with an applied pressure gradient of ~ 1.3 psi/ft and follow immediately with commingled nitrogen, oil and 1000 # sand.
4. put well to the system after cleaning up the nitrogen from the wellstream.

This procedure wold take 3-5 days. It was not uncommon for wells using this procedure to be producing gas to the pipeline within 3 hours of perforating. These wells were gas producers from the start of production. Gas production rates were as high as 1200 MCFD with 2-3 BOPD. The average rate wa sin excess of 400 MCFD.

REPLACEMENT FOR MASSIVE HYDRAULIC FRACTURING

The Prairie Du Chein (PDC) reservoir in Michigan was targeted as having potential for benefitting from the overbalanced surge treatments. The PDC has about 10% porosity and has a highly variable permeability ranging from .05 to 3.0 md. The average net perforation interval is 30' at a depth of 9800'. In the past, the reservoir had been perforated underbalanced, tested, broken down with acid, tested again, and ultimately fracture stimulated for production. Most of the time the perforating and break down failed to show if the reservoir was productive salt between stages for diversion. Table 1 summarizes the results of the first wells. Average production rates for these five wells was 41 BOPD and 418 BWPD. The average WOR for the entire field at the time of this program was 47.

Even with the favorable results of the conventional completion, it was decided that the overbalanced surge method would have application in this program. The next tenwells were perforated with a full column of fluid using a casing gun. The full fluid column resulted in a slight overbalance when perforating. The packer and tubing were run with a pump out assembly below the packer. The shear setting of the assembly would result in a surge pressure of 4700 psi at the perforations, or a 1.5 psi/ft gradient. Table 2 summarizes the ten wells that used the overbalance procedure. Diversion of the acid was taken care of by the high displacement rates at the initiation of the surge. The average production rates from these wells was 47 BOPD and 368 BWPD. The average field WOR at this time was 67.

The first two surge applications only used 650 gallons of acid. The "A" and "B" zones were individually swab tested. From this testing it was determined that the "A" zone was taking more of the acid than the "B" interval. The "B" zone was overbalanced surged separately on these two wells. The fluid inflow did increase after the treatments. The bottom hole configuration was changed in an effort to improve the treatment of the B" zone without a separate treatment. The change only involved adding a tailpipe section to the packer that lowered the end of tubing to a point between the "A" and "B" zones. The acid volume was also increased to about 25 gal/ft to better stimulate the formation. Individual swab testing of the first two wells using the new configuration confirmed that the changes were successful.

The overall results of the overbalanced surged wells compared to the conventional wells were very positive. Both procedures took 3-4 days and cost about $18,500, so there was no time or cost advantage as had been realized in previous applications. The average oil production rate was increased by 15%, or 7 BPD, but more importantly the average water production was decreased by 12%, or 50 BPD. Lower lifting costs were a direct benefit from the decreased volumes. The lower volumes of total fluid should also translate to fewer failures of lifting equipment. Lower water volumes also mean lower chemical treating costs. It is anticipated that the surged wells will have a higher recovery, but this can only be proved by time.

APPLICATION FOR COAL SEAM WELLS

In the 1980's some operators reported on cavitation of coal seam wells in the San Jaun Basin to improve the productivity. They were able to take advantage of the abnormal overpressure that existed in the coal seam that they were working with to cause the coal to slough until a stable cavity was formed in the open hole. Efforts to exploit this means of improving productivity in normally pressured coal seams has been relatively unsuccessful.

In areas where the coal seam production comes from a single seam there could be application for the overbalanced surge to form a enlarged cavity completion, even in low pressure seams. The wellbore scheme would require an open hole completion in the coal with casing down to the top of the pay. A packer would be set in the casing with some type of shear assembly that would allow for quick release of pressure and fluid from the tubing. In some instances the casing could be used as the pressure vessel for the overpressured treatment. The surge would be applied to the coal seam, after which the well would immediately be flowed back as quickly as possible to take advantage of the induced "supercharge" created by the nitrogen. The shock loading to the coal should create an unstable condition in the coal that would be conducive to sloughing and the formation of an enlarged cavity. This application may have to be repeated several times. As was the case in the overpressured coal seam, the hole will not significantly enlarge after an optimal surface area has been established.

of hydrocarbon. The failure to evaluate the reservoir meant that many (more than half) of the stimulations were "blind".

The typical stimulation consisted of an energized fluid with a light weight intermediate strength proppant. Carbon dioxide (CO_2) was the most common gas for energizing the fluid. Foamed fluid was considered essential to minimize the formation exposure to water This gas would have to be cleaned up to a pipeline spec of less than 3% CO_2 prior to gas sales. The proppant was pumped in 1-4 ppg stages in 180 barrels of gelled water. The proppant volumes ranged from 30-60000 lbs. Stimulation cost ranged from $60-100,000. The primary function of the stimulation was to communicate past suspected near wellbore damage.

Overbalanced surge treatments were employed with the expectation that a reservoir assessment of the productive capacity could be made and the fracture stimulation could be optimized. It was decided to pump the overbalance surge with a small amount of proppant to enhance the fractures that would be created by the treatment. The volume used did not exceed 4000 lbs in any treatment. The treatment was pumped as follows after the tubing and packer were run:

1. Pump 2 bbls of a 30 lb polymer slick water.
2. Pump nitrogen to load the tubing and pressure to ~7000 psi with 70-80 MCF nitrogen.
3. Continue pressuring the tubing to 9600 psi surface pressure with slick water to expel a pump-out plug below the packer (estimated BHP 12000 psi).
4. After the plug has sheared switch to all nitrogen at 10-12 MCF/min for 15 minutes.
5. Add a side stream of 1000 gals slick water with the nitrogen, followed by 2000 gals slick water with 2 ppg proppant (effective concentration < 0.3 ppg at perfs)
6. Displace with 180 MCF nitrogen at maximum rate.
7. Flow well back immediately until nitrogen is purged.

Use of this procedure gave results that were even better than expected. The overbalanced surge not only allowed for evaluation of the reservoir potential it completely took away the need for any additional stimulation. One well that was analyzed with pressure transient analysis showed a -5 skin value. This particular example did not make an economic producer as the reservoir permeability was measured at 0.006 md. The results of several other wells did make this a viable procedure. The cost of this stimulation was ~$30,000. This was a savings of $30-70,00 over the conventional fracture stimulation. In addition to a cost benefit, the sale of gas occurred in matter of hours versus days due to the faster cleanup time of the nitrogen versus CO_2.

TREATMENT VOLUME REDUCTION

Several infill wells were drilled in a field in Breckenridge, Texas during the time period of 1993-1995. The producing formation is the Caddo Limestone found at an average depth of 3100'. The pay section consists of two productive intervals referred to as the "A" and "B" (Fig. 2) with average porosities of 12% and 9%, respectively. Reservoir pressure averaged 1400 psi throughout the field. Considering the nature of the rock, acid stimulation could greatly improve a well's productivity.

The first five wells in the program were completed in the same manner as the previous wells in the field. The procedure for these wells called for perforating with 1000 psi underbalance using a casing gun perforator. Following the perforating the tubing and packer were run and the well was acidized. An average acid job consisted of 4-8000 gallons of acid pumped in 3-5 stages with saturated gelled brine carrying 1½ ppg graded rock

SUMMARY

The overbalanced perforating and surging method of completion has been used successfully in a variety of reservoirs and for a variety of reasons. It should not be interpreted that this completion method will be a solution to all problems in the oilfield. If it is properly applied this method can save an operator time and money. It can even enhance production to levels that would not be expected otherwise from conventional completion techniques. The key to successful application is to know what type of problem it is necessary to overcome, and determining if this or something else is the best solution.

The three examples of good applications for the overbalanced perforating and surging technique can be extended to wells with similar situations. Specifically , any area where near wellbore skin damage is suspected, such as was the case for the Strawn Sand and the PDC, this method should always be applied. It reduces treatment volumes and thereby decreases reservoir exposure to potentially damaging fluids. In limestone application, as in the Caddo formation, this treatment method can make placement of acid much more effective, again with significantly smaller volumes.

The potential for coal application has been presented. Because Oryx Energy Company has no coal assets, this method has not yet been tried. This does not preclude other operator who have opportunities to explore this method of completion from doing so.

REFERENCES

1. Handren, P.J., et al,Overbalance Perforating and Stimulation Method for Wells, SPE 26515, 1993.

ACKNOWLEDGEMENT

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Caddo Completions

Well	Net Perfs (ft)	Acid (gal)	Gal/ft	BOPD	BWPD	WOR
1	6	300	50	38	291	7.7
2	12	1400	117	23	639	27.8
3	50	8000	160	32	483	15.1
4	54	8000	147	82	305	3.7
5	32	4000	125	28	371	13.3
		Average	119	41	418	10.3

Table 2
Results for 1993 Caddo Completions

Well	Net Perfs (ft)	Acid (gal)	Gal/Ft	BOPD	BWPD	WOR
6	50	650	13	25	273	10.9
7	61	650	11	15	235	15.7
8	40	1000	25	38	485	12.8
9	60	1600	27	18	230	12.8
10	46	1200	26	82	138	1.7
11	64	1850	29	102	695	6.8
12	54	1500	28	30	307	10.2
13	63	1800	29	62	468	7.6
14	47	1200	26	22	500	22.3
15	57	1600	28	72	345	4.8
		Average	24	47	368	7.9

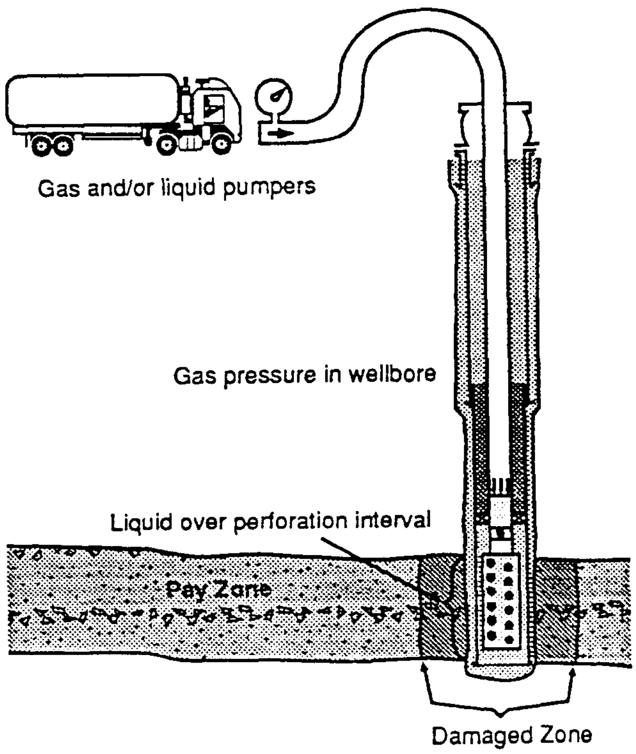

Figure 1 - A typical tubing conveyed overbalanced perforating well configuration .

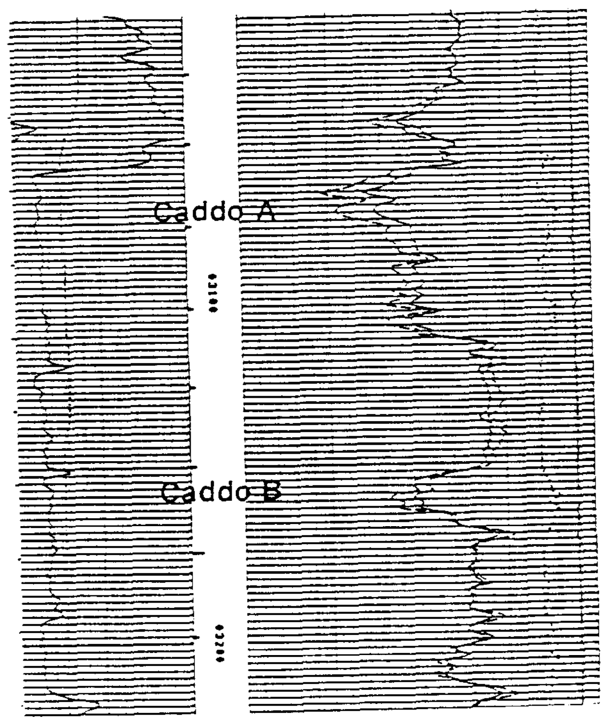

Figure 2 - Caddo Lime type log.