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WELL COMPLETIONS ARE ESPECIALLY IMPORTANT IN PERMIAN BASIN LIMESTONE AND DOLOMITE WELLS

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ABSTRACT

Completion procedures in the Permian Basin, especially in limestone, dolomite, and reef formations, can be tremendously important in determining a well's producing rate and economic return. Every well should be considered as a separate problem, with due thought given to the need for control. Among the controls which should be provided by the completion procedure are control of gas, control of water, control for completion treatments, control for secondary recovery, control of workover costs, and control of expense during completion and subsequent production.

Engineering analysis and mature thought should be used in order to obtain the best possible completions.

BACKGROUND

Oil was first found in West Texas approximately 30 years ago when almost all drilling was done with cable tools. Most of the early drilling was done on surface-indicated structures, and the pays found were shallow. The wells were drilled without fluid in the hole and, on many of the more prolific wells, the first indication of the pay zone was the sight of the tools blowing out of the hole.

Extensions to these fields were completed by setting pipe above the pay zone, and then drilling in with cable tools. Because many of the fields discovered early in the development of West Texas have very effective vertical and horizontal permeability, a well completed in them did not have to do much more than scratch the top of the pay in order to get at least fair drainage to the well bore. If the pay had a rather high pressure, it was often impossible to do much more than scratch the top of the pay before the well started producing. If the field had a natural gas cap, it was common practice to allow the well to blow gas to the air until the gas cap was dissipated and the well started making oil.

Logging on these wells was of the most elementary type and drillers' logs were often the only information that was available to show the productive zones. This caused many people to feel that there might not be drainage of any zones not left in open hole since they could not be certain of the location of these productive zones.

Conservation of reservoir energy, oil proration, and regulations for GOR limitations were not considered. The lack of proration regulations caused unregulated competition to produce the maximum amount of crude from the reservoir with little consideration of the future operations of the well or reservoir. The paramount thought was that if you didn't get the oil today, somebody else might get it tomorrow. The cost of drilling and completing the wells was relatively small, and often this cost could easily be completely returned within a month. Thus, it was of primary importance that the wells be put on production as soon as possible, with a minimum of initial expense.

With this beginning, and considering these pertinent factors, it is obvious that in most cases only one completion procedure, that of open hole-minimum penetration, could be considered.

OPERATIONS-1957

Conditions, equipment, material, and procedures have changed radically in the past 30 years, with completion depths in West Texas now ranging from three ft in the Sunflower Field at Colorado City to 15,000 ft in the Puckett Field of Pecos County. The only completion practice possible 30 years ago is not necessarily an efficient or effective practice at this time, and may well cause economic waste, reduced oil production from a number of fields and wells, and a greatly reduced economic return for money spent in drilling and producing the wells. The wells drilled and completed this year should be completed with an outlook to the future, for these wells will not have paid for themselves for quite some time, and it is hoped that they will continue to produce an economic return over and above the investment involved.

The production of petroleum today is closely regulated, both as to the amount of the oil and the gas produced. Under the limited allowables given to most wells today, the need for haste in the completions is greatly reduced. Other aspects of tremendous importance in the completion of the wells must be given primary consideration in the recommendations for the completion procedure.

The following are some of many factors that need to be carefully weighed in the present day well completions: control of gas, control of water, control for completion treatments, control for secondary recovery, control of workover costs, and the expense during the completions and subsequent production. These items are discussed in detail below. The areal coverage is that of Sun's Midland District and includes all Sun operated oil wells in West Texas, the Texas Panhandle, and Southeastern New Mexico. Some 236 of Sun's 1,210 wells are completed in pays other than limestone, reef, or dolomite, but the exclusion of these wells from the statistical data was not believed to be warranted because of the similarity of the problems involved.

1. Control of Gas

In oil wells with a gas cap or where there is even a remote possibility of a secondary gas cap, it is of great importance to be able to selectively produce the less gassy parts of the pay zone, both on initial completion and during subsequent production. The RRC limiting gas-oil ratios are of tremendous importance in determining the amount of crude that can be produced, both as to the rate of recovery and the ultimate economical recovery.

The following table is presented to emphasize the importance of gas control:

Table 1 GAS-OIL RATIO STATUS. 1-1-57

Area	Active Oil Wells	Wells with GOR Higher Than Field Limiting GOR	% By Area
A	162	29	17.9
B	281	122	43.4
C	299	247	82.6
D	388	48	12.4
E	54	No	0
F	26	10	38.5
Total	1210	456	37.7

From this table, it may be seen that 37.7 per cent of the wells produce with GOR's in excess of the limiting field GOR's. Not all of these wells have the capacity to produce their top oil allowable, but there are a considerable number of the 456 wells on which oil production is penalized because of the high GOR's.

It should be noted that the wells in Area E produce without GOR problems, and it might be pointed out that development of the wells in this area began almost 30 years ago using the open hole-minimum penetration procedure. It is most fortunate that gas production has never been a problem on those leases because the wells were not completed to control that problem.

Most of the wells in Area F do not make any appreciable amount of gas now, though the ratios run as high as 15,000/1. A number of these wells had GOR's in excess of 15,000/1 on completion almost 30 years ago, as open hole-minimum penetration completions, and these oil wells have produced a large total amount of gas during the 30 years.

At Area C a startling 82.6 per cent of the wells have gas-oil ratios above the RRC limiting ratios for the various fields in which these wells are located. The types of completions are mixed, with the great majority of the open hole-medium penetration type. For the most part, these wells are completed in reef fields. These wells are striking examples of the need for gas control in present day completions, and of the fact that the open hole completion can be a poor choice for controlling gas production.

2. Control of Water

It is important that the completion procedure be set out in such a way that provisions are made for water control. The penalty for excess water production is not usually handed down by any regulatory body, though such penalties may be considered in the future, but is apparent in higher lifting and treating costs for the oil produced. This control can be obtained initially by leaving some of the pay unpenetrated or by selective production of pay zones, and during later production only by selective production.

Some 453 of the 1,210 oil wells produce approximately 12,800 bbl of salt water /D. This volume of salt water is roughly one-third of the volume of crude oil produced daily from the 1,210 wells. The salt water causes lifting, treating, corrosion, disposal and other problems that cost a good deal more than would the production of another 12,800 bbl of crude, without providing income.

The following table is presented to show the importance of water control;

Table 2 WATER PRODUCTION STATUS-1-1-57

Area	No. Active Oil Wells	Wells Making Water	Per Cent
A	162	91	56.2
B	281	156	55.5
C	299	47	15.7
D	388	107	27.6
E	54	40	74.1
F	26	12	46.2
Total	1210	453	37.4

This problem is not of the same magnitude as gas control as water usually does not quickly flood out the limestone or dolomite pays in West Texas; water production can be considered an economic nuisance. However, any such circumstance that does bring about lower net revenue is important, and every feasible measure of control should be exerted to reduce such a revenue loss.

Because it has been found that often there is not effective vertical communication between separate porous zones within limestone, dolomite, and reef formations, it should be realized that we may have to produce each separate zone in order to effectively drain that zone even though it might carry a mixture of oil and water. Control of water production includes plugging back or plugging off the zones as the income provided from each zone becomes less than the extra cost incurred in producing the water from that zone.

In my opinion, the best type of completion for water control is the set-through-and-perforate type because of the greater control and lower expense of doing the necessary plug-backs and plug-offs inside casing.

3. Treatment Control

Over the past several years, more than 80 per cent of the new completions required some stimulation or treatment in attempting to obtain the top well allowable. This is true for all types of completions which have been used. Of the 69 wells completed during 1955, only two, or 2.9 per cent, were not treated as part of the completion procedure and one of these two wells was later treated to get the top allowable, after some months production as a limited capacity well. Of the 138 oil wells completed during 1956, only five, or 3.6 per cent, did not require treatment as part of the completion procedure. These completion treatments varied from mud acid washes to multi-stage fracture treatments.

With the presently available refinements in treating procedures for acidizing and fracturing, it has become increasingly desirable and necessary to limit and isolate treating intervals in order to obtain the maximum benefits possible from the treatments. For a selective treatment with the set-through-and-perforate completion, it is necessary that the cement job be a good one that will not break down during treatment. Even with what is believed to be good cementing practice, communication outside of the pipe or through the formation is sometimes encountered. Experience has shown that a minimum of 15 ft should be left between sets of perforations, and that greater intervals are desirable. Selective treatment of separate zones in an open hole usually requires one or more packers with the attendant difficulty of obtaining and maintaining an effective seat during the treatment.

The benefits to be obtained from selective treatments are great, and can be easily shown by a study of the results of various workovers to increase well capacities done in the past years. In a high percentage of these workovers, the selective treatments gave considerable increases, often above what had been obtained on original completion with non-selective treatments. Since the cost of the well treatments on initial completions now runs as high as $6,000, and averages over $1,500 per well, it is apparent that completions should be such as to give the best chance for the success of the necessary completion treatment.

It would be difficult to fully state all of the reasons for the need for selective completion treatments, but one of the most important is that after a selective treatment you know what was done to what interval and why. Where we have checked by radioactive tracers and other means, we have found that non-selective fracturing of multiple sets of perforations has, for the most part, resulted in fracturing only one of the sets. I believe that in treating in open hole the fracturing is almost always done in one porous zone rather than giving multiple fractures in several zones open to the well bore, unless definite treating refinements to obtain multiple fractures are employed.

Under Treatment Control, I believe that the necessity for perforating in moderation where perforating will do some good, should be stressed. Unlimited perforations in a cased hole often will render useless the extra expense of setting through the pay formation, in addition to compounding the difficulties in controlling operations. Perforating many multiple zones of many of the pays in which wells are now being completed is useless unless these pays are to be selectively treated, for they will not produce without treatment. Having all possible pays perforated often does not add to the capacity of the well and often will cause difficulty in obtaining good treatments on the more important zones of the pay in the well.

Perforating all 60 ft of a 60 ft zone of continuous porosity may be desirable in some cases, but consideration should be given to the possibility of water and/or gas production during the later production of the well. If we can expect horizontal drainage from an area with a radius of 660 ft, then we should be able to visualize vertical drainage of 10-15 ft within a continuous porous zone.

In my opinion, in order to obtain the best possible chances for successful completion treatments, perforations should, for the most part, not overlap the formation above and below the porous zone. This is especially true where shales are located right above and/or below pays to be fractured. There have been a rather large number of cases in West Texas during the past three years where, under these circumstances, the fracturing fluid has entered the shale body without helping the productivity of the pay zone. To avoid this possibility, consideration should be given to logging inside casing, with collar finders so that the perforations may be made exactly. It is often less expensive to run the log and then reduce the perforated interval than it is to add two or three ft to each end of the recommended perforations to take care of differentials in measurements.

Considering treatment control only, if a well has only one thin pay section, the open hole completion may be adequate. In my opinion, if the pay section is thick or if the pay is broken into several sections, the open hole completion is often inadequate, and the set-through-and-perforate completion with reasonable perforations is much to be preferred.

4. Secondary Recovery Control

Almost every reservoir being produced today will be considered seriously for some type of secondary recovery process in the future.

As a matter of interest, it should be noted that the 1,210 wells produced roughly 34,200 B/D during December, 1956, and that approximately 21,800 B/D were produced from wells in fields in which some form of pressure maintenance and/or secondary recovery is aiding in maintaining this production.

It is important that control of the placement of the displacing medium be available, and it will often be uneconomical to provide that control after the initial completion of the well. Thus, the initial completion should provide means for selective primary production, selective secondary production, and selective secondary displacement.

A specific example of the need to look ahead of the initial completion to secondary recovery, is the Kelly-Snyder Canyon Reef Field of Scurry County, now unitized as SACROC. Almost every one of the 26 wells now being used for injection in SACROC, Segment 3, had to be deepened prior to the start of water injection, and several of these wells have subsequently had to have liners run in order that we might inject water selectively. In addition, a number of the producing wells offsetting the line of injection have had to be deepened in order that we might effectively drain the lower porous zones being flooded.

In my opinion, the only completion procedure which can give the control often needed for effective secondary recovery operations is that of maximum penetration, set-through-and-perforate. The procedure of full penetration is often needed to provide enough data to justify a secondary recovery project.

5. Control of Future Workover Costs

It is apparent that the completion procedure should be considered with the idea of keeping future workover costs to a minimum.

During 1955, 66 workovers were completed on the wells at a cost slightly greater than $450,000. During 1956, 85 workovers were completed on the wells at a cost slightly greater than $440,000. These figures do not include routine work to clean out cavings which is a considerable expense in some of the older wells.

Strong consideration must be given to those completion practices that will tend to reduce costs for any future workover and will also reduce or eliminate the need for some phases of present workovers.

A large number of workovers to increase capacity in the past several years had costs running well above 30 per cent of the original cost of drilling and completing the well. Data on our workovers and those of other operators in this area indicate that the per cent of success for workovers where pipe has been set through the entire producing section is much greater than that for open hole completions. It also should be noted that the cost of workovers when working inside of casing is less expensive than similar workovers in open hole.

A rather large number of workovers were undertaken to deepen in the same pay where an original completion of drilling the entire pay and setting through would have eliminated the need for any subsequent deepening workover and thus eliminated the entire cost of that workover. Another classification of workovers that should be almost entirely eliminated are those in which liners must be run in order to set through an expanding gas cap, even where the original casing seat was well below the gas-oil contact. These two types of workovers can often cost as much as 30 per cent or more of the original well cost.

A study [1] of the completion methods used on 235 wells in the Diamond M Canyon Reef Field was made in the latter part of 1952. The conclusions are paraphrased below as being true for the Diamond M Canyon Reef Field at that time and indicative of conditions of many fields in West Texas:

[1] Capacity of a well is not usually adversely affected by setting through and perforating, and in many cases is greater than for open hole completions. One explanation for this might be the greater amount of pay available for production in the set-through-and-perforate wells.

[2] High ratio wells in open hole completions are much more prevalent than in those wells where casing has been set through due to greater selective control when the hole is cased.

[3] To date, set-through-and-perforated wells have shown the longest top allowable life, due to the greater amount of pay available for production.

[4] Pumping wells are more numerous in the group of wells with deepest penetration, due to water production.

[5] Percentage of water produced from these wells increases with percentage penetration. The production of water has increased lifting costs somewhat, though this extra cost is more than offset by the ability of these wells to make increased production.

[6] Cost of workovers on minimum penetration wells is much greater than cost on wells with maximum penetration.

[7] The percentage of success of workovers is greater for cased off wells than for open hole completions, being in this survey 88 per cent as compared with 50 per cent.

In my opinion, the open hole completion is not as desirable as the set-through-and-perforate completion when workovers are to be done, and the expense of working on an open hole completion is usually greater than that of similar work in cased hole, with greater chances of success in the cased hole. Several of the most expensive types of workovers can be eliminated by using the set-through-and-perforate completions.

6. Control of Expenses

To use the set-through-and-perforate completion, one must expect to spend some small additional amount of money initially. However, this extra expense is minor when compared to the many advantages that are gained and the lessened expenses expected during the producing life of the well.

The exact amount of the extra expense in completing any one particular well by the set-through-and-perforate method can be calculated, but no overall figure for all wells can be exactly stated because of the different approaches that are taken to the completions. The most important initial extra costs for the set-through-and-perforate completion are for drilling and casing the extra hole drilled, and for perforating for completion. This extra cost on most wells will not exceed $2,000.

The average cost of a workover to run and cement a liner in West Texas for the past few years has been about $10,000 per well. On that basis, if by using the set-through-and-perforate completion, it can be insured that liners will not have to run during later production on the wells now being completed, a considerable amount of money will be realized.

The unfortunate part about many poorly completed wells is that in their later stages of producing life it is often impossible to justify spending the large amount of money to work them over completely, where it would have required only a small extra expenditure initially to complete the well correctly.

Expenses for well work can often be justified if there is a sound basis to a well's reserves. Unless the pay has been penetrated, reserve estimations are often based only on hunches or wishful thinking, and workovers based on such factors are often a source of discouragement.

The fact that set-through-and-perforate completions often have a longer life as full allowable, low gas-oil ratio wells is most important, and any completion practice which will help in that direction should be given a good deal of consideration, even though there may be some additional initial expense involved.

SUMMARY

When an oil well is completed initially, some man or group of men must make the decisions as to how and where the well should be completed. It is often only after years of the well's productive life that anyone can say for sure that this was a good completion or that this was not a good completion. Because of the many unforeseeable precedures, difficulties, and reservoir problems that can come up during the life of any one well, it is my firm belief that most Permian Basin wells should be completed using the set-through-and-perforate completion to provide controls to meet those problems.

It is not enough to insure a good completion that casing is set through a pay. The perforations should be made with careful moderation, exactly as needed. To perforate every 1/2 ft of pay shown on the log may satisfy someone's desire to have all the possible pay open to the well bore, but in many cases this will nullify all of the benefits to be gained by setting through the pay. Many multiple sets of perforations in the poorer pays are often useless, and complicate the treatment procedures without which these pays are uneconomic.

I do not wish to belittle or imply criticism of those who may not agree with me. I do wish to emphasize that the method in which a well is completed is tremendously important, and a great deal of mature thought and engineering analysis should be given to the problems known to exist on the perplexing well completions in the Permian Basin.

REFERENCES

1. Rogers, C. E. Company Report, Nov. 11, 1952.