Drilling and Completion Practices, Spraberry Trend[†]

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ABSTRACT

A total of 582 wells were producing as of October 1, 1951, and over 200 rigs were operating in the Spraberry trend. Of these producing wells, 41 percent were completed with a salt string set at approximately 4,000 ft. The standard practice is to set the liner or long string above the Spraberry sand before the pay interval is drilled.

Practically all of the operators cement each string of casing in a single stage, circulating the slurry only behind the surface pipe. Mud problems are not considered serious; however, a light system must be maintained while drilling weak formations below 4,000 ft.

The majority of the operators drill the pay interval with rotary tools, using crude oil as the circulating fluid; although some of them prefer to drill the Spraberry with cable tools. Overall, 82 percent of the completed wells were Hydrafraced during the initial completion operation. The remaining 18 percent were shot, acidized, or completed naturally.

The average period of time necessary to drill and complete a Spraberry well with rotary tools is approximately 36 to 40 days.

INTRODUCTION

The first Spraberry well was completed by the Seaboard Oil Company on January 22, 1949. This discovery well, the S. E. Lee No. 2 located in Dawson County, Texas, was drilled as an Ellenberger test; and upon finding no shows in this formation, it was plugged back and completed in the open hole in the upper Spraberry formation. Approximately six months later, the Tex Harvey Oil Company's B. W. Floyd No. 1-16 opened the Tex Harvey Field and paved the way for the discovery of Germania, Pembrook, Midkiff, Huddle-Manning, Smith, Glass, Driver, Weiner-Floyd, Benedum (Spraberry), Snowden, North Pembrook, Weddell, Aldwell, and Flatrock Fields in that order.

This paper was originally prepared in October 1951 utilizing data available October 1 of that year. However, in order to show the most recent trends in development rate, Fig. 1 has been revised to include information available as of September 1, 1952. On this latter date, 2,007 Spraberry wells had been completed and approximately 71 rigs were active in this area. The development rate for the month of August, 1952 experienced a rapid decline. This was due primarily to the steel strike, but it was also effected by operators who are reluctant to develop on 40-acre proration units.

As previously stated, this paper is based upon information available October 1, 1951. Notwithstanding that a greater portion of development has occurred since that date, the majority of the operators are still following one or more of the drilling and completion techniques outlined herein.

During the early stages of development it became apparent that many, or possibly all, of the foregoing fields would eventually prove to be one vast reservoir. In order to prevent additional complication in naming new fields with different field rules, the Railroad Commission issued an order whereby future discoveries will carry the name of the nearest producing Spraberry field. Discovery allowables may still be granted when these discoveries are three miles or further from a producing area.

As of October 1, 1951, 582 wells were producing and over 200 rigs were operating. A survey conducted in October 1951 recorded 203 operators in the Spraberry area. It will not be possible to cover here every variation in drilling and completion technique practiced by all operators. Consequently, only the more general procedures used by the majority will be presented.

Drilling Technique

While drilling to a depth of 4,000 ft, from 3 to 15 drill collars are used with rotary speeds of from 70 to 125 rpm. Some operators carry a small amount of weight and tend to "wash" the hole down by maintaining high pump pressures and rotary speeds; whereas others maintain slower rotary speeds in conjunction with more weight on the bit. Practically no difficulties are encountered during this operation. Below 4,000 ft, 15 to 25 drill collars are used with rotary speeds ranging from 65 to 90 rpm. The pump pressure is kept at a minimum, usually below 500 psi, because of the lost-circulation hazards. An average of 35,000 lb is carried on the bit.

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Although conventional rock bits are used from top to bottom, no unusually hard formations are penetrated while drilling Spraberry wells. From 25 to 40 bits are needed to drill to the top of the Spraberry sand.

Casing Programs

There are two general types of casing programs used in the Spraberry trend: One is to set pipe through the salt section at approximately 4,000 ft prior to drilling to the casing point above the Spraberry sand; the other program consists of drilling all the way from the surface casing to the top of the pay before running pipe. A slight variation in these programs consists of setting the production string in the top of the lower Spraberry when completing in both zones or in the lower Spraberry alone.

On the basis of a survey in which various operators submitted data on 274 producing wells, an average of 33 days is required to drill and set pipe above the Spraberry sand using either a two-string or a salt-string–liner casing program. Therefore, it appears that the only advantage of setting the salt string lies in the reduction of the mud cost by minimizing lost-circulation difficulties. The disadvantage is the additional tonnage of steel required. Currently, operators are using both types of casing programs, depending largely upon the availability of pipe.

As shown on Fig. 2, the size of casing used in both types of programs varies considerably. The salt string ranges from $7\frac{5}{8}$ in. to $9\frac{5}{8}$ in., whereas the liner and long string varies from $5\frac{1}{2}$ in. to 7 in. As of October 1, 1951, 238 wells (or 41 percent) were completed with the salt-string–liner casing program. Also, as shown on Fig. 2, the tonnage of steel required for each program varies from 55 tons for the long string of $5\frac{1}{2}$ in. casing to 116 tons for the $9\frac{5}{8}$ in. salt string with a 7 in. liner. These figures do not include the tubing or wellhead equipment.

Cementing Practices

Cementing techniques vary widely among the operators. The majority of them are following the practice of only cementing around the shoe and a short distance behind the pipe, while a few are circulating cement behind the salt string, liner, and long string. As a rule cement can be circulated in one stage behind the salt string; but in order to obtain a complete fill-up behind the long string and liners, from 2 to 5 stages are necessary. The operators who are not going to the additional expense of stage cementing feel that the Spraberry wells will have a relatively short producing life and that

Fig. 1 – Number of Producing Wells in the Spraberry Trend (All Fields)

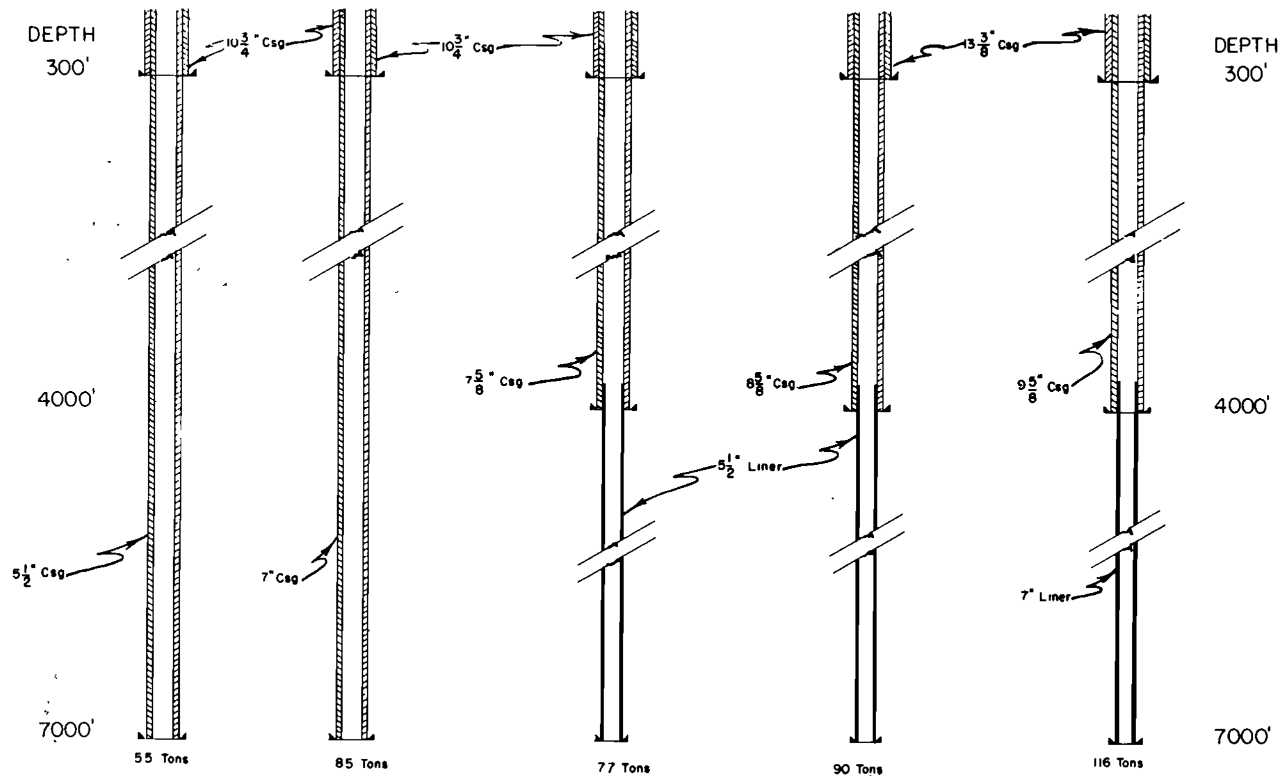

Fig. 2 – Casing Program–Spraberry Trend

corrosion will not present a very serious problem. Gel and perlitic material are used by practically all operators to reduce the hydrostatic head against the formation during the cementing operation. When these materials are used, a small neat cement slurry is pumped behind the main slurry in order to insure a good cement bond around the casing shoe or behind the perforations.

Mud Programs

Mud problems are not considered serious, as no special characteristic is necessary other than keeping the weight to a minimum while drilling the weak formation below 4,000 ft. The most noticeable lost-circulation zones are at approximately 4,300 ft, 5,300 ft, and 6,500 ft, with some difficulty encountered at any depth below 4,000 ft.

Clear water is used to spud and set surface pipe at approximately 300 ft. Clear water is also used to drill out below surface casing, but the red beds encountered to a depth of approximately 1,100 ft quickly build a high-viscosity native mud which is controlled by the addition of fresh water. Salt and anhydrite beds penetrated from 1,100 ft to 4,000 ft completely saturate the mud during the drilling operation. The native mud, weighing from 10.6 to 10.8 lb per gal, is often used to run the salt string without further treatment. After the salt string is set, the saturated salt mud is jetted and the pits cleaned thoroughly. Fresh water is used to drill out below the salt string, and the weight is maintained at approximately 8.3 lb per gal by the addition of crude oil. In the event that lost-circulation difficulty is encountered under these conditions, lost-circulation material and additional oil is added to lighten the mud to as low as 7.5 lb per gal. As high as 75 percent oil has been used. The water loss is reduced to 10 cc or less, and the viscosity increased to 50 sec or above before running the liner.

In wells where a salt string is not used, the foregoing program is employed to a depth of 4,000 ft. At this point the pits are jetted clean of all cuttings and oil is added to the remaining mud, reducing the weight to approximately 9 lb per gal. Salt gel is also added, along with a small treatment of starch or soda ash to aid in emulsifying the oil and water. Strictly speaking, the mud is not a true emulsion as free oil will break out if the mud is allowed to stand idle in the pits. However, the oil serves its sole purpose in reducing the weight of the circulating fluid. Upon reaching the casing point, the mud is conditioned as described previously, prior to running the long string.

When the oil string is set through the upper zone, a light-weight oil-emulsion mud with a water loss of 10 cc or less is maintained to the casing point in the lower Spraberry.

Mud bills, excluding the cost of crude oil, range from $500 to $2,000 in wells where a salt string is used, and from $1,000 to $10,000 for wells using the two-string casing program. Average mud costs are $1,500 and $4,500, respectively, for the two programs with these values increasing in proportion with the amount of lost circulation encountered.

Drilling-in Practice

Upon cementing the long string or liner above the top of the pay, the Spraberry sand is drilled with either rotary tools, using conventional or reverse circulation, or cable tools. The standard practice is to use crude oil as the circulating fluid while drilling in. This is done in an attempt to minimize the amount of damage to pay during the completion operation. The depth of penetration depends upon the individual operator. Many wells are currently being completed in only the upper portion (60 to 90 ft) of the upper Spraberry, which has an overall thickness of approximately 210 ft. Initial potential tests of these wells compare favorably with those which open the full section for production. Fig. 3 reflects the most common types of completion. There are also a few wells producing from perforations. These are cases where the lower zone or some deep test failed to produce satisfactorily and the upper Spraberry was perforated for production.

Although cable-tool penetration rates are much slower than rotary-tool rates, many operators believe that less damage will occur to the pay when this drilling-in practice is used. Wells in which the interval from the casing seat through the entire upper Spraberry is drilled required approximately 30 days to cable tool as compared to 4 days using rotary tools.

It is difficult to evaluate the merits of either rotary or cable-tool completions because of the relatively short producing history of Spraberry wells. Inasmuch as the initial potential tests were taken on various choke sizes and the testing procedure is non-uniform for all operators, it is not considered practical to use these tests as criteria for determining the superiority of either type of drilling-in practice.

Air Drilling

Another drilling-in procedure which has been used in an effort to afford the advantages of cable-tool drilling at rotary penetration rates is that of air drilling. This technique replaces the circulating media with compressed air. At the present time, this practice has been used to drill the Spraberry sand in two wells by the Penntex Oil Company and Wilshire Oil Company. The first attempt resulted in drilling 922 ft of formation which proved to be barren. The first 48 ft of formation which is below the 7-in. casing at 6,620 ft was drilled by conventional circulation. A penetration rate of 5½ ft per hour was attained by applying only 4,000 to 6,000 lb of weight and rotating 35 to 40 rpm. Returns at the surface were in the form of dust and were of no value from the standpoint of geologists' analysis. It also appeared that the hole was not being properly cleaned, as considerably dragging was noted when pulling the bit.

The remaining 874 ft were drilled by reverse circulation, which proved to be much more satisfactory in cleaning the hole and the recovery of formation samples suitable for examination. Air circulation proved particularly conducive to cleaning out after shooting this well. An interval of 100 ft was cleaned out in 6½ hours following a selective shot of 100 qt of liquid nitroglycerin. Large particles of the bomb and shell case, along with formation fragments and shot gravel, were lifted by reverse circulation.

The Wilshire experiment successfully drilled 108 ft of formation below the oil string. During drilling operations, oil was continuously jetted at the rate of approximately 10 bbl per hour from 7,185 to 7,198 ft. The first 81 ft of formation were drilled below the casing shoe at a penetration rate of 9 ft per hour using reverse circulation. The bit was pulled for inspection after drilling this 81 ft and was found to be in fairly good condition. No abnormal wear appeared to have occurred in the bearings, as would have been expected. The second bit cut 19 ft in 2 hours before plugging. Upon pulling this bit, two stands of oil were recovered indicating that the plugging difficulties resulted from this initial fluid. Another bit was run, but became plugged before any additional hole could be made. A skirted bit made 8 ft of hole in 2 hours before the casing collapsed causing a twist-off. The use of compressed air was discontinued after the hole was filled with oil for milling operations.

In weighing the different problems encountered during these two experimental operations, the plugging tendency of the bit and drill collars has caused the greatest concern. The task of unloading the fluid that entered the hole while making a trip was solved by installing three conventional pressure-flow valves below 5,000 ft. These valves set at opening pressures of 550, 525, and 515 psi, respectively, were able to unload a 2,100-ft oil column in 3 hours from a depth of 7,200 ft.

The surface equipment for both operations was very similar. Fig. 4 is a schematic drawing of the surface equipment used on the latest experiment.

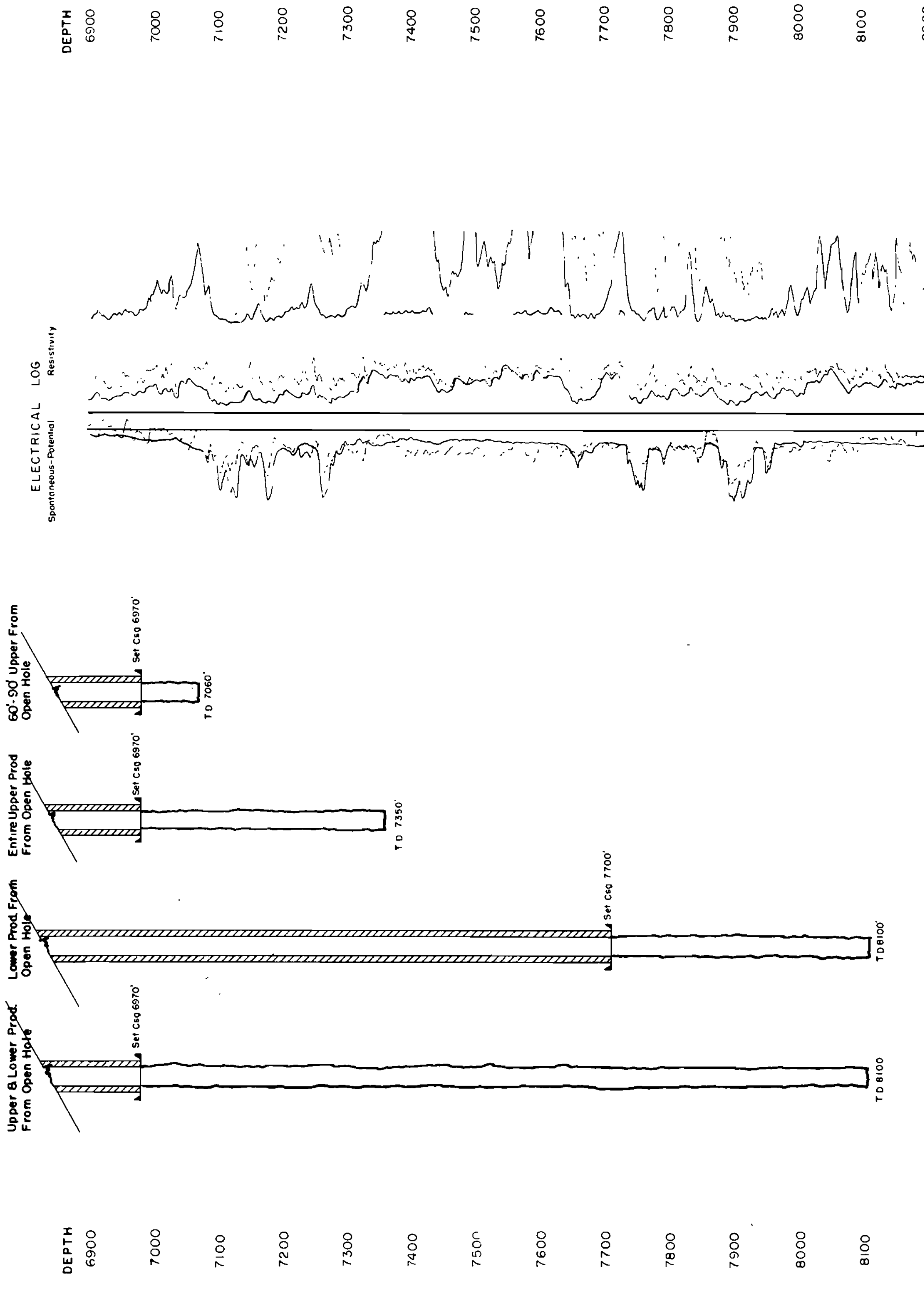

Fig. 3 – Completion Practices—Spraberry Trend

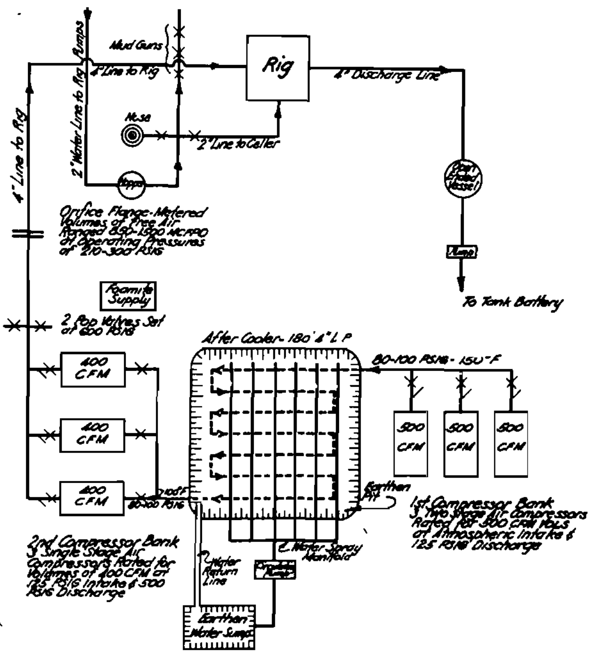

Fig. 4 – Air-drilling Flow Diagram

As may be seen, the compressing equipment consists of two stages. The first stage is composed of three compressors, each of which is rated for 500 cu ft per min at atmospheric intake and 125 psig discharge. From these compressors, the air travels at 100 to 125 psig through a cooling system where the temperature is reduced from 150 to 100F., which in turn reduced the intake pressure to 80 to 100 psig. The second stage consists of three compressors rated at 400 cu ft per min at an intake pressure of 125 psig and 500 psig discharge. This system is designed to furnish from 1 to 1½ MMcf per day at a maximum pressure of 600 psig. Normal drilling operations are carried on with a circulating pressure of approximately 200 to 250 psig.

Some concern has been expressed as to the hazards involved in drilling a hydrocarbon-bearing reservoir with air. An insurance company assured the Wilshire Oil Company that the use of compressed air presented no greater danger, in their opinion, than the use of oil. As a precautionary measure against igniting the discharge oil spray, flood lights were mounted around the rig at a distance of 100 ft, allowing all rig lights to be extinguished, and the well effluent was directed into an open vessel approximately 500 ft from the rig.

Completion Technique

Development in the Spraberry trend is being carried on at a rapid rate, with most of the operators using one or more of the following open-hole completion techniques:

1. Drill 20 to 125 ft of pay with either conventional or reverse circulation and Hydrafrac in one stage.
2. Drill 20 to 125 ft into the pay with cable tools and Hydrafrac in one stage.
3. Drill the entire upper Spraberry with either conventional or reverse circulation, and selectively Hydrafrac from 4 to 7 sections using the straddle packer.
4. Drill the entire upper Spraberry with conventional or reverse circulation and shoot the open hole with from 2 to 4 qt of nitroglycerin per foot.
5. Cable-tool drill the entire upper Spraberry and selectively Hydrafrac four intervals with a straddle packer.
6. Set pipe above the upper pay and complete both the upper and lower Spraberry sands by selectively Hydrafracing each zone.
7. Set pipe through the upper Spraberry and complete, using one of the foregoing practices in the lower Spraberry. The upper Spraberry may later be perforated and treated, at the operator's discretion.

Data available on 582 wells which were completed as of October 1, 1951, revealed by far the majority of the operators are using the first-named completion practice, viz., drilling only a portion of the way into the upper pay and Hydrafracing with a single stage. There is a question, however, regarding the ultimate recovery of wells producing from only a portion of the upper pay. In some wells completed in this manner, the pressure–production-decline curves reflect a steeper decline rate than wells which were completed through the entire upper Spraberry. This would indicate that the vertical fractures existing in the pay interval are not continuous throughout the section, and that wells completed in only the upper portion of the sand will not effectively drain the reservoir. Overall, 477 (82 percent) of the 582 wells completed as of October 1, 1951 were Hydrafraced and yielded an average initial potential of 325 bbl of oil per day. A total of 94 (16 percent) of the wells were shot and yielded an average initial potential of 263 bbl of oil per day. This latter figure is misleading in that these wells were still producing load oil during the test period. Acid alone has been used in 5 wells during the initial completion and yielded an average initial potential of 124 bbl of oil per day. Also, 5 wells were completed naturally for an average initial potential of 304 bbl per day.

A total of 551, or 94.8 percent, of the wells are open-hole completions. The majority of the perforation completions are a result of plug-back operations after a deeper zone was tested and found to be barren. Approximately 2 percent of the wells were completed through both zones. Of these, some have been plugged back and are now producing from the upper Spraberry only. Approximately 5 percent (29 wells) producing from the lower pay yielded average initial potential of 187 bbl per day.

Cable-tool completions appear to result in good producers, but the extended completion period has discouraged many operators from using this technique.

Special Equipment

Extended clean-out periods ranging up to 30 days have been noted after shooting wells with nitroglycerin. This, coupled with the loss of from 2,000 to 3,000 bbl of crude oil to the formation during the clean-out operation, has discouraged the widespread use of this completion practice. Also, difficulty is often experienced in maintaining circulation while drilling weak formations below 4,300 ft. A tool recently introduced and gaining popularity in controlling this problem is the fluid control and jet sub. Three or four of these subs, when used in the string of drill pipe, aid in maintaining circulation in a conventional manner while drilling a weak formation or cleaning out after shooting, with a minimum loss of circulating oil. One operator cleaned out in only two days after shooting the entire upper Spraberry with 4 qt of nitroglycerin per foot. Numerous operators have successfully used these subs to regain circulation while drilling weak formations. A cutaway diagram of one of these is shown in Fig. 5. As stated previously, under normal operations, less than 500 psi pump pressure is maintained below 4,000 ft. The fluid control and jet sub permits pump pressures in excess of 1,000 psi to be used without exerting great pressures against the formation being drilled. As low pump pressures are applied, the fluid circulates conventionally through the bit only. However, as greater pressures are applied, the 100-psi spring is collapsed, permitting the piston to move downward, opening two ¼-in. jet tubes which discharge the circulating fluid in an upward direction. In the event the bit becomes plugged, the pressure equalizes above and below the sub allowing the piston to return to normal position, thereby closing off the jet tubes.

Plugged-bit troubles have been greatly relieved by using skirted bits while drilling or cleaning out with reverse circulation. These are regular rock bits with a restriction welded over the discharge ports, allowing only small cuttings to enter the drill pipe.

Undoubtedly, as development progresses a greater number of new tools and techniques will be introduced which will materially reduce the cost of drilling Spraberry wells; and, in turn, brighten the picture for many operators who are investing large sums of money in developing their acreage.

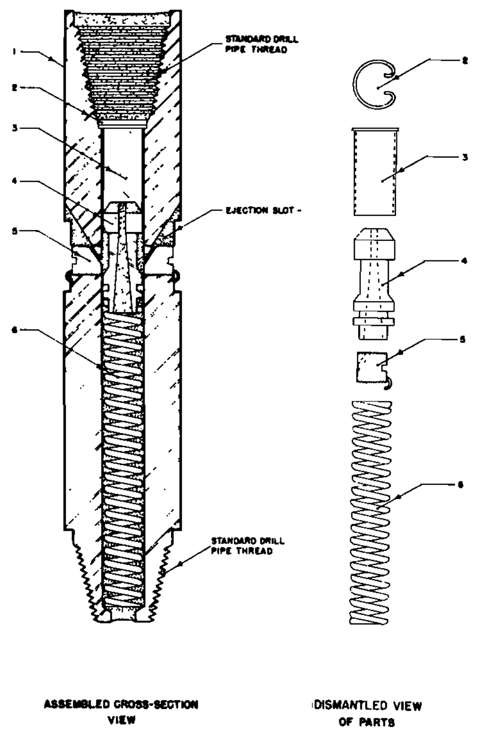

Fig. 5 – Fluid Control and Jet Sub

ACKNOWLEDGEMENT

Acknowledgement is hereby given to D. V. Carter, C. H. Hudson, F. S. Wright, Jr., R. W. Lewis, and O. J. Ford, Jr. of Magnolia Petroleum Company for their assistance in preparing this paper. Acknowledgement is also given to all operators in the Spraberry area, particularly the Wilshire Oil Company, for their cooperation in submitting and releasing data regarding their drilling and completion practices in the Spraberry trend.

DISCUSSION

David Johnston (Humble Oil and Refining Co., McCamey, Texas) (written): Since the effective date of Mr. Franklin's summary of well completions and casing programs, drilling the Spraberry has been continuing with approximately 230 to 240 rigs so that on February 8, 1952, the total number of completions was 1,134 with completions at the rate of 30 to 35 wells per week. Based on our own experience and conversations with other operators, it is believed that almost 90 percent of the completions since October 1, 1951 have been two-string wells without a salt string.

Another procedure which appears to be gaining favor is the practice of drilling to total depth, setting pipe, and completing through perforated casing. The trend toward perforated-casing completions results primarily from sloughing problems in uncased open hole and difficulties encountered in drilling the small hole required below the oil-string casing seat. It is too early to determine the exact advantages and disadvantages of open-hole and perforated-casing completions; however, it is encouraging to note that satisfactory completions have been made through perforated casing in Spraberry wells.

The necessity for reducing Spraberry drilling costs is apparent to all operators in view of indications of limited per-well recoveries. One technique which offers distinct savings, provided proper application is made, is the use of jet-type rock bits. Use of jet rock bits with nozzle velocities in excess of 225 ft per sec and bit weights of approximately 5,000 lb per inch of diameter, at least to depths where extreme lost return occurs, will increase both penetration rates and bit life.

E. E. Young (Sohio Petroleum Co., Midland, Texas) (written): The author has presented a very informative and enjoyable paper on the various drilling and completion practices in the Spraberry trend area. It is readily seen that there are indeed a great variety of completion methods occasioned by: *1*, the characteristics of the Spraberry itself; *2*, the casing available to each operator; and *3*, the large number of operating companies. As Mr. Franklin has stated, it would be impossible to cover in detail all of the variations in completion practices. However, he has certainly covered many general techniques used to complete Spraberry wells.

Sohio has been more active in the Driver area of southwest Glasscock County and the North Pembrook area of Upton County than in any other portion of the Spraberry Trend. For those not too familiar with the Spraberry trend, North Pembrook is approximately 13 miles southwest of the Driver area. On the first few wells in each field, the completion practice was to set approximately 300 ft of 10¾-in. surface casing, drill 8¾-in. hole to within 30 ft of the top of the Spraberry with rotary tools, and set 5½-in. or 7-in. casing. The wells were then completed with cable tools by drilling into the Spraberry approximately 70 ft, or 100 ft below the casing point. Originally, the wells were fractured with 1,500 gal by using a formation packer set near the top of the Spraberry and treating only the 70 ft exposed below the packer. A later revision of this treatment was to set a packer with holddown slips in the casing and treat the entire zone below the pipe with 1,500-gal treatment.

In order to properly evaluate the reservoir to the best of our ability, a diamond coring program was started very soon after June, 1951. The general practice was to complete all wells, as mentioned previously, with the exception of two wells per section. These two wells were diamond cored through the upper Spraberry with casing set through and cemented in a single stage. In this same area, key wells were picked to be diamond cored through the upper and lower Spraberry and the Dean sand. On the basis of results obtained in completing wells which had been diamond cored with rotary tools, Sohio adopted the general practice of drilling the pay zone with rotary and setting casing through. In the North Pembrook area, inasmuch as the lower Spraberry was found non-productive, the wells are drilled through the upper Spraberry with casing set through this zone only. In the Driver area, because the lower Spraberry has been found productive over a rather large area, the wells are drilled through the lower Spraberry with casing set through both zones. The casing is cemented in a single stage, and the normal completion is in the upper Spraberry.

Although the initial potentials are rather poor criteria for judging the proper completion practice, the well behavior to date has indicated that Spraberry wells can be properly completed by drilling through the pay and setting pipe through. In conjunction with a good cement job, the energy of a fracture treatment can be confined to a given zone. The only true criterion for judging the best completion practice is the net profit per well after the wells have reached the economic limit which we all hope will be far ahead of us. I believe it is generally agreed that the lifting costs should be less with casing set through by eliminating the clean-outs necessary later with shale sections exposed in open hole. With lower lifting costs throughout most of the producing life, a set-through program may be more profitable even though the ultimate recovery might be slightly less than on an open-hole completion program.

Another phase of Spraberry completion which many operators may be facing in the near future is the deepening and completion in the lower Spraberry of wells now producing from the upper Spraberry with casing set on top of the upper zone. At the present time we are contemplating deepening one such well through 7-in. casing and setting a 5-in. OD liner. The deepening of wells with 5½-in. casing presents entirely different problems, particularly on the liner setting. Some operators have deepened wells through 5½-in. and 7-in. casing without setting a liner, but the clean-out problems may be severe later on with the long shale section exposed in open hole.

On the long deepening jobs (750 ft to 900 ft), the operators have been having success with a diamond drilling bit used in conjunction with the jet collars mentioned by the author. The diamond drilling bit is similar to a diamond coring bit with a small inside diameter and another diamond mounted inside to drill up the core as it is cut. From data assembled, it can be expected, with the diamond drilling bit, to drill 900 ft of hole in 10 to 12 days without making over one round trip. The same interval has been drilled in less time with no round trips.

Operators normally use oil and conventional circulation for the deepening process. By using jet collars, it is my understanding that the normal loss of oil is in the vicinity of 30 to 50 bbl per day. The entire deepening operation, including setting a liner, perforating, and fracturing the lower Spraberry, will cost approximately $30,000. For completion in open hole without a liner, the cost should be approximately $25,000.

With the intense activity in the Spraberry trend, with all operators attempting to complete wells in the most efficient and economical manner, many new techniques and completion practices will be tried. For example, all operators have their own ideas on the most effective amount of fracturing fluid. The treatments vary at the present time from the general figure of 1,500 to 3,000 gal upward to several thousand gallons. The operator must weigh the cost vs. possible return and base his decision accordingly. Perhaps with more complete production history vs. pressure-decline curves, many of the varied techniques as now employed in well completions will be condensed to more or less standard procedures in the later wells. Quite naturally, as in every other field in the country, each and every operator is trying to complete wells in the manner he believes will yield the most oil for the least possible expenditure.

J. H. Marsee (Phillips Petroleum Company, Odessa, Texas) (written): The author has made no attempt to cover every variation in drilling and completion techniques practiced by all operators, but he has covered the most generally used procedures quite thoroughly. In presenting a discussion of his subject I am forced to draw on somewhat limited experience to present observations of the drilling and completion practices of my company.

Our practice in the Spraberry trend is generally as follows: Surface pipe is set to approximately 280 ft; cement is circulated. Drilling proceeds to 4,000 ft, using water as the drilling fluid. At that depth the pits are cleaned thoroughly and refilled with water. Salt gel is mixed while drilling until a funnel viscosity of 36 to 38 sec is reached. Crude oil is added to the drilling fluid until a weight of 9.2 to 9.4 lb per gal is obtained. No emulsifying agents as such are used. Sealing material is also added at this time.

Drilling proceeds to 30 or 40 ft above the Spraberry formation, where casing is run. Our company follows the practice of cementing only around the shoe and for a short distance up behind the pipe.

After drilling the casing shoe and a few feet of formation below the oil-string casing point with a conventional bit, the mud in the hole and in the circulating system is displaced with oil and preparations are made to diamond core approximately 200 ft of the upper zone of the Spraberry. From 3 to 5 days are required for the coring operation.

Once the diamond coring is accomplished, logs are taken, the 2⅞-in. drill pipe is laid down, and the rotary rig is released. Mast-pole units are then moved in to make the final completion which consists of Hydrafracing and swabbing.

The evolution of the mud program to its present state has been interesting to observe. The first well along the Spraberry trend to be drilled by our company tools was drilled in the Tex Harvey area. The intermediate casing point was to be approximately 4,750 ft. This depth was established for the purpose of casing off the porous zones of the San Andres formation. We had some experience in drilling an intermediate hole to this depth in other areas, and had encountered the same stuck-pipe difficulties which we encountered in drilling our first Spraberry well. The procedure was to mix starch mud beginning at approximately 4,200 ft to obtain water-loss and filter-cake control. As a result, in our first Spraberry operation we had extremely good mud for drilling this part of the hole, but the story was the same as always—the drill pipe stuck in the bottom porous zone of the San Andres. Other operators were drilling this zone with water and no stuck-pipe difficulty occurred, so shortly thereafter the casing point was moved up the hole to approximately 4,000 ft. As stated in Mr. Franklin's paper, until the shortage of casing came into the picture an intermediate casing point of approximately 4,000 ft with clear-water drilling below the casing point became standard practice.

To many people whose experience had caused them to conclude that good mud was always preferable for combatting such difficulties as stuck pipe, the success of the clear-water program was somewhat confounding. Nevertheless, acceptance of the facts as illustrated has resulted in the use of water in lieu of mud in many other instances. One explanation as to why stickiness always occurred when drilling the lower porous zone with starch mud is that a reaction between the mud and the sulfur water contained in the formation would occur. This reaction results in localized dehydration, causing a large wall cake to be formed.

When the present casing program was planned and discussed with men who were to drill our Spraberry trend holdings much skepticism was voiced. It was thought in order to maintain satisfactory bore-hole wall through the red-bed zones it would be necessary to carry a viscosity which would materially reduce penetration rates. Some very limited trouble has occurred with the use of clear water but it is doubtful that anyone has suffered greatly, for the overall drilling time required to drill a well is approximately what it was when the intermediate casing string was set, or perhaps somewhat less than that time.

Inquiry was made of various operators as to whether they were satisfied with the present procedures. The purpose of such inquiry was to gain an opinion as to whether the expedient methods brought about by the casing shortage might not be as satisfactory as the earlier programs. Unfortunately, no one chose to give a direct answer. The point I wish to make is that often we become satisfied with an established procedure and only the press of circumstances will bring about improvement in that procedure. Circumstances in the development of Spraberry trend holdings contain a lesson from which the industry is benefitting; i. e., that we need to be less self-satisfied with existing programs or techniques and be more venturesome in various other areas in which we operate.

Robt. Sweeney (Murphy Corporation, El Dorado, Ark.): I wonder if you have any figures on percent production decline for the various methods of completion?

Mr. Franklin: The only figures I have at the present time are those on a group of wells in the Tex Harvey Field and they may or may not be applicable to other areas.

In wells completed in the upper Spraberry, having the entire interval of 200 ft open for production, the pressure decline is in the order of 1.8 lb per day for wells producing at top allowable rate. This ranges from 100 to 121 bbl per day per well. Wells completed in only the upper section of the upper Spraberry, offsetting the aforementioned wells and producing at approximately the same rate, experienced a pressure decline of approximately 4 lb per day. On the basis of this information, many operators have deepened wells through the upper Spraberry and are now producing from the entire section.