Deep Well Drilling and Completion

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The first field progress toward the discovery of the Hamon (Ellenberger) Field, Reeves County, Texas, was begun on October 20, 1963, the spud date of the Jake L. Hamon No. 1 Waples Platter. Considerable time had elapsed since the drilling deal was first envisioned on the drafting board and many hours had been spent by both the geologists and landmen prior to the final approval by Management of the 12 working-interest owners. There were several times during the 579 days required to drill and complete this well when the possibility of an ultra-deep Delaware Basin gas discovery seemed rather remote. Through close coordination of Management with field personnel and utilization of the most recent developments in technology and services, the well was completed as the world's deepest commercial producer on May 20, 1965, for an absolute open-flow potential of 50,000 MCFPD.

The drilling prognosis for this well was developed after consideration of the meager information that had been released concerning the drilling of the discovery well in the Gomez (Ellenberger) Field, Pecos County, Texas, the Pure Oil Company No. 1 W. C. Tyrrell, which was completed September 27, 1963. The original total depth was projected to 16,500 ft., and to a greater depth if the structural position so warranted. The tentative casing program was: 26-in. casing to 350 ft., 20-in. casing from surface to 1600 ft., 13⅜-in. casing from surface to 6000 ft., 9⅝-in. casing from surface to 14,000 ft., and 7-in. casing from surface to the lowest productive formation. The casing program was proposed realizing that a degree of flexibility in altering the program would be necessary to meet the specific wellbore conditions or problems. No coring was planned but it was proposed to drill-stem test all possible productive horizons.

After the 26-in. casing was set and cemented at 352 ft., it was decided to drill the 17½-in. hole to such depth that the expected sulphur water flow from the Rustler curtailed drilling operations. Then the hole would be reamed to 24-in. and 20-in. casing set. The 17½-in. hole was drilled with brine to 5893 ft., without encountering the sulphur water flow and 13⅜-in. casing was set at 5893 ft. Cement was circulated to the surface through the use of two-stage collars set at 5013 ft. and 1185 ft. and a total of 5633 sacks of cement containing various additives. A slip weld bradenhead with a 72-in. landing base was installed to withstand the compressive loading that would be caused by the remaining strings of casing. The cellar was then filled with concrete to provide a permanent base for the bradenhead.

Drilling progressed through 12-in. hole with brine to 6446 ft. and loss of circulation was encountered. Due to the loss of circulation the system was changed from brine to 8.6 lb./gal. fresh water mud at a depth of 6545 ft. The first gas kick occurred while drilling the Wolfcamp section at 10,999 ft. Because of the prior lost circulation zones, the fresh water, low solids, ligno-sulfonate mud system was held to a maximum weight of 9.8 lb./gal. and the trip gas was controlled by diverting the returns through the drilling wellhead manifold. The manifold pressure would occasionally increase to 1700 psi for short periods of time while unloading slugs of dry gas. The gas continued to feed into the wellbore during drilling operations but was removed from the mud system through the use of a degasser. Notwithstanding these conditions, eight successful drill-stem tests were run and the hole was drilled to the tentative 9⅝-in. casing seat at 14,145 ft. An attempt was made to log at 14,145 ft. but the logging sonde stopped at 13,432 ft. During the process of drilling out bridges, loss of circulation developed in the Canyon zones at approximately 6700 ft. Thirty days had elapsed during the attempt to seal the thief zones, when the bit stuck at 9305 ft. while pulling the drill pipe. While attempting to work the drill pipe free, the hook failed and the drill string dropped until the swivel hit the rotary table. The impact caused the drill pipe to part 5652 ft. below the rotary table and the remaining 3653 ft. of fish dropped down the hole. The fish consisted of 105 joints of 4½-in. drill pipe, twelve 8-in. drill collars, a 9-in. cross-over sub, a 9-in. bit sub and a new 12-in. bit. An attempt to retrieve the fish resulted in a 68-day fishing job.

Fifty-two days were spent in attempting to seal the lost circulation zones in the Canyon zones at 6700 ft. Tracer surveys were run to locate the thief zones. Mud mixed with various types of additives along with other temporary plugging mixtures would seal the thief zones until such time that the heavily gas-cut mud and dry gas pockets from the Wolfcamp were circulated by the patched zones. The thief zones would then re-open. In order to mechanically seal these zones, a 10¾-in. liner was set and cemented from 5669 to 8773 ft. prior to determining the depth of the top of the fish. After drilling out below the 10¾-in. liner, additional lost circulation zones were encountered in the Bone Springs section, but were sealed by cement-squeezing short intervals at a time. A major portion of the mud costs was expended while attempting to seal the thief zones since large volumes of mud were lost each time because of the capacity of the 12-in. borehole.

Twelve days after drilling out below the liner, the top of the fish was found at 10,461 ft. which meant it had dropped 4809 ft. and had stopped, depending upon the condition of the drill pipe, 31 ft. or less from bottom. All of the 4½-in. drill pipe was recovered after 10 additional days. At this point, the question arose as to the economics of additional fishing versus drilling in deviated hole. The advantages of straight-hole drilling as compared to deviated-hole drilling for the extended length of time required to reach the ultra-deep horizons dictated additional fishing operations. A screw-in sub was run and screwed into the top of the drill collars at 13,646 ft. Even though 56 days had elapsed since dropping the fish, circulation was established, the drill collars were worked free and drilling operations were resumed. Although it is contrary to engineering practices, 12-in. hole was drilled below the 10¾-in. liner. The bit made 178 ft. during 180½ rotating hours, whereas the average bit life had been 14 to 18 hours. The extended run on the bit was an attempt to lock the cones to facilitate the backoff of the drill collars. The drill collars were backed off and recovered. A 13.5 lb. jet charge was fired on top of the bit and the bit was recovered during two runs with a junk basket and rotary shoe and one run with bit and junk basket. At this point, it seemed the impossible had been accomplished in a minimum of time, considering the depth of 14,323 ft.

Drilling operations continued through 9⅝-in. hole to 15,300 ft. and 8⅝-in. casing set from surface to this depth and cemented. This casing was set after considering two possibilities; the re-opening of the patched thief zones immediately below the 10¾-in. liner, or the penetration of a high pressure Mississippian zone which could not be controlled with higher weight muds because of the patcher thief zones. With the possibility of the high pressure Mississippian zone, 8⅝-in. casing instead of 7⅝-in. was set, since it would be necessary to seal the high-pressure zone with a liner prior to penetrating the Devonian. Normal drilling operations through 7⅜-in. hole was continued to 16,935 ft. and the gas from the Mississippian zone cut the mud from 10.2 to 7.5 lb./gal. Mud weight was raised to 14.0 lb./gal. and drilling was continued to 17,059 ft. A drill-stem test was run which indicated the initial shut-in pressure of the Mississippian to be in excess of 10,327 psi. Even though the gas continued to cut 15.2 lb./gal. mud, the hole was drilled to 17,360 ft., 12 ft. below the top of the Devonian, and a 7-in. flush joint liner was set and cemented through the 7⅜-in. borehole from 14,997 to 17,357 ft.

After setting the 7-in. liner, the mud weight was cut to 9.1 lb./gal. and drilling continued through 5⅞-in. hole with diamond bits to 21,745 ft. Four additional drill-stem tests were attempted in the Devonian section, two being successful. These tests were conducted without water cushion and utilizing the nitrogen valve to overcome the collapse resistance of the lower section of the drill pipe. A 5-in. liner, with tie-back sleeve was set from 14,797 to 21,735 ft. in order that the Ellenberger could be produced through casing that had very little wear from drill pipe. The well was then drilled to a total depth of 21,800 ft. and drill-stem tested gas and salt water was recovered from the Ellenberger open hole section from 21,735 ft. to 21,800 ft. This finalized drilling operations.

After successfully drilling the world's deepest producer, the record holder for only a short while after its completion, it was anticipated that completion operations would be normal other than excessive treatment pressures which were to be expected. Many unforeseeable hazards, however, developed during the completion operations. Some of these hazards were failure of 8⅝-in. casing coupling at 3129 ft., necessitating the running of the longest string of 7-in.

flush joint casing from surface to tie-back sleeve of 5-in. liner, failure of primary cement job around 5-in. liner, and failure of tubing joint in lower section of work string. After squeeze cementing perfs. 21,334 to 21,600 ft. which tested gas and salt water, perforations 21,100 to 21,169 ft. were tested and found to be water free. A bridge plug was set at 21,070 ft. and perforations 20,470 to 21,070 ft. were opened for completion.

Two permanent packers were set in the 5-in. liner at 14,830 and 14,824 ft. The tubing string was fabricated from 4½-in. drill pipe tubes that were threaded for modified buttress casing couplings and internally coated with high-temperature plastic coating. The tubing was landed in the permanent packers utilizing a telescoping joint and 16 ft. of sealing elements.

The acid stimulation treatment consisted of four separate stages. Prior to the first stage the well tested 800 MCFPD. The first two stages consisted of a 3000 gal. mixture followed by a 8000 gal. mixture of hydrochloric and acetic acid and were performed prior to the running of the tubing string. The third stage consisted of a 50,000 gal. mixture of hydrochloric and acetic acid converted to a surfactant retarded acid containing corrosion inhibitor, chelating agent and 300 standard cu. ft. of nitrogen per bbl. The acid was pumped down the 4½-in. tubing at 18.6 bbl./min. at 8400 psi. The well was cleaned until the majority of spent acid water was recovered.

Prior to the fourth stage, additional research was necessary since there were no known blocking materials that would remain stable at the reservoir pressure and temperature. The final treatment consisted of 15,000 gal. of special high-temperature-retarded acid emulsion and 125,000 gal. of mixture of hydrochloric and acetic acid converted to a surfactant-retarded acid separated in four stages followed by 10,000 gal. of mixture of hydrochloric and acetic acid. The total acid volume contained corrosion inhibitor, chelating agent, gelling agent, friction reducing agent and 352 standard cu. ft. of nitrogen per bbl. The acid was pumped down the tubing at 22.5 bbl./min. at 7800 psi. The Hamon (Ellenberger) Field, despite the hazards involved in the drilling and completion of the discovery well, is today considered to be a commercial gas field because of the overall effect of the 211,000 gal. acid stimulation treatment. The deliverability of the Waples Platter was increased from 800 to 17,700 MCFPD and was potentialed for 50,000 MCFPD of dry gas on May 20, 1965.

Although the discovery well is shut-in, pending pipeline connection, three additional development wells are being drilled in the Hamon (Ellenberger) Field. Texaco, Inc. is drilling to the west and Jake L. Hamon is drilling one to the north and another to the south of the discovery well. The drilling program for each of the development wells being drilled by Hamon was finalized after careful review of the hazards involved and consideration of the knowledge and experience gained during the drilling and completion of the discovery well.

In an effort to control the lost circulation zones in both the Canyon and Bone Springs, the casing program was designed as follows: 36-in. conductor set to 25 ft.; 20-in. casing set to 1600 ft. and cemented to surface; 13⅜-in. casing set to 9500 ft. and cemented to surface utilizing two-stage collars; 10¾-in. liner set and cemented from 9000 to 13,000 ft., and 7⅝-in. liner with tie-back sleeve set and cemented from 12,400 to 17,400 ft. If the Ellenberger is found to be productive, the 7⅝-in. liner will be extended back to the surface and a 5-in. liner will be set and cemented from 15,800 to 21,400 ft.

For further evaluation of the possibly productive horizons encountered during the drilling of the discovery well, the large casing strings were designed so cores could be taken in the Wolfcamp, Mississippian and Ellenberger zones. For additional evaluation, drill-stem tests are proposed for all zones that warrant same either by coring or sample analysis. It was recognized that additional monies would be expended because of maintenance of large mud systems, additional tonnage of steel and expense of coring and testing, but it was felt that the additional information would compensate through increased savings of additional wells drilling in the area. Since the Ellenberger gas contains in excess of eight per cent carbon dioxide, the value of these reserves could be greatly enhanced if additional reserves of sweet gas could be developed and blended prior to sale into a gas pipeline.

Presently both wells operated by Jake L. Hamon are drilling below 17,000 ft. and are progressing according to the original time schedule. Assuming the original time schedule can be followed to completion, the time required to drill and complete a development well can be reduced by 40 per cent or more which would reflect a decrease in costs in direct proportion. Although considerable time and monies are still involved in the completion of an ultra-deep prospect, it is felt that only additional experience and improved drilling and completion techniques in the Delaware Basin are the answer to the reduction of time and costs. Due to the large number of tests now drilling in the Delaware Basin, an intensified effort of producing companies, drilling contractors and service companies should be directed toward reducing costs to enhance the economics of deep drilling.