Offset Brine Wells by Directional Drilling

by
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ABSTRACT

Directional drilling has been used for many years by the petroleum and related industries to provide low cost multiple well completions from a single surface installation. The application of this method for installation of brine wells is thought to be somewhat new to the salt industry.

In the summer of 1961, an offset brine well was completed by directional drilling techniques at the Moundsville, West Virginia plant of Allied Chemical Corporation, Solvay Process Division. A depleted well was used to provide surface facilities and a large portion of cased hole for installation of the offset well. The well was bottomed at a location which fit the existing well spacing pattern.

Detailed planning and careful drilling control contributed to the successful completion of the new installation. Additional applications of directional drilling techniques for general brine field use are contemplated for the future.

The results achieved from this installation demonstrate that depleted wells offer an opportunity for installing offset wells at substantial cost savings.

INTRODUCTION

In the summer of 1961, an offset brine well was completed by directional drilling at the Moundsville, West Virginia, plant of Solvay Process Division, Allied Chemical Corporation. Directional drilling as a method of well installation has been used for many years by the petroleum and related industries to provide low cost multiple well completions from a single surface installation. The application of this method to the installation of brine wells is thought to be somewhat new to the salt industry.

The Moundsville Plant of Solvay is located on the Ohio River in the panhandle of northwestern West Virginia. The region is underlain, at about 6400 ft. depth, by a continuation of the extensive "Salina" salt of Silurian age. Artificial brine is obtained from wells which penetrate this salt and is used by Solvay to manufacture such items as chlorine, caustic and organic chloride compounds. The stratigraphy of the Moundsville area is shown in Figure 1 on the following page.

At the Moundsville brine field, the wells are operated in groups by injecting water into one well and withdrawing saturated brine from one of the other wells through a tailpipe or tubing which extends to the bottom of the well cavity. When the cavities reach maturity, it is not uncommon for roof falls to occur which break off the tailpipe and fill the lower portion of the cavities with broken rock. When this occurs, it is necessary to either repair the well by re-inserting a new tailpipe to the bottom of the cavity, or to abandon the well and install a replacement.

Repair of mature brine wells is usually quite difficult since a hole for the replacement tailpipe must be drilled through the pile of broken rubble in the bottom of the cavity. In addition to

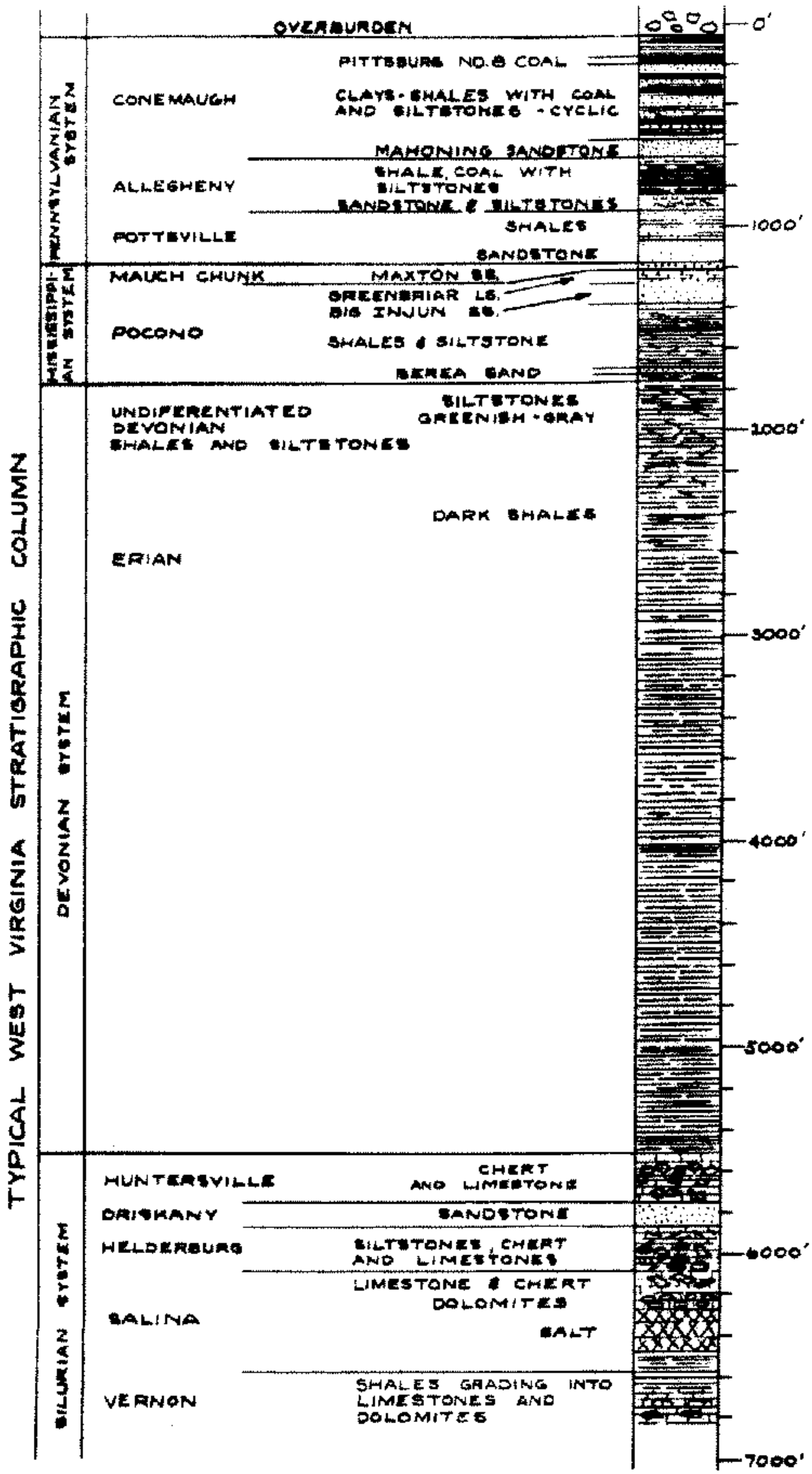

TYPICAL WEST VIRGINIA STRATIGRAPHIC COLUMN
OVERBURDEN
PENNSYLVANIAN SYSTEM
CONEMAUGH
PITTSBURG NO.8 COAL
CLAYS - SHALES WITH COAL AND SILTSTONES - CYCLIC
MAHONING SANDSTONE
ALLEGHENY
SHALE, COAL WITH SILTSTONES
SANDSTONE & SILTSTONES
POTTSVILLE
SHALES
SANDSTONE
MISSISSIPPIAN SYSTEM
MAUCH CHUNK
MAXTON SS.
GREENBRIAR LS.
BIG INJUN SS.
POCONO
SHALES & SILTSTONE
BEREA SAND
DEVONIAN SYSTEM
UNDIFERENTIATED DEVONIAN SHALES AND SILTSTONES
SILTSTONES GREENISH - GRAY
DARK SHALES
ERIAN
SILURIAN SYSTEM
HUNTERSVILLE
CHERT AND LIMESTONE
ORISKANY
SANDSTONE
HELDERBURG
SILTSTONES, CHERT AND LIMESTONES
LIMESTONE & CHERT
DOLOMITES
SALINA
SALT
VERNON
SHALES GRADING INTO LIMESTONES AND DOLOMITES
0'
1000'
2000'
3000'
4000'
5000'
6000'
7000'

Figure 1.

large blocks and slabs of broken rock, the rubble pile almost always contains pieces of old tailpipe. Penetration of this type of material by either cable tool or rotary drilling methods has been found to be quite expensive and time-consuming. Also, once a new tailpipe is installed, it can easily be damaged or broken at any time by a slight shift of the rubble pile. Therefore, before extensive well repairs are undertaken, a careful evaluation must be made to compare the cost and life expectancy of a repair job with a new well installation.

During the summer of 1961, roof falls occurred in one of the well groups at the Moundsville brine field which made it necessary to consider repair of one of the wells, or installation of a new offset well. Since the well considered for repair was essentially depleted, any repairs made were expected to be quite expensive and to have a short life expectancy. Therefore, a decision was reached to install a new offset well rather than attempt to repair the old well. During a study of well installation methods, the possible use of the upper portion of the old well appeared to offer an opportunity for saving installation of surface facilities, and considerable drilling and casing.

The use of directional drilling for the proposed offset well was discussed with the McClure Drilling Company, a drilling contractor, and Houston Oil Field Material Company, commonly called HOMCO, a directional drilling service company. Both concerns were quite confident that the job could be completed successfully at substantially less cost than installation of a new well. With this encouragement, the decision was made to proceed with the directional drilling attempt.

PLANNING THE PROGRAM

Since this was Solvay's first attempt at directional drilling, a detailed study was made to prepare an overall plan for the program. Figure 2 illustrates the original well installation:

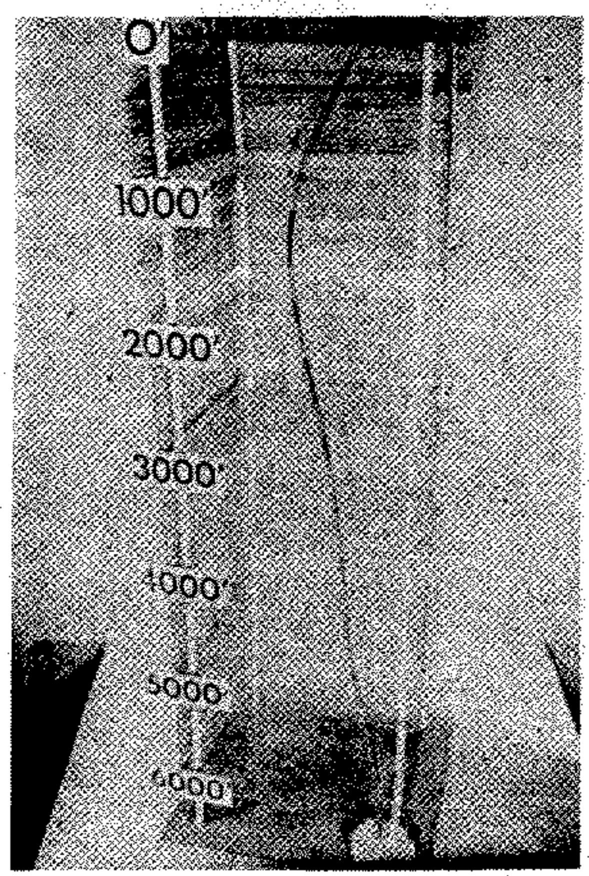


Figure 2.

Figure 3 shows the proposed shipstocked offset.

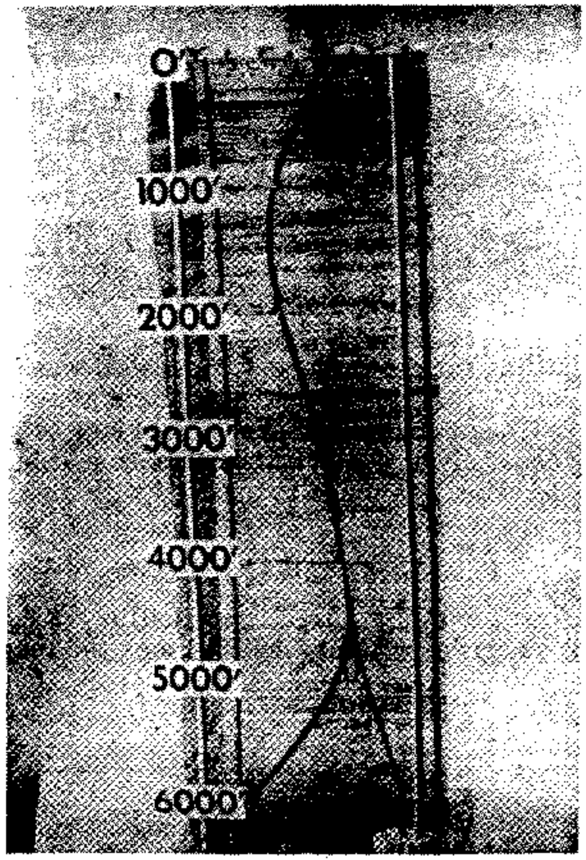


Figure 3.

A target area was selected so that the lower portion of the new offset well would fall in the existing well spacing pattern. It was decided that the bottom of the offset hole should be located at a point no less than 300 ft and no more than 350 ft. from the base of the previous hole. The horizontal location was to be due east of the old well, with a 15° allowable deviation.

After the target area was determined, the drilling record of the old well was carefully studied to select the location of the kick-off point from which to commence the directional drilling. It was learned from discussions with HOMCO that the point of kick-off should be selected in an area where the existing hole had at least 2° of inclination in order to provide a base for accurately orienting the deviation tools. Also, the kick-off area should be located in a reasonably hard formation so that the maximum angle of deviation could be obtained in the shortest drilling distance.

The McClure Drilling Company (now North American Drilling) was retained as the drilling contractor to conduct the directional drilling operations. Various drilling methods were appraised and it was decided that fluid drilling would be used in order to maintain the maximum control of drilling variables. Although air drilling might have been considerably faster, it was not seriously considered because of possible difficulties in obtaining a straight hole. However, in view of the problems encountered in drilling the extremely hard formations above the salt, serious consideration will be given to air drilling for the next offset attempt.

With the cooperation of HOMCO personnel and the drilling contractor, a sequence of operation for the proposed whipstock offset was devised. The following table shows the steps outlined for completing the proposed offset well.

SEQUENCE OF OPERATIONS -- WHIPSTOCK OFFSET WELL

I. PLUG LOWER PORTION OF ORIGINAL WELL

II. ORIENT AND WHIPSTOCK HOLE

III. INSTALL AND CEMENT LINER CASING

IV. DRILL FRAC HOLE

V. SET PACKER AND FRAC

VI. WASH AND COMPLETE

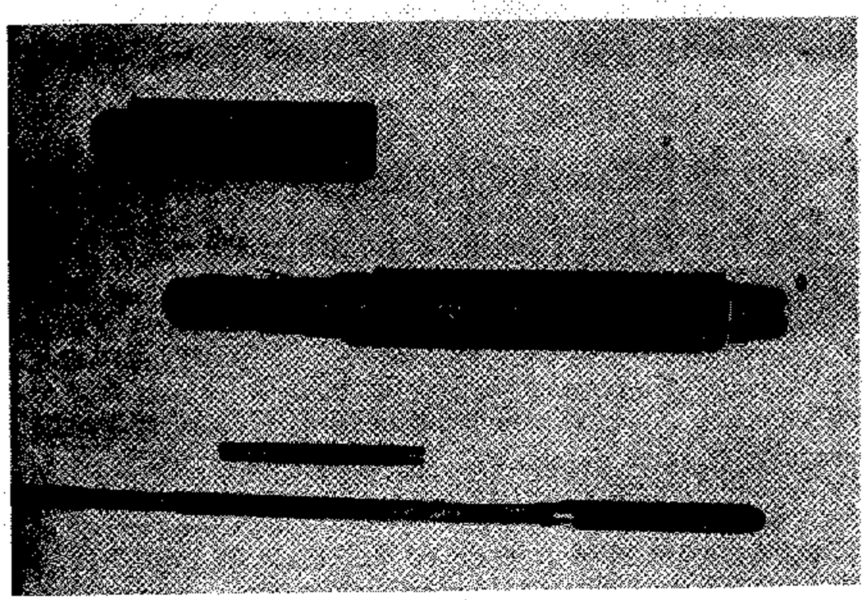
SEQUENCE OF OPERATIONS

Step 1 -- Plug Lower Portion of Original Well

McClure's rotary drilling equipment was set up, and surveys were run to determine the exact point from which drilling was to commence. An electric line bridge plug was set 80 ft. below the chosen kick-off point and a 23 ft. cement plug was placed on top of this bridge by means of an electric dump bailer. This completed Step 1 as shown in the table.

Step 2 -- Orient and Whipstock Hole

To assure proper hole orientation, a wire line, single shot photographic orientation device was used by HOMCO. Figure 4 illustrates this instrument and the non-magnetic monel drill collar, in the bottom of the photo, within which it is used.

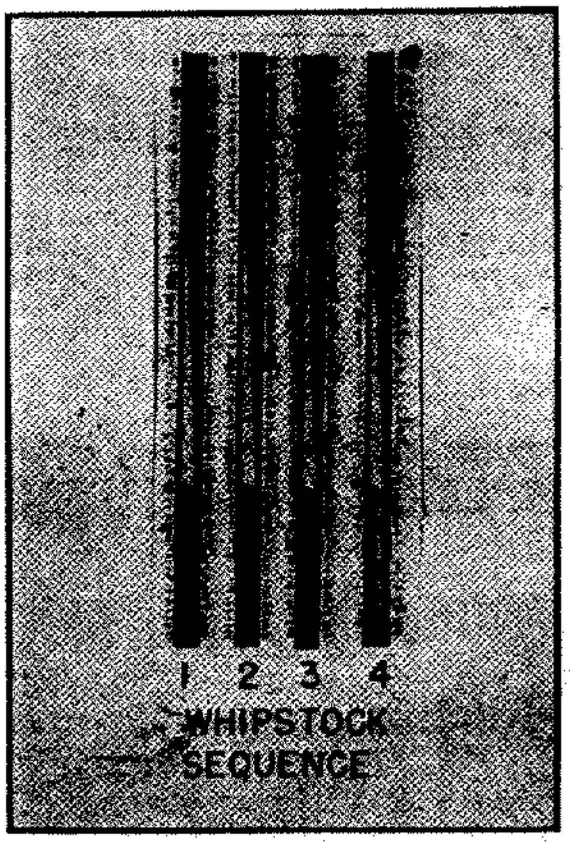


Courtesy of HOMCO.

Figure 4.

The term "single shot" is generally used to describe a well surveying instrument which requires a trip into the well for each survey point obtained. In order for this instrument to be used, it is necessary that a non-magnetic drill collar be placed in the string of tools. This collar, known as an indirect orienting sub, is designed so that the single shot instrument will set down within it close to the base of the hole. A photograph is then obtained which provides a means for measuring the inclination of the hole and the angular difference between a fixed magnet and true north to orient the attached tools. When the orientation of the deflecting tools has been made, they are then set in the hole.

There are numerous deflecting tools available. However, for use within the installed casing, we selected a permanent whipstock. This whipstock and sequence of operation are shown in Figure 5.



Courtesy of Bowen Kinzbach.

Figure 5.

The prime advantage of using a whipstock, in this instance, for sidetracking lies in the fact that the casing string remains intact and will not be completely severed. The whipstock shown in the photo is essentially a long, slender, hinged, tapered steel wedge with a concave groove on the inclined face. The hinged portion allows the top of the whipstock to lie back against the wall of the pipe at all times, permitting easy passage of drilling tools.

After the whipstock had been correctly oriented with the inclined face pointing toward the desired direction of deviation, it was slowly raised until the attached trigger became engaged in a casing collar. This released the slips which were then firmly set against the steel casing by lowering the weight of the drill string on the whipstock, as shown by No. 1 of the photo sequence.

The drill mill attached to the top of the whipstock was sheared free by the added weight and wedged the top of the whipstock against the wall (No. 2 in sequence). The mill was then used to cut a window through the casing wall. The snout of the attached drill mill followed the tapered face of the whipstock and forced the mill to cut through the pipe wall without damaging the top ction of the whipstock (No. 3 in sequence).

After the initial window had been opened for a length of approximately 18 in., a flat-head mill was run on the drill string to continue milling the remaining portion of casing adjacent to the angular face of the whipstock as shown in No. 4 of the photo sequence.

When the casing had been satisfactorily milled, and the hole opened into the rock a short ways, a reasonably limber drill string was inserted through the window opening to initiate rock drilling. Orientation of the hole was periodically checked by running the single shot survey instrument on a wire line to provide a record of the angle of deviation and direction in which the new hole was being drilled. Typical results are shown in Figure 6 of a drill hole survey record.

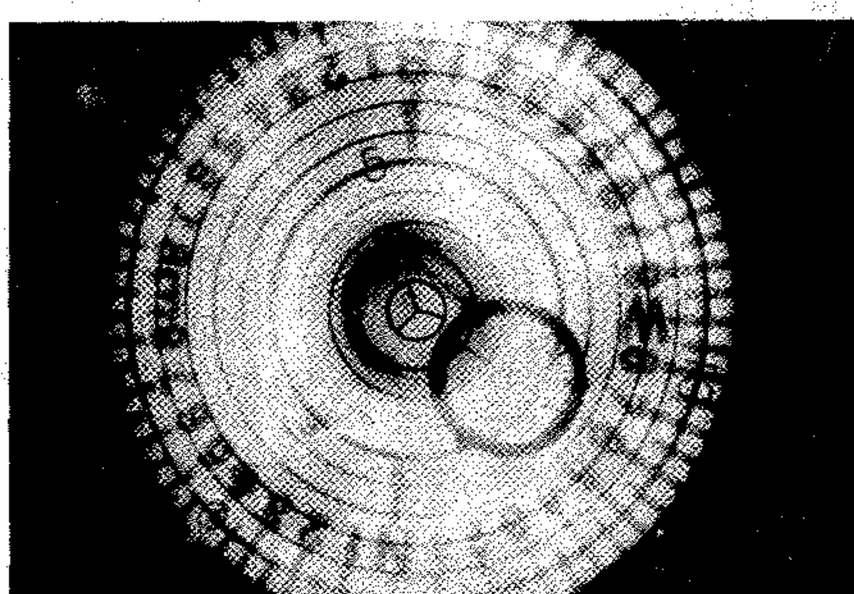


Figure 6.

This particular survey record shows that at the depth of the survey the hole had an inclination of 4° and a bearing of N 60° W. The periodic deviation surveys were used to assist in evaluation of changes in drilling variables, such as bit type, speed of rotation, weight, pump pressure, etc.

Now that the new hole had been started, stabilizers were placed in the drill collar string to provide deviation control during the drilling operation. Depending on their position in the string with respect to the bit, the triple wing, blade-type stabilizers were used, as shown in Figure 7.

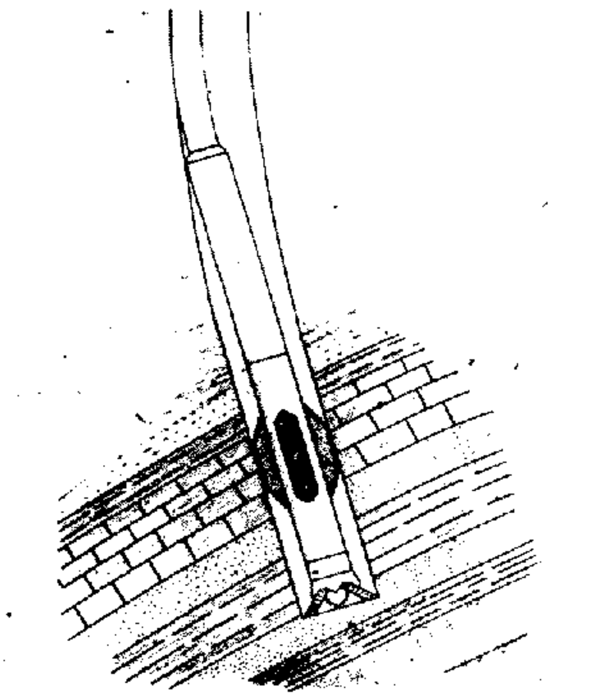
a. To produce a high angle when placed just above the bit; and as shown in Figure 8.

b. To decrease the angle when placed below the point of tangency of the drill collars. Stabilizers also are used:

c. To keep the hole on course after the desired angle had been established.

d. To help maintain full circulation and reduce dog-legs and kinks.

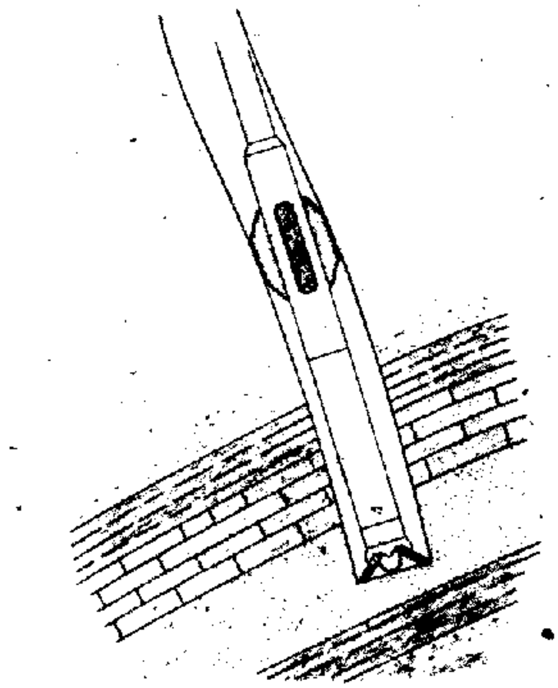
PICKING UP ANGLE



Courtesy of HOMCO.

Figure 7.

STRAIGHTENING THE HOLE



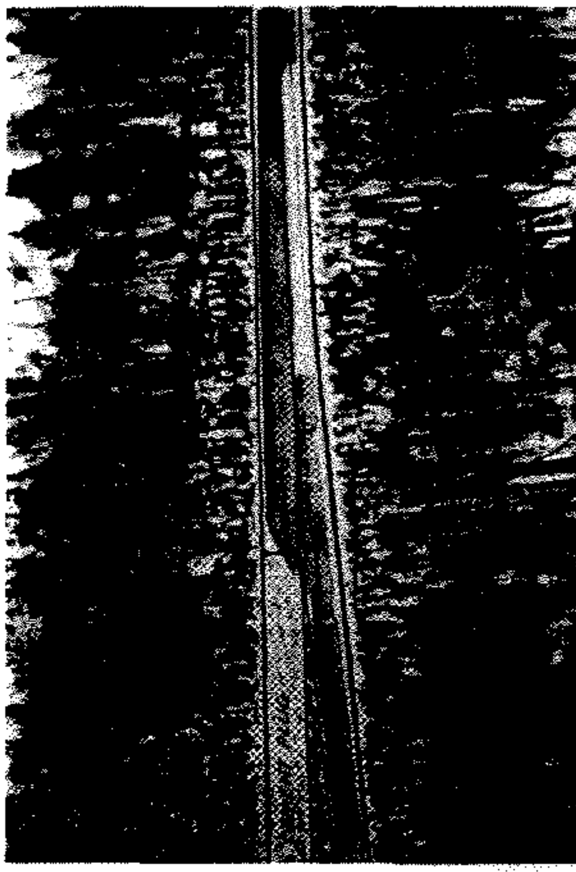
Courtesy of HOMCO.

Figure 8.

Examination of records of the previously drilled hole indicated that the new hole could be expected to spiral counter-clockwise naturally and drift north. It was hoped that, by rigid control of the major drilling factors, this spiraling could be eliminated. In spite of remedial drilling techniques, the periodic surveys of hole deviation indicated that the hole was drifting away from the target area. To overcome this drift, a retrievable whipstock was used in two instances to bring the hole back on course. This type of whipstock is shown in Figure 9.

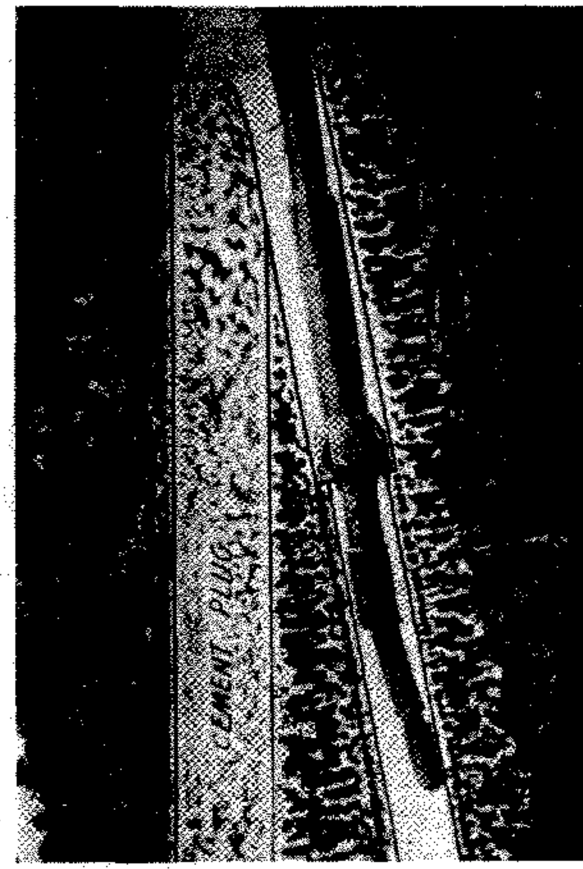
The retrievable whipstock used was approximately 10 ft. long. A small hole through the whipstock permits circulation to be maintained for washing sediments or cuttings free which may impede its setting. After the wedge-shaped face of the whipstock had been correctly oriented, in a manner similar to that used to orient the permanent whipstock, the chisel-shaped end was driven into the bottom of the hole. Circulation was diverted by dropping a ball through the drill pipe and pumping it down to a landing seat. When disengagement of the attached bit was accomplished by shearing of a pin, rotation was commenced and the bit drilled a rat hole off the deflecting face of the whipstock. This hole was advanced 10 ft. below the whipstock to establish the newly oriented course. The drill string was then lifted until the bit engaged the collar of the whipstock and the entire unit was removed from the well. The deflected hole was reamed with a specially designed follow-up bit before drilling with regular equipment was resumed.

Once the original direction had been re-established, control of the slope or drift angle of the hole was generally maintained without further use of retrievable whipstocks. This was accomplished by close regulation of bit pressure, rotation speed, pump pressure and drill pipe torque. The drilling control instruments, particularly the weight indicator, were invaluable for providing the rigid control needed.



Courtesy of HOMCO.

Figure 9.



Courtesy of HOMCO.

Figure 10.

Further drilling progressed at an average rate until the hole had been satisfactorily placed within the target area at the predetermined depth. At this time, a caliper log was run to measure variations in hole size to determine the volume of cement needed to install the liner casing. This completed Step 2 of the sequence of operation.

Step 3 -- Install and Cement Liner Casing

Considerable engineering time was devoted to obtaining the most desirable casing arrangement for the newly drilled 6 1/4 in. hole. It was decided that 5 1/2 in. OD flush joint casing would be installed, equipped with a liner hanger and cementing shoe. The flush joint casing was selected to eliminate collars so the largest size casing possible could be used while still providing a free flow of cement. Since there was not sufficient clearance to install centralizers, four 8 ft. sections widely separated were under-reamed to prevent channeling of cement and to anchor the pipe at these points. The liner was cemented in the new hole with 150 sacks of regular Portland cement. Returns were obtained within the section of liner casing installed and flushed out. Step 3 of this portion of the sequence of operation was completed after the cement had been allowed to set 72 hr.

Step 4 -- Drill Frac Hole

In order to complete the offset hole to the same elevation as the old well, a 4 3/4 in. bit was inserted through the cemented casing string. Saturated brine was used as the drilling fluid for drilling the cement plug and remaining salt section. Following this drilling, a mechanical notching tool was used to ream the salt at the predetermined frac level. This completed Step 4 of the planned sequence of operation.

Step 5 -- Fracture and Wash-out

Step 5 was initiated by running an inflatable packer on 2 7/8 in. tubing through the 5 1/2 in. casing and 4 3/4 in. open hole. The inflatable packer unit was set in the open hole immediately above the frac notch level and a service company was called in to fracture the well to the adjacent cavity. The formation breakdown was obtained in less than an hour with saturated brine being used as the fracture fluid. The packer and 2 7/8 in. tubing were then removed from the hole to reduce the input pressure.

Following the formation breakdown and removal of tubing, the fractured opening was washed-out by use of fresh water. This completed the satisfactory installation of the offset well. The brine well was now installed as shown in Figure 11 of the well.

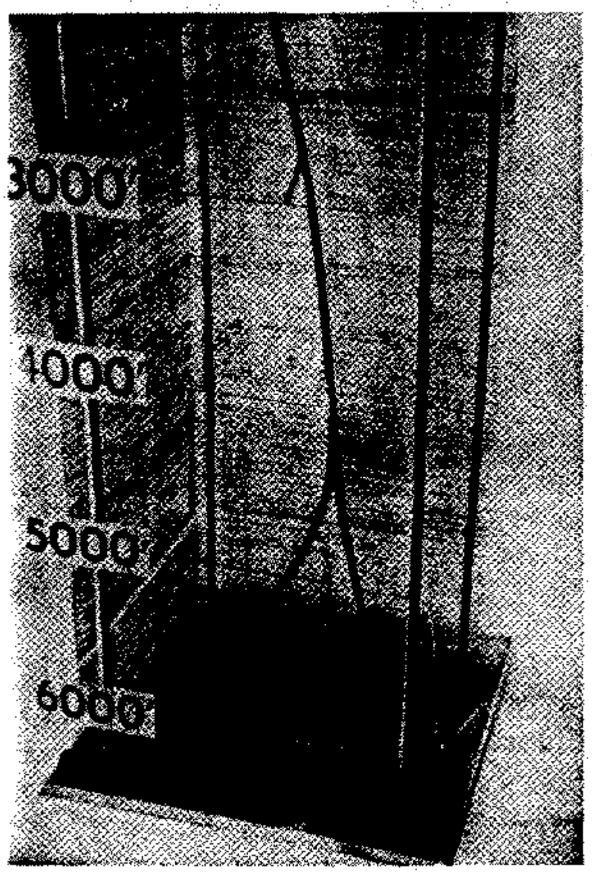


Figure 11.

With the satisfactory installation of this well, additional situations where directional drilling might be applied to brine field use were considered. The following sketches in Figure 12 illustrate some of these situations.

Sketch 1 shows a well deviated by whipstocking and subsequent drilling to bypass a rubble pile and connect within the existing cavity.

Sketch 2 illustrates an instance where the surface area vertically above a part of the brine field is inaccessible for drilling purposes. Wells situated laterally some distance away could be deflected to intersect the salt-bearing formations below these inaccessible locations. Some situations which come to mind might be drilling under a river or lake, drilling under existing waste beds, drilling under an area where rough topography prohibits installation of additional wells, etc.

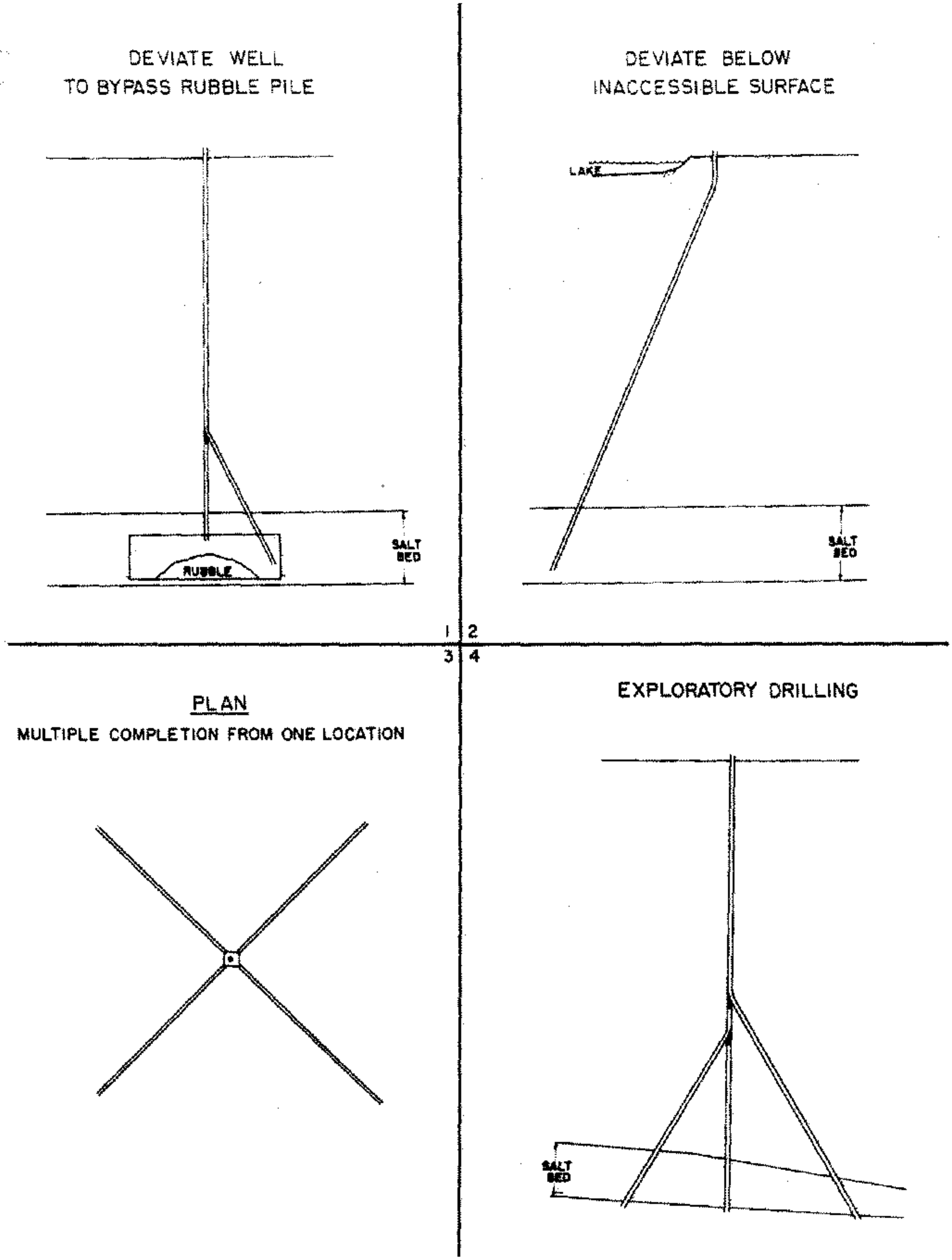


Figure 12 (1), (2), (3), (4).

Sketch 3 is a plan view showing multiple wells installed from a single surface location. This could provide economy in well installations through use of a single pad and production area for the several wells, pipe lines could be shortened and pumps centrally located. Also, the several holes could be drilled with a single rig set-up charge.

Sketch 4 illustrates a case where directional drilling techniques might profitably be used in exploration for a new field. As an example, a well could be drilled vertically to intersect the salt zone, and then plugged back a few hundred feet and deflected in another direction to penetrate the salt at a different point. After this, the hole could again be plugged back and redrilled, deflecting to penetrate the salt at a third point. With the information thus obtained, the structural features of the locality and variations in the salt would be known. The illustration depicts bedded salt; however, a salt dome could also be explored by this technique.

The well installation shown in Sketch 5 offers considerable potential for reducing the cost of new well installations. This is a multiple completion from a single well bore, wherein an inverted Y-shaped completion is effected and the wells connected by fracturing or other means. This provides the advantages of dual well operation through a single well-head.

MULTIPLE COMPLETION
FROM A SINGLE WELL BORE

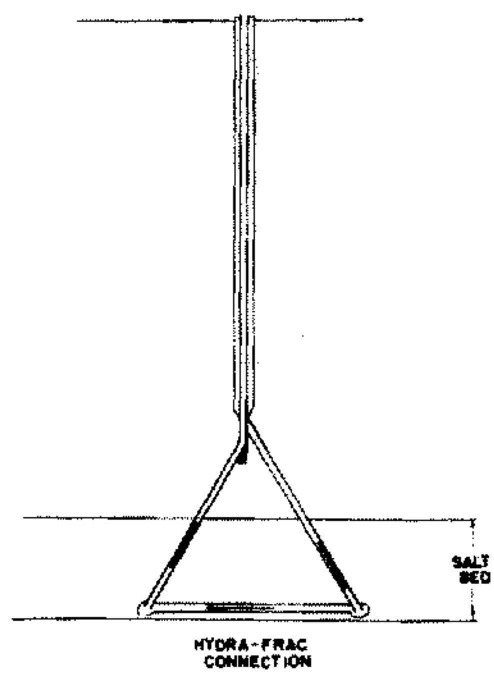


Figure 12 (5).

At this time, we feel that with detailed planning and careful drilling control numerous additional applications exist for use of directional drilling in brine field installations. Further, we feel that the results achieved from the Moundsville installation demonstrate that depleted wells offer an opportunity for installing offset brine wells at substantial cost savings.