# INTRODUCTION

An investigation has been made of the physical requirements of tubular goods employed in wellbores and in ordinary field operations. Under the current proration schedule and that which is anticipated for the foreseeable future, normal rates of production from a majority of wells may readily be obtained through smaller sizes of tubular goods than have been used in past well completions. There was no particular word definition assigned when the industry began substituting 5-1/2-inch OD casing with 2-3/8-inch OD tubing for the 7-inch OD casing with 2-7/8-inch OD tubing which had been regularly employed previously. The term "slim-hole" has been accepted in the past several years to denote the use of 5-inch or smaller casing rather than 5-1/2-inch casing although 2-3/8-inch OD tubing may be employed in either case. Slim-hole completions with 2-7/8-inch OD casing may be equipped with (1) hollow sucker rods, (2) non-upset tubing as large as 1-1/2-inch, or (3) with no tubing string.

A review of the New Mexico Oil Conservation Commission rules and regulations indicates that techniques and practices for slim-hole completions with 2-7/8-inch OD casing are in accord with all rules except 107 (d) which states:

1. All flowing oil wells shall be tubed.
2. All gas wells shall be tubed.
3. Tubing shall be set as near the bottom as practical and tubing perforations shall not be more than 250 feet above the top of the pay.

### History

Until recently, the mechanical limitations previously associated with small bore completions were not compensated by the reduction in initial investment. The increasing interest in this style of completion is due in large part to the successful development of through tubing tools and equipment ordinarily used in permanent-type well servicing and workovers. Originally, small bore completions were considered to permit the drilling of wells at locations where ordinary wells would yield unattractively low rates of return under the present producing schedule. The success of these minimum cost wells, however, prompted the expansion of this program to all areas where it is practical.

### Application

In flowing wells where tubing is not required, the maximum rate of production would be the same as from any ordinary well equipped with 2-7/8-inch OD tubing. Relatively lesser volumes may be obtained where flow must be restricted to smaller tubing , although equipment such as hydraulic subsurface pumps is commercially available to produce small bore wells at rates comparable to rates obtained from ordinary wells. The daily rates of production which may be obtained using various forms of artificial lift are shown graphically in Figure 1. Small bore wells are employed satisfactorily also, as injection wells in water flood operations.

## DRILLING

### Rig Selection

Contractors are not yet regularly equipped to drill and complete small bore wells and in some cases must charge premium rates for these

## PRODUCTION vs DEPTH ARTIFICIAL LIFT METHODS 2 7/8 INCH O.D. CASING COMPLETIONS

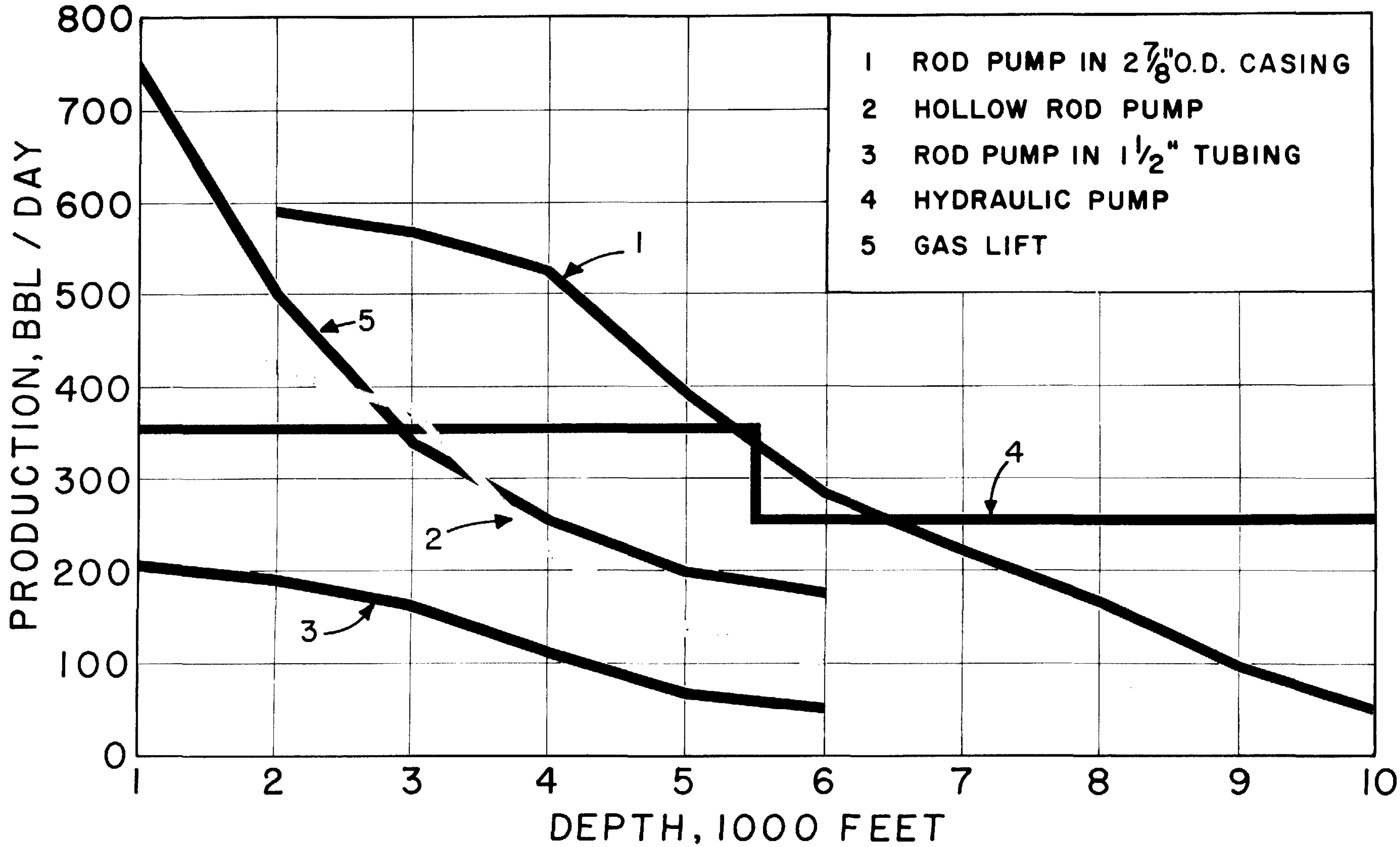



Figure 1

operations. Even greater economic advantages may be expected from 2-7/8-inch OD casing completions as smaller rigs become more readily available which will be fitted with equipment sized for this purpose. In this respect, consideration has been given wherever possible to the use of trailer-mounted or truck-mounted exploratory type rigs which are highly mobile and available at costs relatively lower than even the smallest ordinary rigs.

Hole Size

The optimum hole size to be drilled or the least expensive wellbore has been based on factors such as (1) rate of penetration, (2) bit life, and (3) thickness of cement sheath to surround the oil string casing. The size of the surface casing may be dependent on whether air drilling is to be employed, in which case it may be desirable to set a water shut-off intermediate casing. Where only water or mud are considered, 7-inch OD casing is adequate to permit the use of bits as large as 6-1/4-inches in the lower wellbore. A satisfactory hydraulics program may be prepared using 4-1/2-inch OD drill collars and 3-1/2-inch OD drill pipe in 6-1/4-inch hole. If larger sizes of wellbore can be drilled at lesser costs than 6-1/4-inch wellbore, the hole size may be reduced to 6-1/4 or 5-1/8-inches from a level of several hundred feet above the highest production interval anticipated in the wellbore to (1) permit improved penetration of perforators through a slimmer cement sheath, and (2) minimize the volume of cement required. In areas where a hole size of 5-1/8-inches can be drilled below the surface casing at an economic advantage, 4-inch OD drill collars may be employed on 2-7/8-inch OD drill tubing fitted with tool joint connectors.

Cementing Casing

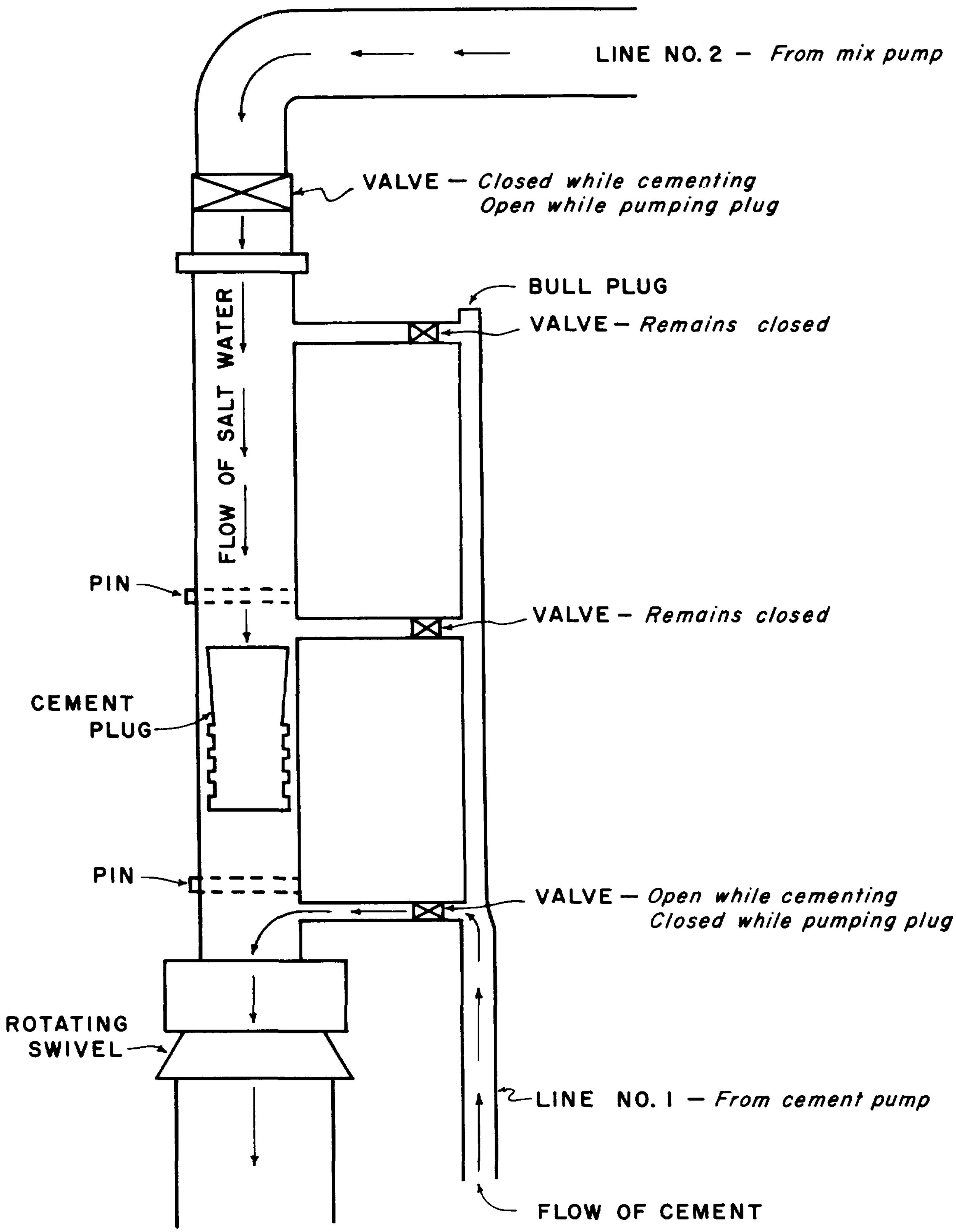
Float collars, float shoes, guide shoes and automatic fill-up collars in sizes for 2-7/8-inch OD casing are commercially available. Latch-on type centralizers and scratchers for use with 2-7/8-inch OD casing may be obtained readily. Rotating scratchers have been employed to cover the anticipated production interval when mud is used to drill the well. The casing has been rotated during cementing whenever possible in order to obtain complete coverage and a uniform sheath. Scratchers usually have been omitted where water is used for the drilling fluid. Reciprocating scratchers may be used where rotation of the casing would present undesirable conditions in the wellbore.

The success of subsequent work to be done in the reduced diameter casing will depend in part on the assembled condition of the string. Bending, mashing, or otherwise offset dimensions may seriously hamper the use of proper through-tubing tools and particular care should be exercised in handling the small diameter casing. Power tongs may be slowly rotated for at least the first three threads of cleaned and doped joints which are held as low as possible in the slips. Joints of 2-7/8-inch OD casing should be checked using an API drift to insure adequate tool passage. A 2.29-inch ID API 6-inch long seating nipple may be included in the 2-7/8-inch string at a distance above the anticipated perforated interval for seating a subsurface pump if desired.

Where excessive external corrosion or rod wear is anticipated, consideration may be given to the eventual replacement of the major portion of the 2-7/8-inch OD oil string casing. Centralizers for the casing may be spaced at the top of the cement in addition to those normally employed at the float joint and through the productive interval of the well. If it is then desired to replace any casing section above the cement, the casing may readily be backed-off and the new section rejoined to the cemented casing which is positioned by the centralizers at this level.

One arrangement of surface equipment which may be employed in an efficient cementing procedure is illustrated in Figure 2. A single plug head is preferred because of its compactness, although a double plug container may be used as shown. Line 1 from the cement pump is used to place the cement in the casing and Line 2 from the mix pump is used while the plug is being pumped down. A minimum of down time is desired during cementing and Line 1 containing surplus cement should not be flushed until the plug is being pumped satisfactorily through Line 2.

Salt water may be employed to pump the plug into place. This medium is entirely satisfactory for subsequent perforating and will eliminate a round trip with small tubing to displace the fresh water or mud which otherwise would be required. Oil would be satisfactory as a pumping fluid except that service companies reasonably decline to measure oil in the open tanks on their trucks. Small tank trailers are available from some companies to eliminate this objection. Fine, granular salt, either sodium chloride or calcium chloride, may be mixed in pump truck tanks at a ratio of approximately 15 pounds per barrel of water if lease salt water is not available. To insure adequate solution, this operation should be done at least one hour prior to cementing. It is necessary to clean and flush the pumps and hopper after mixing the salt to prevent contamination




DOUBLE PLUG CONTAINER

( NOTE: *Similar hookup if Single Plug Head is used* )

Figure 2

of the cement.

Excessive pump pressures at high rates of plug placement may cause the casing to buckle or to be pumped up the hole. A special short length of 2-7/8-inch OD casing may be employed as the top joint while the plug is being pumped. When this joint, approximately 5 to 6 feet long, is removed immediately after the cement is in place, any tendency of the casing to buckle or otherwise deform will be corrected and the casing remains set in tension.

Although it is desirable to provide a uniform sheath of neat cement through all productive intervals in the wellbore, gel cement modified in accordance with local conditions, may be used to obtain the desired fill-up. Granulated plastic or similar bridging materials may be employed where severe lost circulation conditions are anticipated. The quantity of neat cement to be placed opposite the lower section of casing preferably should be prepared so that the entire volume of neat cement remains in the casing while the cement wiper plug is being released and this operation should be planned in order to be performed with minimum down time. These precautions will minimize exposure of a high water-loss cement to natural formations.

Wellheads and Surface Equipment

Several manufacturers offer relatively inexpensive wellheads and surface equipment for small bore completions. Arrangements shown in Figure 3, 4, ánd 5, consist of ordinary equipment modified to serve with the reduced sizes of tubular goods. It is anticipated that competitive

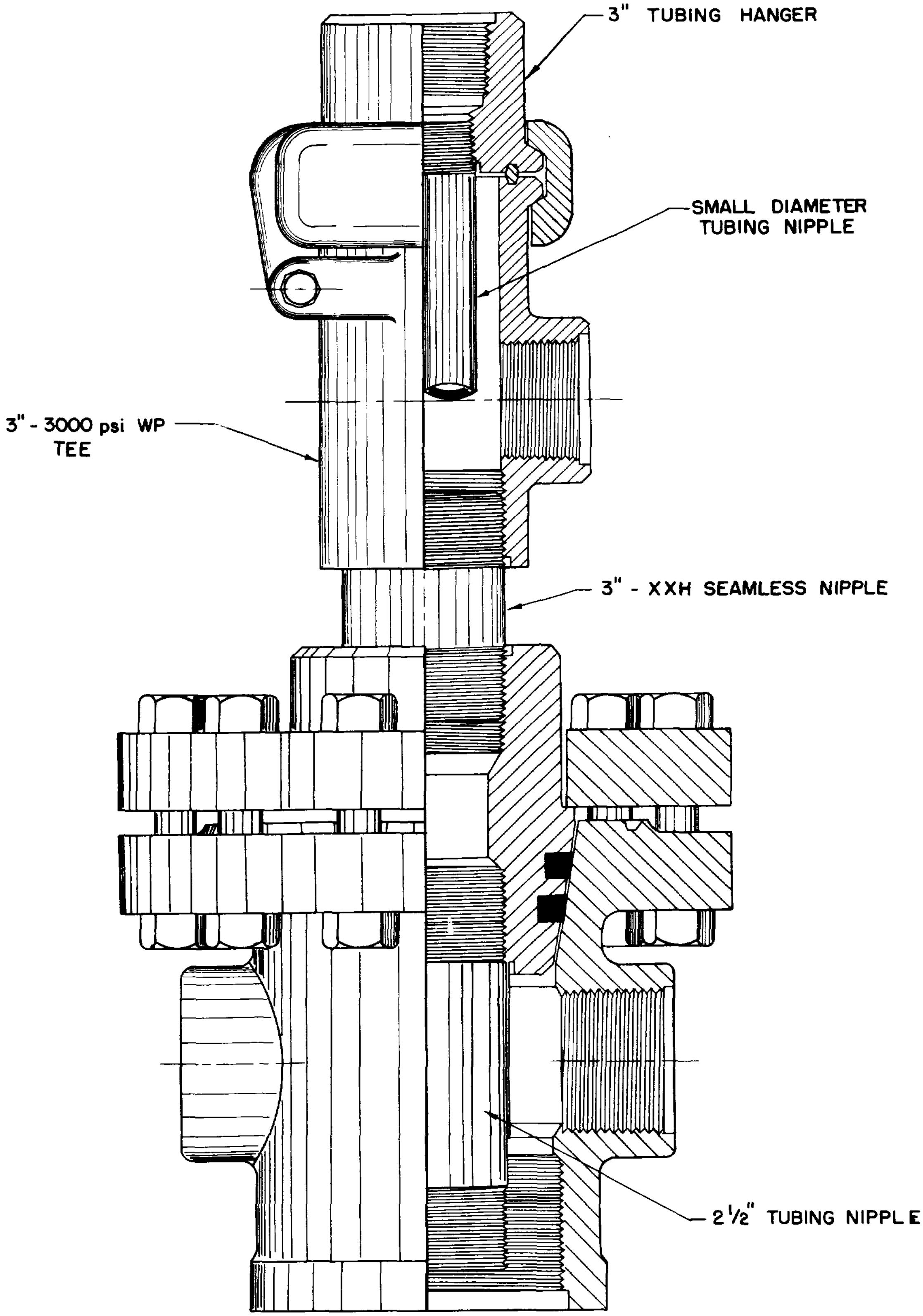
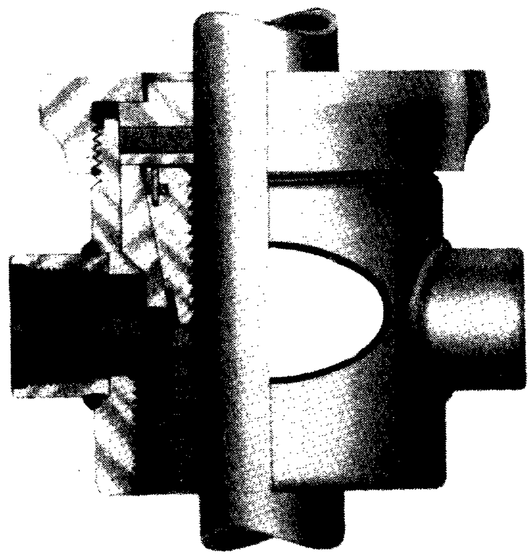
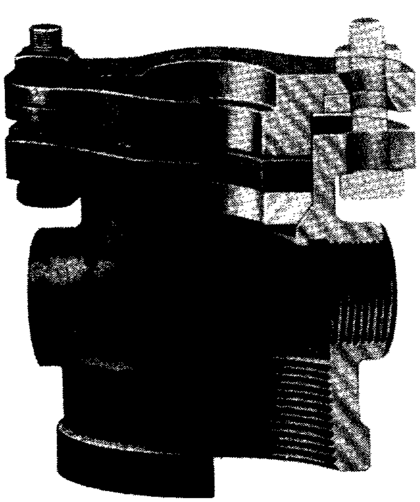

3" TUBING HANGER
SMALL DIAMETER TUBING NIPPLE
3" - 3000 psi WP TEE
3" - XXH SEAMLESS NIPPLE
2 1/2" TUBING NIPPLE

Figure 3

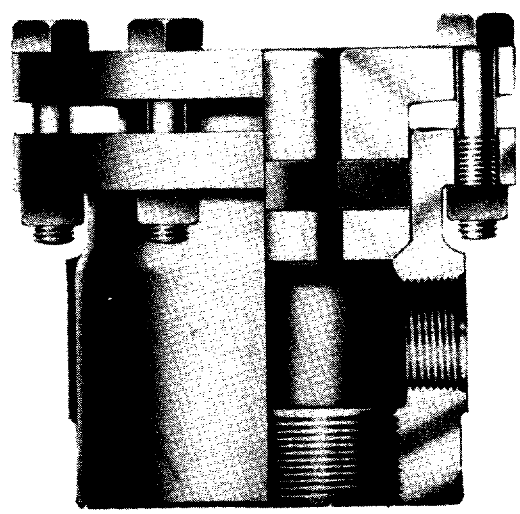


1000 PSI WOG
42,000 LB. LOAD

Figure 4



750 PSI
25,000 LB. LOAD



750 PSI
35,000 LB. LOAD

WELLHEADS

Figure 5

equipment will steadily become available from other manufacturers entering this line.

## COMPLETION OPERATIONS

### Logging

Formation logging tools for use in reduced hole sizes are offered by several service companies. All the services normally employed in any size wellbore except the dipmeter may be employed in holes having a diameter as small as 5-1/8-inches. The dipmeter may be used only in holes having a diameter of six inches or larger. Gamma ray and neutron surveys and collar logs may be run inside of 2-7/8-inch OD casing.

### Perforating

Steel carrier through-tubing perforators to reduce casing splitting and eliminate debris are regularly available from service companies. Expendable through-tubing perforators may be employed where minor casing splitting and debris fill-up can be tolerated.

### Fracturing

With the curtailment of allowed production and attendant tightening of economy within the domestic oil industry, it has been necessary to reduce costs where possible in drilling and producing operations. A practice of stimulating wells at low injection rates in a number of fields in its Western Division has been followed to reduce the expenditure necessary for fracturing pump trucks.

During the period from August 1, 1958 to January 1, 1959, fifty two fracture stimulation jobs at injection rates of 15 barrels per minute or less were performed in the New Mexico - West Texas area. These jobs included 27 initial completions in eight fields and 25 jobs performed during workover operations in 17 fields. Potential tests of the initial completions averaged 91 percent of top allowable. Potential tests of the workovers averaged 67 percent of top allowable. The results of these stimulation jobs are considered normal, in view of the areas involved and high injection rates are not considered essential for successful well stimulation by fracturing. It is indicated that a "one-truck job" may be utilized for a 2-7/8-inch casing completion for the same costs and with results comparable to a "one-truck job" at an ordinary well.

## PRODUCTION OPERATIONS

### Flowing Wells

When an exemption is granted by the New Mexico Oil and Gas Conservation Commission, a naturally flowing well may be produced directly through the 2-7/8-inch OD casing. Tubings as large as 1-1/2-inch, non-upset may be employed if excessive (1) paraffin, (2) sand, (3) corrosion, or (4) other condition indicates it would be desirable to restrict the produced fluids to an inner bore. Such tubing will be installed only as a last resort since it is anticipated that a majority of these conditions may be handled in a routine manner using through-tubing tools currently available or small tubing as a well servicing string.

### Artificial Lift

Artificial lift equipment employed for small bore completions as shown in Figure 6 is similar to that used in ordinary wells. In conformance with field practices in the areas of the 20 completions made in

# ARTIFICIAL LII Γ METHODS
## $2\frac{1}{2}$ INCH CASING COMPLETIONS

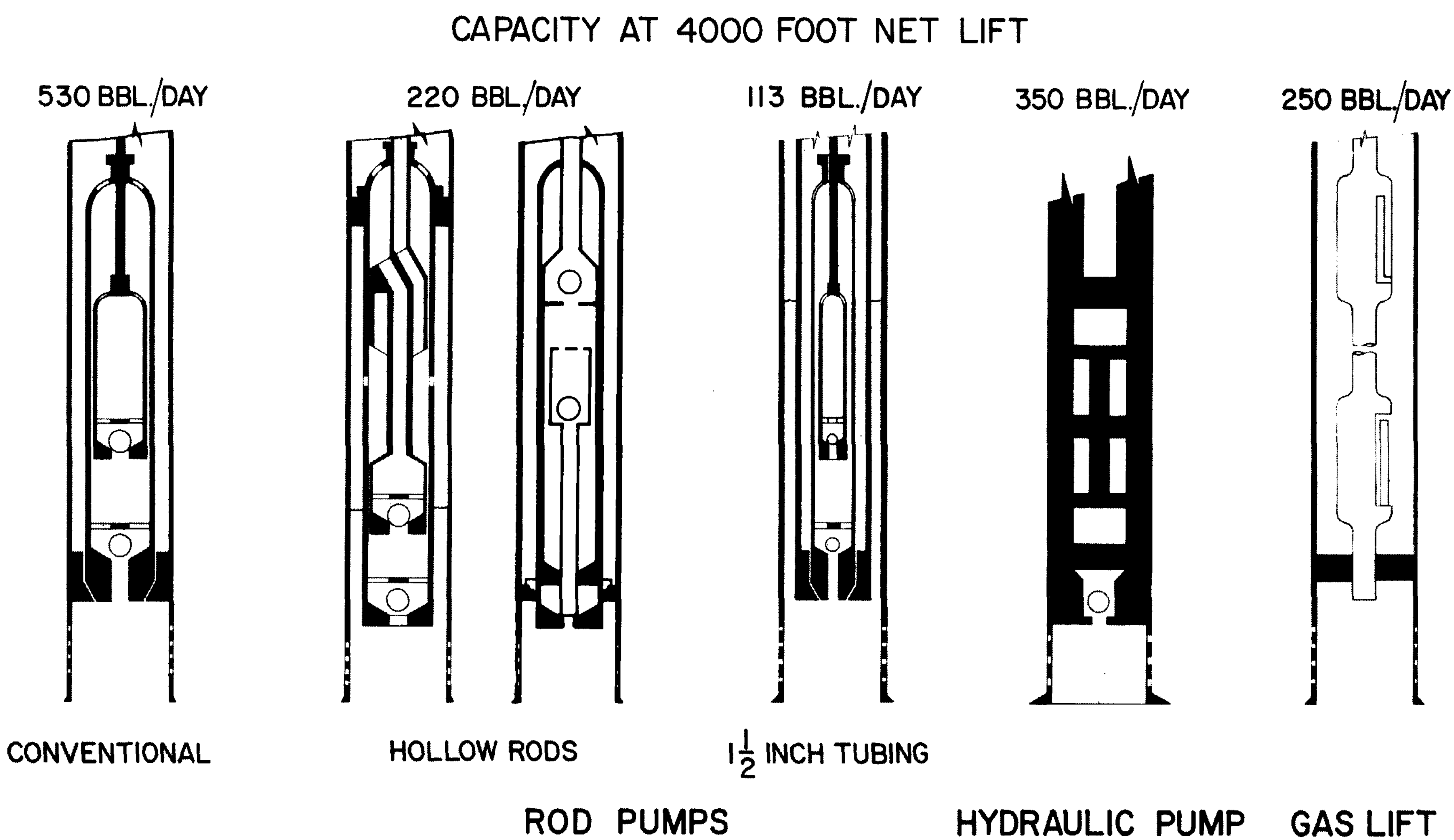
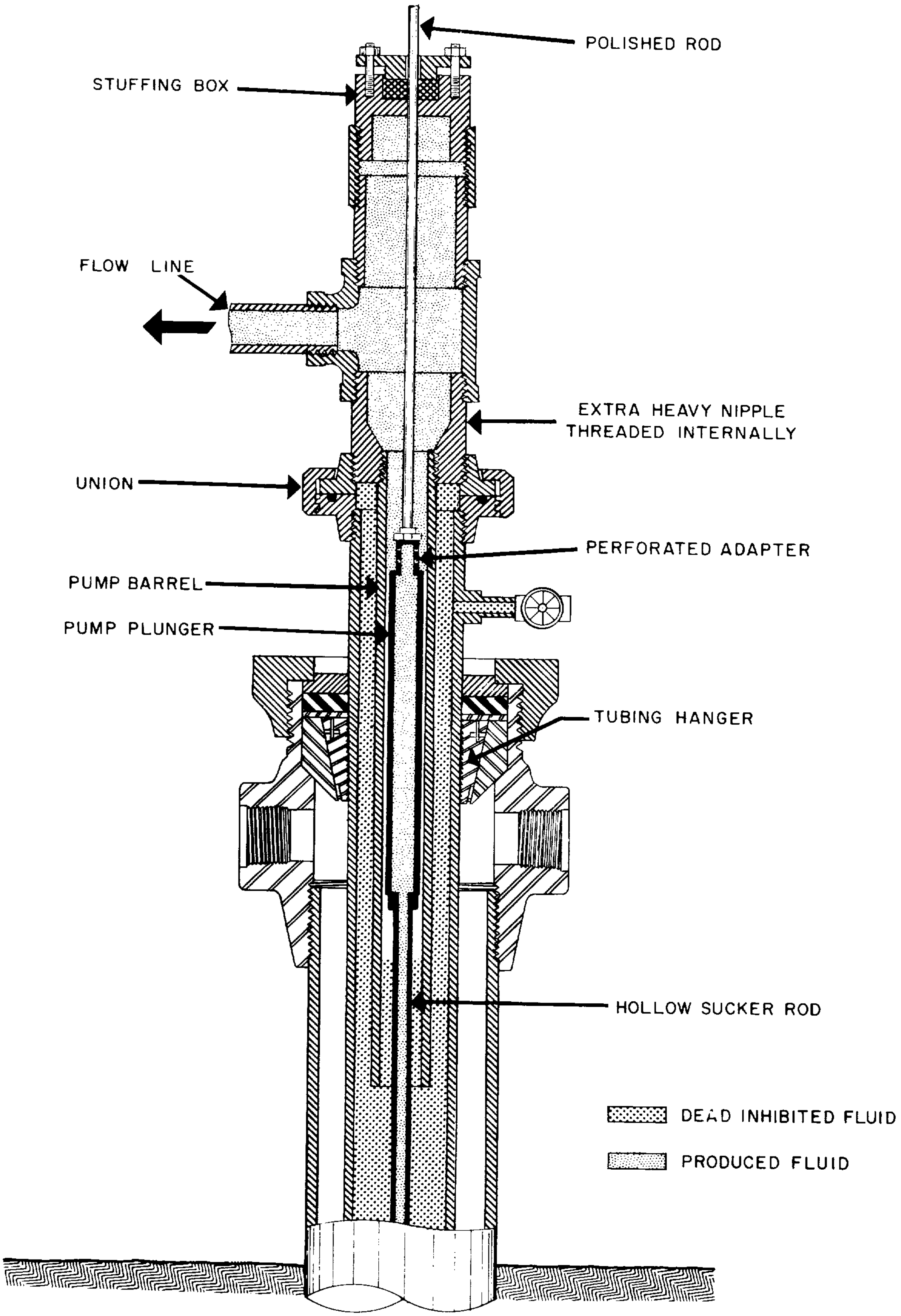



Figure 6

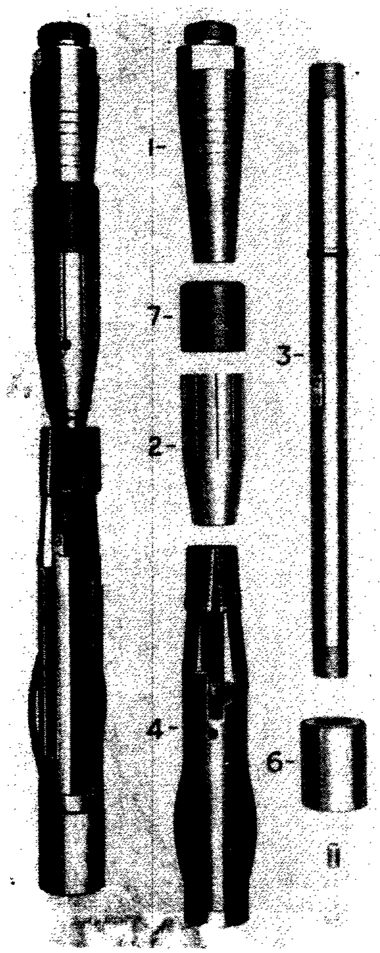
the West Texas area during 1958, these wells were equipped with beam-type pumping units. No mechanical difficulties have been experienced in any of these wells although an apparently limited rate of production of one or two wells may be due in part to the use of 3/4-inch OD upset tubing as sucker rods. Where increased rates of production are desired, consideration should be given to the use of larger tubing as sucker rods or hydraulic subsurface pumps. A special arrangement of equipment has been employed to eliminate the installation of flexible piping at the surface when hollow sucker rods are used with beam-type pumping units. As seen in Figure 7, a perforated adapter allows the produced fluids to pass from the 3/4-inch tubing into a pump barrel positioned at the top of the casing string. The fluid is then pumped through the pump tee into the flow line. A union connection is provided in the 2-7/8-inch OD casing below the level of the pump barrel suspension to facilitate the installation and removal of the assembly. This arrangement which has proven entirely satisfactory may be installed at approximately the same cost as flexible piping.

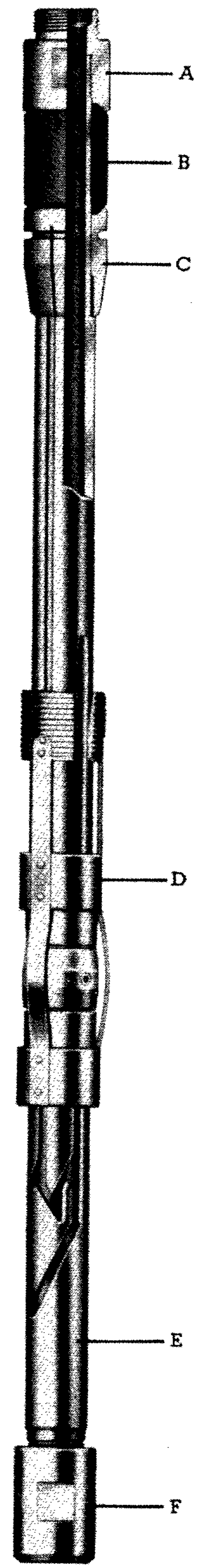
Conventional insert pumps for 2-7/8-inch tubing may be utilized in small bore wells. Usually no provision is made for gas venting when hollow sucker rods are employed in the packed-off annulus. However, if gas is a severe problem, a pump holddown may be employed to permit the annulus to remain opened for use as a gas vent, although pumping speed may be limited with this type arrangement. Typical mechanical holddowns for use in this arrangement include those shown in Figure 8.




METHOD OF ELIMINATING FLEXIBLE CONNECTION
WHEN USING HOLLOW SUCKER ROD

Figure 7




PUMP ANCHORS

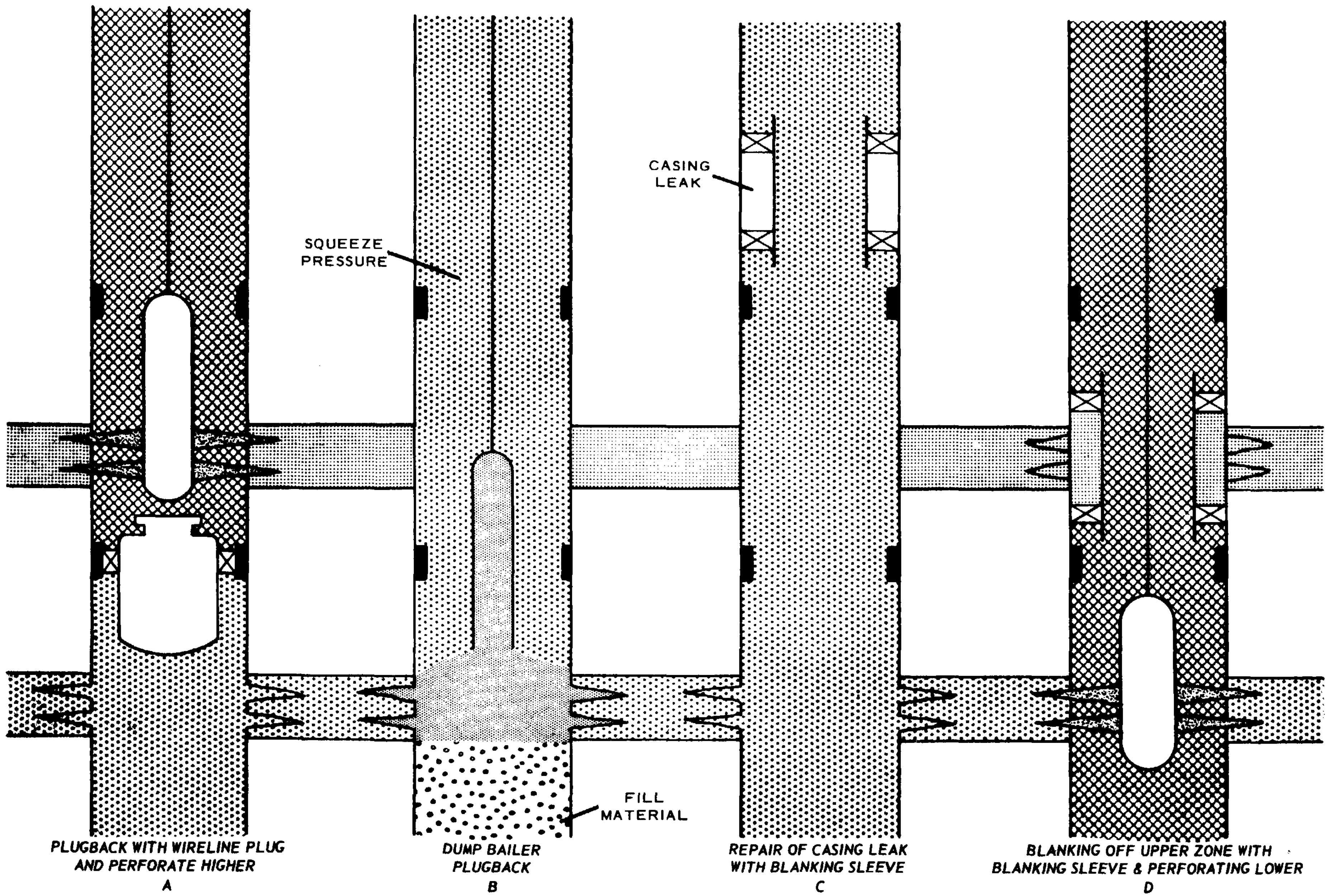
Figure 8

Although normal rod wear of the 2-7/8-inch OD casing will occur where beam-type pumping is employed, this may be minimized by the use of corrosion inhibitors or by mechanical devices such as nylon rod guides or by installations using colmonoy rod couplings. The tubing is cemented in tension which will eliminate tubing buckling and further reduce rod and tubing wear. Consideration should be given to provision for replacement of the oil string casing where extreme wear is anticipated. This may be accomplished as previously described if cement is placed only at the lower section of the casing which is fitted with a back-off joint and is adequately centralized to facilitate joining of the replacement section.

Workover Operations

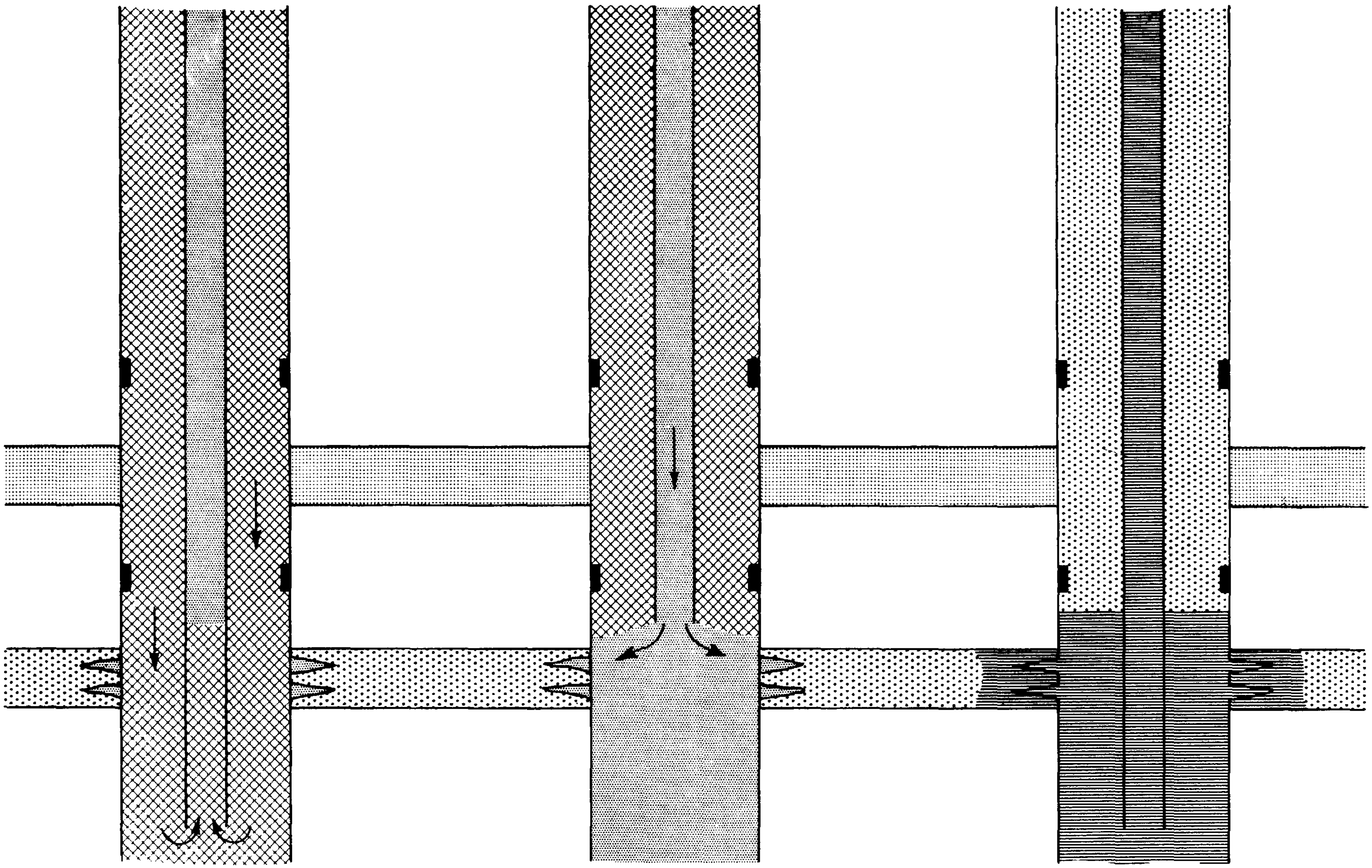
Only one workover has been performed in a 2-7/8-inch OD casing completion. In this operation a set of perforations was squeeze cemented through a macaroni string with low pressure techniques and the well was completed in a higher interval. Typical workover operations that may be conducted inside 2-7/8-inch OD casing are as follows:

1. Plugback with wireline plug and perforate higher. (Figure 9 A)
2. Dump bailer plugback. (Figure 9 B)
3. Repair of casing leak with blanking sleeve. (Figure 9 C)
4. Blanking off upper zone with a blanking sleeve and perforating lower. (Figure 9 D)
5. Set through squeeze cement. (Figure 10 A)
6. Plugback squeeze cement. (Figure 10 B)
7. Plasticizing. (Figure 10 C)




SERVICING SINGLE 2 7/8" O.D. COMPLETION WITH PTWC TECHNIQUES

Figure 9



SET THROUGH SQUEEZE CEMENT
A

PLUGBACK SQUEEZE CEMENT
B

PLASTICIZING
C

**SERVICING SINGLE $2\frac{7}{8}$" O.D. COMPLETION WITH CONCENTRIC TUBING**

Figure 10

Corrosion Control

Corrosion of subsurface equipment in slim hole completions with 2-7/8-inch OD casing deserves serious consideration at both the engineering and the operating levels. Methods are available to control corrosion as an operating problem in New Mexico and certainly adequate effective control measures are available to eliminate corrosion as a major factor in considering the use of 2-7/8-inch OD casing.

Field records of the New Mexico-West Texas area indicate that most corrosion failures occur from internal attack. Figure 11 presents the results of a study of casing failures reported in the New Mexico-West Texas area from 1941 through 1958. Only eight of the failures or 7.6 percent were definitely attributed to external attack, whereas 57 or 54.3 percent were caused by internal corrosion.

It is generally agreed that the production of large volumes of highly concentrated salt waters containing high hydrogen sulfide and carbon dioxide concentrations is responsible for internal corrosion failures observed in the New Mexico-West Texas producing area. There are three effective means of countering this corrosive environment; (1) organic inhibitors, (2) protective coatings, and (3) alloys. Of these three measures, inhibitors have demonstrated conclusively their effectiveness in reducing rod and tubing failures. For an inhibitor to function effectively, there are two fundamental requirements: (1) the inhibitor chosen must form a tightly adherent protective film on the metal surface which is resistant to removal, and (2) mechanical means of placement of the inhibitor at those points where corrosion is occuring must be available.

With respect to the former requirement, laboratory tests are available to choose such inhibitors, and both laboratory and field re-

FIGURE 11

SUMMARY OF CASING LEAKS
WESTERN DIVISION
1941 - 1958

| | Number | Probable Cause: Unknown | Probable Cause: Mechanical | Probable Cause: External Corrosion | Probable Cause: Internal Corrosion |
|---|---|---|---|---|---|
| New Mexico | 11 | 2 | 2 | 1 | 6 |
| West Texas | 94 | 15 | 21 | 7 | 51 |
| Totals | 105 | 17 | 23 | 8 | 57 |
| % of Total Leaks | 100 | 16.2 | 21.9 | 7.6 | 54.3 |

sults have indicated that such inhibitors adhere more tenaciously to a sulfide-filmed metal surface than to a sulfide-free metal surface.

Means of placement of the inhibitor are readily available in the 2-7/8-inch OD casing completions by either of two means. In a flowing well, a "formation inhibitor squeeze" technique is very effective; and in the rod pumped well, whether it is a conventional or hollow sucker rod installation, circulation of the chemical is equally effective. Figure 12 illustrates various types of completions in a 2-7/8-inch OD casing and paths of corrosion inhibitor flow.

To demonstrate the effectiveness of inhibitors in the treatment of typical wells pumping sour crude with high water percentages, the results of work in the Salt Flat Field of the Gulf Coast area are presented. Figure 13 shows a marked decrease in well maintenance cost as a result of the use of inhibitor to reduce rod and tubing failures.

With respect to the accumulation of paraffin or salt incrustations in 2-7/8-inch OD casing completions, no faster rate of deposition is anticipated than with conventional installations. Due to the greater fluid velocities, there should be less tendency for the accumulation of such deposits. Use of circulating valves placed immediately above the pump in the hollow sucker rod installations provides a ready means for the circulation of hot oil or other paraffin dispersants and solvents. Methods currently being used for the application of scale inhibitors in conventional wells may readily be used in the 2-7/8-inch OD casing installations.

In gas lift wells, which are relatively few in number in New Mexico, inhibitors have had limited success; however, the use of plastic coated tubing for corrosion protection has been very effective.

# METHODS PROVIDING PROTECTION FROM INTERNAL CORROSION IN WELLS PRODUCED BY ARTIFICIAL LIFT

## $2\frac{7}{8}$ INCH OD CASING COMPLETIONS

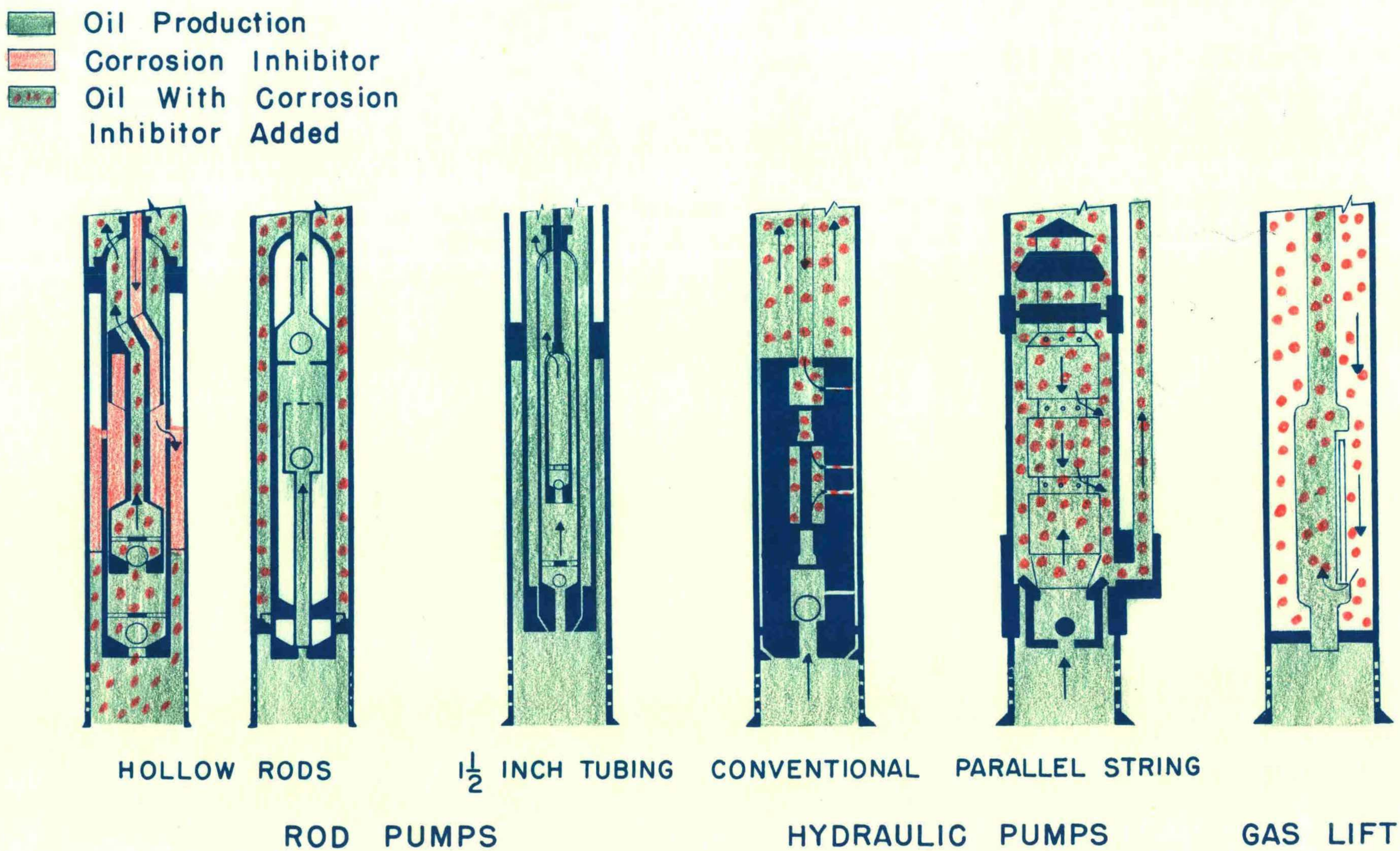



Figure 12

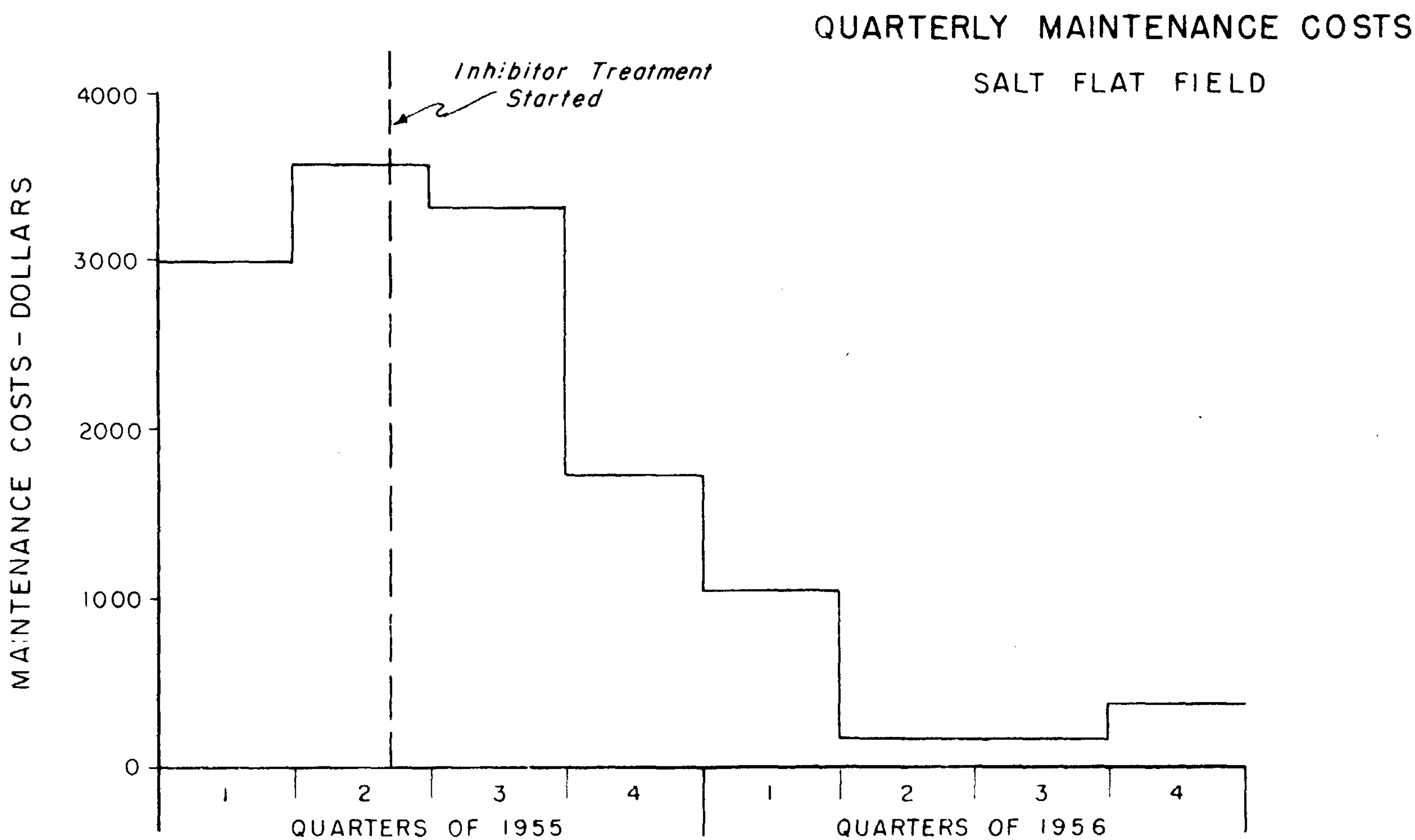

QUARTERLY MAINTENANCE COSTS
SALT FLAT FIELD
Inhibitor Treatment Started
MAINTENANCE COSTS - DOLLARS
4000
3000
2000
1000
0
1
2
3
4
QUARTERS OF 1955
1
2
3
4
QUARTERS OF 1956

Figure 13

For mitigation, the presently practiced method of loading the annulus with inhibited crude is very effective against internal corrosion of casing from acid gases in the vapor space because the vapor space is eliminated. Where the annulus cannot be sealed, the previously recommended circulation of inhibitor should provide very effective control. For those limited areas in which external attack is prevalent, cathodic protection has demonstrated its effectiveness in preventing such failures. Also, external corrosion can be minimized by cementing through the corrosive zone or through the use of a high alkaline mud in the uncemented section.

In summary, there appears to be no reason to anticipate a faster rate of corrosion, paraffin accumulation, or water scale depositions in a 2-7/8-inch casing completion than in the conventional installations. Recognized methods that are currently being employed to control corrosion, paraffin or scale in conventional wells are also applicable in wells using 2-7/8-inch OD casing as a producing string.

## Economic Evaluation

Twenty wells with 2-7/8-inch OD casing were successfully completed during 1958 in five fields at depths ranging from 1500 to 3300 feet as shown in Figure 14. The final average cost was 16 percent less than the cost of wells completed by conventional methods. Due to the many changes in drilling and completing practices that have been made in recent months to lower costs, the reduction has been adjusted to reflect actual savings attributable to the new technique.

# FIGURE 14

## ECONOMIC ANALYSIS

## 2-7/8-INCH OD CASING COMPLETIONS

| Field | Average Depth - Ft. | Number Completions | Reduction in Well Cost - % |
|---|---|---|---|
| A | 2700 | 4 | 20 |
| B | 2800 | 2 | 13 |
| C | 2900 | 2 | 20 |
| D | 3300 | 3 | 16 |
| E | 1500 | 9 | 14 |
| Total | | 20 | |
| Average | | | 16 |

How many did I lose.

Conclusions

It is recognized that future developments of small portable rigs and equipment for small diameter holes should provide further substantial cost reductions with 2-7/8-inch OD casing completions. Also, sufficient history is not yet available to allow a final evaluation of operating costs in the smaller diameter casing. Results from development operations to date indicate that this technique offers the industry an important economic tool for the future.