Multiple Well Completion Applications

By J. T. LEWIS
Kobe, Inc.

Introduction

The competitive position in which oil companies now find themselves -- with other energy suppliers as well as in their own industry -- has demanded that they deliver, to the market, oil products as efficiently and cheaply as possible. This position has required a look at all phases of the industry: exploration, drilling, production, transportation, refining, manufacturing, and marketing. One factor which has received considerable study and development has been multiple zone completions.

Because of its normal application in producing oil, hydraulic pumping has many desirable features as applied to multiple zone completed wells, when artificial lift is required. This paper will discuss some phases of this application.

General Application of Hydraulic Pumping

To better understand the application of hydraulic pumping to multiple zone application one must have a general understanding of this type of artificial lift. The bottom hole production units now being used are liquid powered, reciprocating positive displacement units. A general description of these units is offered in "Design and Operation of the Double Acting, Reciprocating Hydraulic Production Unit" published in the Proceedings of the West Texas Oil Lifting Short Course, April 21-22, 1960.

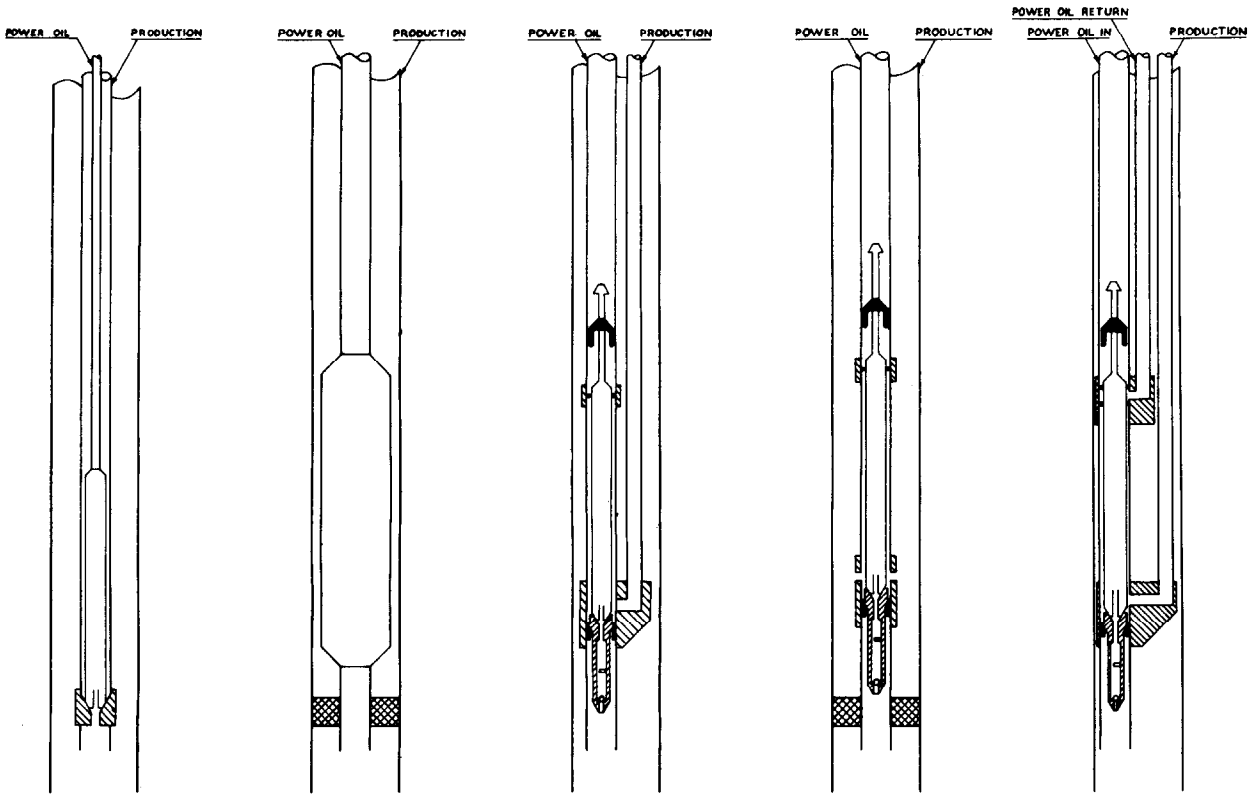
As described above, the production unit is installed in the well and becomes an integral part of the system. The central plant develops the power of the system; the power oil treating and storage with the well installation completes the closed circuit of Hydraulic Pumping. The selection of these various components is described in "Selection and Analysis of Hydraulic Production Systems" printed in the Proceedings of the West Texas Oil Lifting Course, April 20-21, 1961, and / or Theory and Application of Hydraulic Oil Well Pumps written by C. J. Coberly and published in 1961.

The various zones in multiple zone completed wells are treated as separate and complete installations, and the methods of application, of course, will vary. Print A shows the most common single zone applications of one manufacturer, and a combination of two or more of these will handle most multiple zone well requirements.

Print A, Figure 1, Fixed Insert

The Fixed Insert Installation allows for separation of

KOBE SINGLE ZONE APPLICATIONS



FIXED INSERT FIG. 1 | FIXED CASING FIG. 2 | PARALLEL FREE FIG. 3 | CASING FREE FIG. 4 | CLOSED POWER OIL PARALLEL FREE FIG. 5

PRINT A

gas in the well, positive paraffin control, chemical injection for inhibiting all surfaces in the well, and a minimum of trouble because of solids.

Print A, Figure 2, Fixed Casing

The Fixed Casing application is normally used where gas separation is not necessary and large volumes are required.

Print A, Figure 3, Parallel Free

The Parallel Free jump allows for gas separation in the well, positive paraffin control, chemical injection for inhibiting all surfaces in the well, accessibility of well data by use of a bomb, ability to handle solids, and retrievability of the pump by lease labor only.

Print A, Figure 4, Casing Free

This application allows for use of larger pump size, accessibility of well condition data by use of a bomb and retrievability of pump by lease labor.

Print A, Figure 5, Closed Power Oil, Parallel Free

The Closed Power Oil System may be used with any of the above applications. The primary feature is the returning of exhaust power fluid by a separate route with no commingling with well production.

Multiple Zone Application of Hydraulic Pumping

Some of the hydraulic pumping features which are desirable in multiple zone completions are:

(1) All moving parts in the well are confined inside the production unit; thereby casing wear is eliminated.
(2) A minimum of vibration and hammering is present, a requirement which is desirable in the use of packers.
(3) Individual and complete control of the equipment producing each zone is possible.
(4) Increased lift depth can be obtained. It is possible to lift fluid from below 20,000 ft with equipment now in use. With slight variations fluid may be produced from below 30,000 ft with present materials and design (Print B).
(5) Increased volume from 5,000 ft in 5-1/2 in. casing or smaller compared to other mechanical methods, 3760 BPD at 100% (Print B).
(6) In most applications remedial work on one zone does not affect production from the others.
(7) Efficiency of power transmission assures a minimum of power cost.
(8) Where it is possible to use the free pump, well servicing cost is reduced.
(9) Other factors inherent in the single zone application such as chemical injection, paraffin control, availability of bottom hole data, etc. are also applicable to most multiple zone installations.

To properly apply the available equipment or to design special equipment, one should secure as much information as possible concerning the multiple zoned well and its formations. The factors below are important in the selection of the proper application:

(1) Number of zones present
(2) Type of completions:
  (a) Multiple tubeless completion in a single drilled hole
    [1] Single Tubes (Size and Weight)
    [2] Parallel Tubes (Size and Weight)
  (b) Single casing (Size and Weight)
(3) Characteristics of each zone
  (a) Producing formation
  (b) Production required
    [1] Oil
    [2] Water
  (c) Saturation pressure of oil
  (d) Gas to produce (GOR)
  (e) Chemical properties of fluid
    [1] Corrosive
    [2] Chlorides
    [3] Viscosity
  (f) Solids in fluid to be produced:
    [1] Sand
    [2] Iron Sulfide
    [3] Iron Oxide
    [4] Etc.
  (g) Zone depth
  (h) Static fluid level
  (i) P I of zone (bbl per lb pressure drop)
  (j) Paraffin

Print C (Kobe Dual Applications: 5-1/2 in. casing) and Print D (Kobe Dual Application: 7 in. casing) are schematic prints of various dual installations which have been designed and/or installed. There are others; however, these are representative and are not necessarily confined to dual zoned wells.

Print C, Figure 1

In this application the bottom hole assembly is run in on the large string of tubing. The lower intake is open through the packer; the upper intake is permitted through a double standing valve. The two small outside strings are run independently and stabbed in. The pumps may be run separately or connected on the power oil tubing for the upper pump. The production from the upper pump, which produces the upper zone, and its spent power oil are directed to the surface through the annular space between the power oil tubing and production tubing. Power oil for the lower pump, which produces the lower zone, is (1) pumped down one of the outside tubing string, (2) exhausted in the annular space between the pump and pump casing of the bottom hole assembly, (3) mixes with the production, and (4) is directed to the surface through the other outside tubing string. The various seals in this system may be affected by "O" rings or Bridgeman seals; and the bottom hole assembly may be designed with both production intakes through a common, retrievable standing valve.

This type of installation allows for gas separation in the upper zone and adaptability to 5-1/2 in. casing in which both pumps may have a displacement of 590 BPD. In 7 in. casing, with 2-1/2 in. tubing as the large string, 1054 bbl displacement from each zone may be affected.

Print C, Figure 2

This type of installation is an adaption of Print C, Figure 1. The production and power oil return line for the lower pump is eliminated and the casing annulus is used for this passage. One more packer -- either permanent or retrievable -- is required and is set above the upper zone.

Gas produced from all zones must come through the pumps. This application has been installed in 4-1/2 in. casing and uses 2 in. pumps.

Print C, Figure 3

This is an adaptation of the fixed casing single zone installation to produce the upper zone and the fixed insert to produce the lower zone. The intake of these pumps may be reversed. The upper dual packer is run on the large or long string, with the lower tube through the lower packer and set above the upper zone. The pump to produce this zone is run on the power oil tubing and seated in the long string; this seat may be installed when run or set independently with a wire line when equipment is necessary. Power oil to operate this pump is down the power oil tubing, while the spent power oil and production from the lower zone are directed to the surface through the annulus between this tubing and the long string. The fixed casing pump is run in the well on the outside tubing and seated in the dual packer bowl. Intake to this pump is through the upper packer, and the power oil to this pump is down the outside string of tubing. Exhaust power oil and production is directed to

PUMP SELECTION TABLE

PUMP SIZE	SPECIFICATIONS										
NOMINAL PUMP SIZE TUBING X ENGINE X PUMP X PUMP	OUTSIDE DIAMETER (INCHES)	STROKE (INCHES)	PISTON SIZES DIAMETER (INCHES)		AREA RATIOS		RATED SPEED (SPM)	PUMP DISPLACEMENT @ RATED SPEED B/D	DISPLACEMENT (B/D PER SPM)		MAX. SETTING DEPTH (FEET)
			ENGINE	PUMP	E/P	P/E			ENGINE END	PUMP END	
2 x 1 x 1 3/16	1 7/8	12	1	1 3/16	1.83	.547	91	104	2.15	1.15	15,000
2 x 1 x 1	1 7/8	12	1	1	1.00	1.00	91	191	2.15	2.10	10,000
2 x 1 x 1 3/16	1 7/8	12	1	1 3/16	.647	1.55	91	295	2.15	3.25	6,500
2 x 1 3/16 x 1	1 7/8	12	1 3/16	1	1.55	.647	91	191	3.30	2.10	15,000
2 x 1 3/16 x 1 3/16	1 7/8	12	1 3/16	1 3/16	1.00	1.00	91	295	3.30	3.25	10,000
2 x 1 3/16 x 1 x 1	1 7/8	12	1 3/16	1 x 1	.773	1.29	91	382	3.30	4.20	7,700
2 x 1 3/16 x 1 3/16 x 1	1 7/8	12	1 3/16	1 3/16 x 1	.607	1.65	91	486	3.30	5.35	6,100
2 x 1 3/16 x 1 3/16 x 1 3/16	1 7/8	12	1 3/16	1 3/16 x 1 3/16	.50	2.00	91	590	3.30	6.50	5,000
2 1/2 x 1 1/4 x 1	2 5/16	18	1 1/4	1	1.92	.520	75	192	5.02	2.56	15,000
2 1/2 x 1 1/4 x 1 1/8	2 5/16	18	1 1/4	1 1/8	1.34	.747	75	275	5.02	3.67	13,400
2 1/2 x 1 1/4 x 1 1/4	2 5/16	18	1 1/4	1 1/4	1.00	1.00	75	369	5.02	4.92	10,000
2 1/2 x 1 1/4 x 1 7/16	2 5/16	18	1 1/4	1 7/16	.699	1.43	75	527	5.02	7.03	7,000
2 1/2 x 1 7/16 x 1 1/4	2 5/16	18	1 7/16	1 1/4	1.43	.699	75	369	7.13	4.92	14,300
2 1/2 x 1 7/16 x 1 7/16	2 5/16	18	1 7/16	1 7/16	1.00	1.00	75	527	7.13	7.03	10,000
2 1/2 x 1 7/16 x 1 1/8 x 1	2 5/16	18	1 7/16	1 1/8 x 1	1.13	.886	75	467	7.13	6.23	11,300
2 1/2 x 1 7/16 x 1 1/4 x 1 1/4	2 5/16	18	1 7/16	1 1/4 x 1 1/4	.715	1.40	75	738	7.13	9.84	7,200
2 1/2 x 1 7/16 x 1 7/16 x 1 1/4	2 5/16	18	1 7/16	1 7/16 x 1 1/4	.588	1.70	75	896	7.13	11.95	5,900
2 1/2 x 1 7/16 x 1 7/16 x 1 7/16	2 5/16	18	1 7/16	1 7/16 x 1 7/16	.50	2.00	75	1054	7.13	14.6	5,000
3 x 1 1/2 x 1 1/4	2 13/16	24	1 1/2	1 1/4	1.69	.593	65	364	9.61	5.59	15,000
3 x 1 1/2 x 1 3/8	2 13/16	24	1 1/2	1 3/8	1.27	.787	65	483	9.61	7.43	12,700
3 x 1 1/2 x 1 1/2	2 13/16	24	1 1/2	1 1/2	1.00	1.00	65	614	9.61	9.44	10,000
3 x 1 1/2 x 1 3/4	2 13/16	24	1 1/2	1 3/4	.675	1.48	65	909	9.61	14.0	6,700
3 x 1 3/4 x 1 1/2	2 13/16	24	1 3/4	1 1/2	1.48	.675	65	614	14.17	9.44	14,800
3 x 1 3/4 x 1 3/4	2 13/16	24	1 3/4	1 3/4	1.00	1.00	65	909	14.17	14.00	10,000
3 x 1 3/4 x 1 1/4 x 1 1/4	2 13/16	24	1 3/4	1 1/4 x 1 1/4	1.25	.80	65	728	14.17	11.18	12,500
3 x 1 3/4 x 1 1/2 x 1 1/2	2 13/16	24	1 3/4	1 1/2 x 1 1/2	.741	1.35	65	1228	14.17	18.88	7,400
3 x 1 3/4 x 1 3/4 x 1 1/2	2 13/16	24	1 3/4	1 3/4 x 1 1/2	.597	1.68	65	1523	14.17	23.44	6,000
3 x 1 3/4 x 1 3/4 x 1 3/4	2 13/16	24	1 3/4	1 3/4 x 1 3/4	.50	2.00	65	1818	14.17	28.00	5,000
4 x 2 x 1 3/4	3 13/16	30	2	1 3/4	1.45	.688	58	837	21.44	14.40	14,600
4 x 2 x 2	3 13/16	30	2	2	1.00	1.00	58	1220	21.44	21.00	10,000
4 x 2 x 2 3/8	3 13/16	30	2	2 3/8	.646	1.55	58	1880	21.44	32.50	6,500
4 x 2 3/8 x 2	3 13/16	30	2 3/8	2	1.55	.646	58	1220	32.94	21.00	15,000
4 x 2 3/8 x 2 3/8	3 13/16	30	2 3/8	2 3/8	1.00	1.00	58	1880	32.94	32.50	10,000
4 x 2 3/8 x 2 x 1 3/4	3 13/16	30	2 3/8	2 x 1 3/4	.917	1.09	58	2057	32.94	35.40	9,200
4 x 2 3/8 x 2 x 2	3 13/16	30	2 3/8	2 x 2	.773	1.29	58	2440	32.94	42.00	7,700
4 x 2 3/8 x 2 3/8 x 2	3 13/16	30	2 3/8	2 3/8 x 2	.607	1.65	58	3100	32.94	53.50	6,100
4 x 2 3/8 x 2 3/8 x 2 3/8	3 13/16	30	2 3/8	2 3/8 x 2 3/8	.50	2.00	58	3760	32.94	65.00	5,000

PRINT B

the surface through the casing.

This type of installation allows for a minimum of tubing strings in the well, and no special equipment is used. Remedial work on one zone has no effect on the other. Reduced friction allows for maximum production with the fixed casing pump, and the zones to be pumped may be reversed to adapt to this increased volume if required. In 7 in. casing, displacement up to 1,818 BPD may be obtained by using a 3 x 1-3/4 x 1-3/4 x 1-3/4 in. pump, with a 2 in. pump producing the other zone.

Print C, Figure 4

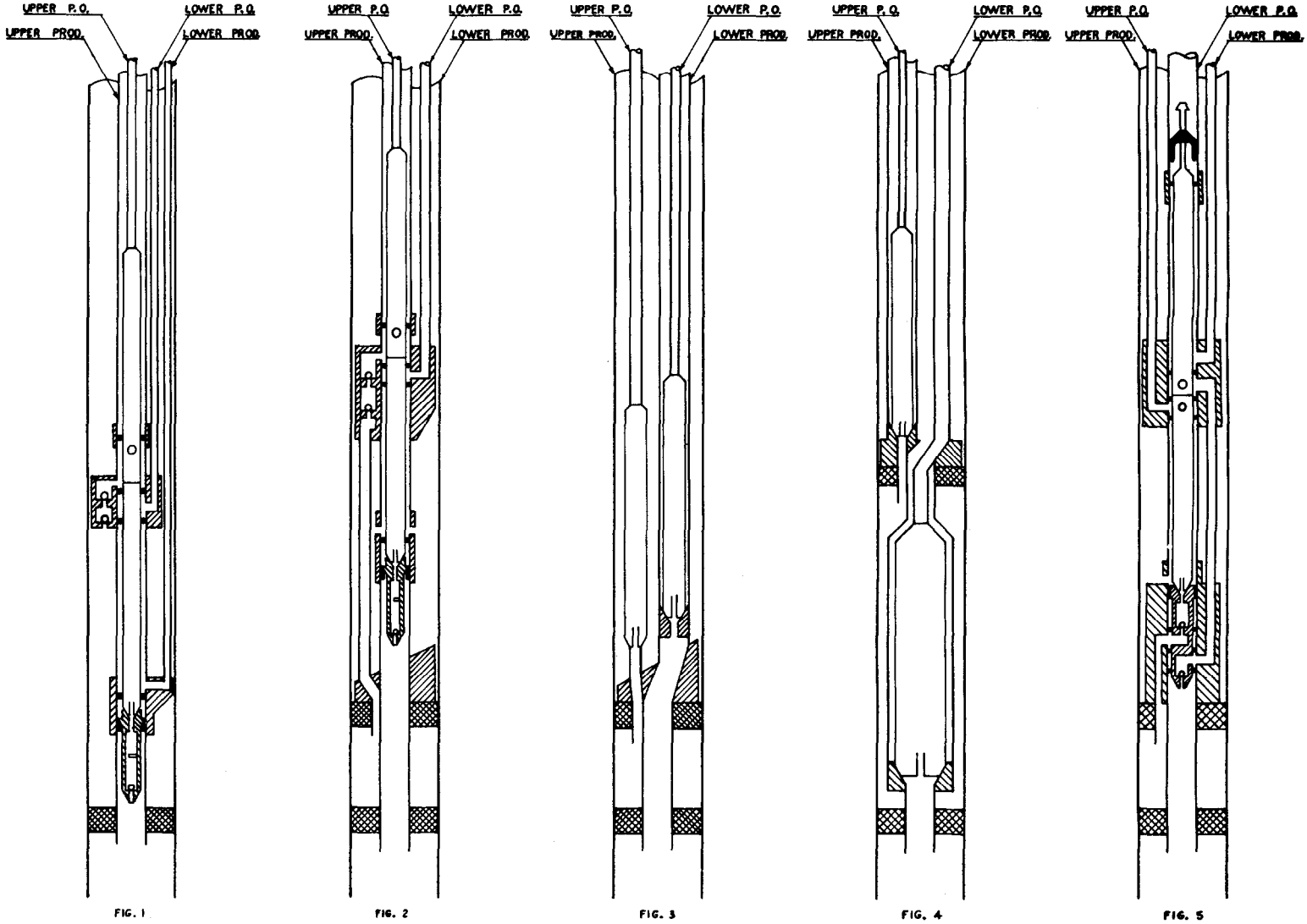
This application is for high volume production and should possibly be considered only when other installations will not suffice. The lower zone is produced as a combination fixed insert - casing installation with the pump installed between the two packers. The lower pump and adapters, upper packer, and bowl are run into the well on the production string for the upper zone. Intake from the lower zone is through the lower packer and drop pipe connected to the pump case. The power oil tubing is run independently, through the upper packer and stabbed in a bowl on top of the pump. Exhausted power oil and lower zone production are directed to the surface through the annular space between the pump and case, through the special adapter, and up the casing. The upper zone is produced with a 2 in. fixed insert installation.

This application is for large volume pumping. The lower pump may be installed above the upper packer, with a by-pass around this pump from below the upper packer to the intake of the upper pump. Displacements of 3760 BPD are possible with a 4 x 2-3/8 x 2-3/8 x 2-3/8 in. pump installed to produce the lower zone in 5-1/2 in. casing. In both applications it is necessary to pull all tubing to service the lower pump. However, to service the upper pump, it is necessary to pull only its power oil tubing.

Print C, Figure 5

The free type dual as shown in Figure 5 is an adaption of Figure 2 with the added feature of the free pump. The bottom hole assembly is run in the well on the 2 in. string of tubing, and the two outside strings of tubing are run independently and stabbed in. Production from the lower zone is through both packers and a retrievable double standing valve and is by passed into the intake of the upper pump. Power oil for this pump is pumped

KOBE DUAL APPLICATIONS — 5½" CASING



PRINT C

down the 2 in. tubing, while exhaust power oil and production are directed through one of the outside strings and to the surface. Production from the upper zone is through the upper packer and standing valve and into the lower pump intake. Power oil for this pump is injected down one of the outside strings, while power oil and production are directed through the casing and to the surface.

Both pumps are retrievable by merely reversing circulation of power oil down the casing; thereby, costly tubing jobs are eliminated. Data on each zone are readily available by the use of pressure bombs. In 5-1/2 in. casing, displacements of 590 BPD are available with the 2 x 1-3/16 x 1-3/16 x 1-3/16 in. pump; in 7 in. casing, displacements of 1054 BPD with the 2-1/2 x 1-7/16 x 1-7/16 x 1-7/17 in. pump are permissible. If desirable the upper packer could be replaced by running a third outside string of tubing for the lower pump exhaust. This string would allow for gas separation of the upper zone in the well bore.

Even though the above installations were designed for 5-1/2 in. they are adaptable to larger casing.

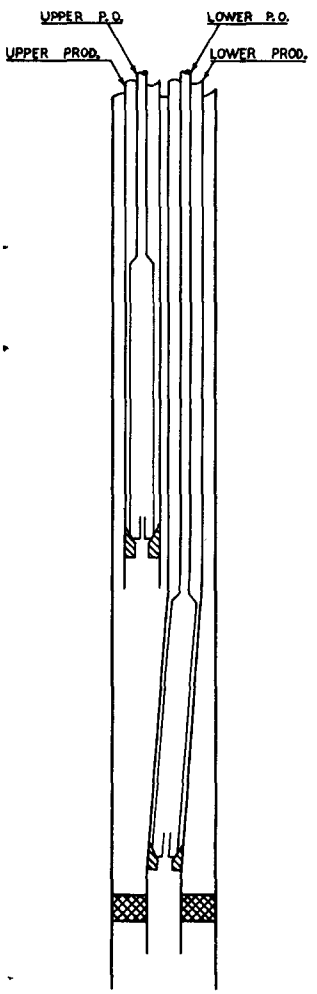
Print D, Figure 1

This is the simplest of all dual applications, for both zones are produced with fixed insert pumps run in the production string on the power oil tubing. Power oil for each pump is forced down the power oil string, and exhaust power oil and production are pumped up the annular space between this tubing and the production string. The lower zone intake is through the packer. Gas venting below the packer may be affected by the addition of a vent string. The upper zone is produced through the other production string which hangs free in the well. Gas from this zone may be removed through the casing.

Print D, Figure 2

This is an adaption of Print D, Figure 1 with the additional feature of one zone being produced as a parallel free pump. As shown, the upper zone is being produced in the normal fixed insert manner. The bottom hole assembly is run in the well on the large or long

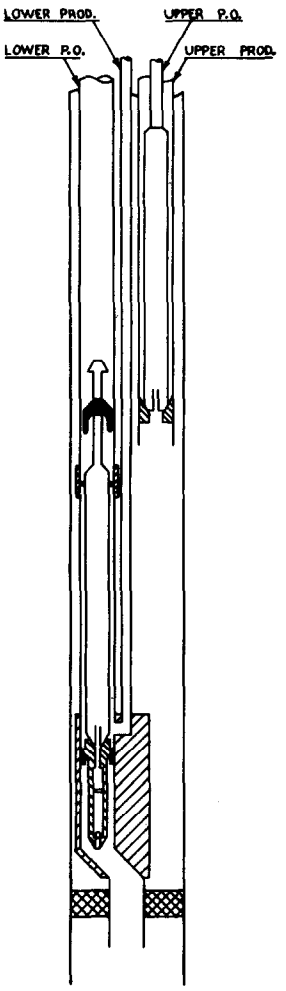
KOBE DUAL APPLICATIONS — 7" CASING



UPPER — FIXED INSERT

LOWER — FIXED INSERT

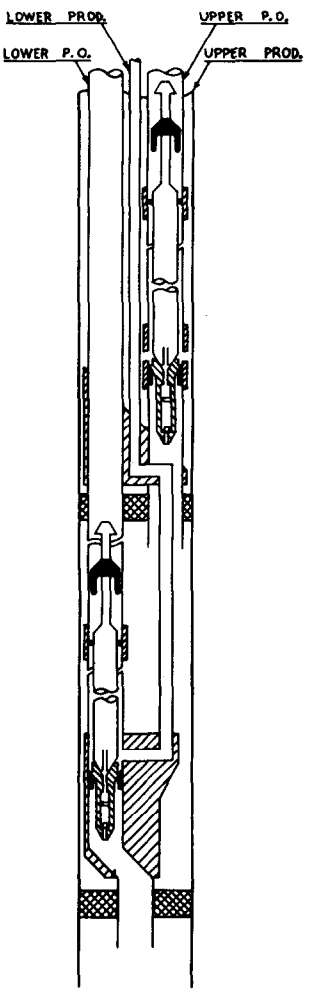
FIG. 1



UPPER — FIXED INSERT

LOWER — PARALLEL FREE

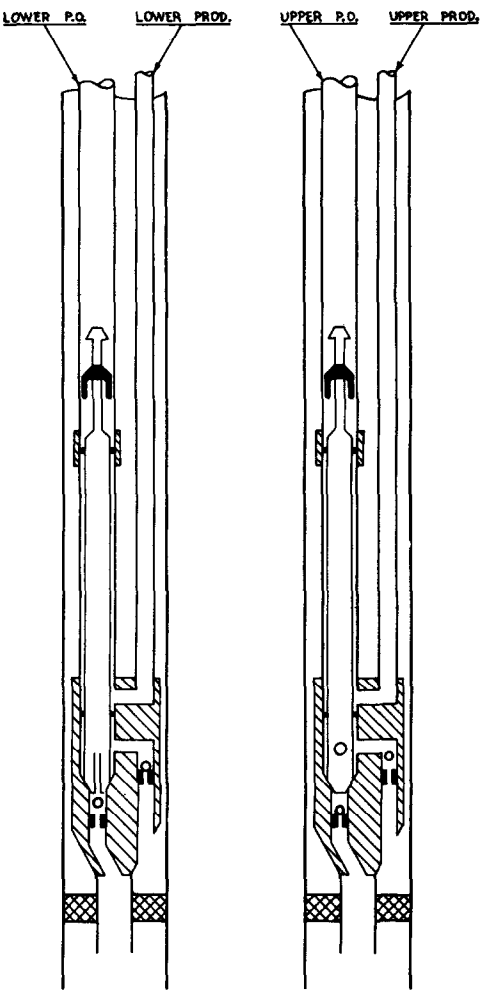
FIG. 2



UPPER — CASING FREE

LOWER — PARALLEL FREE

FIG. 3



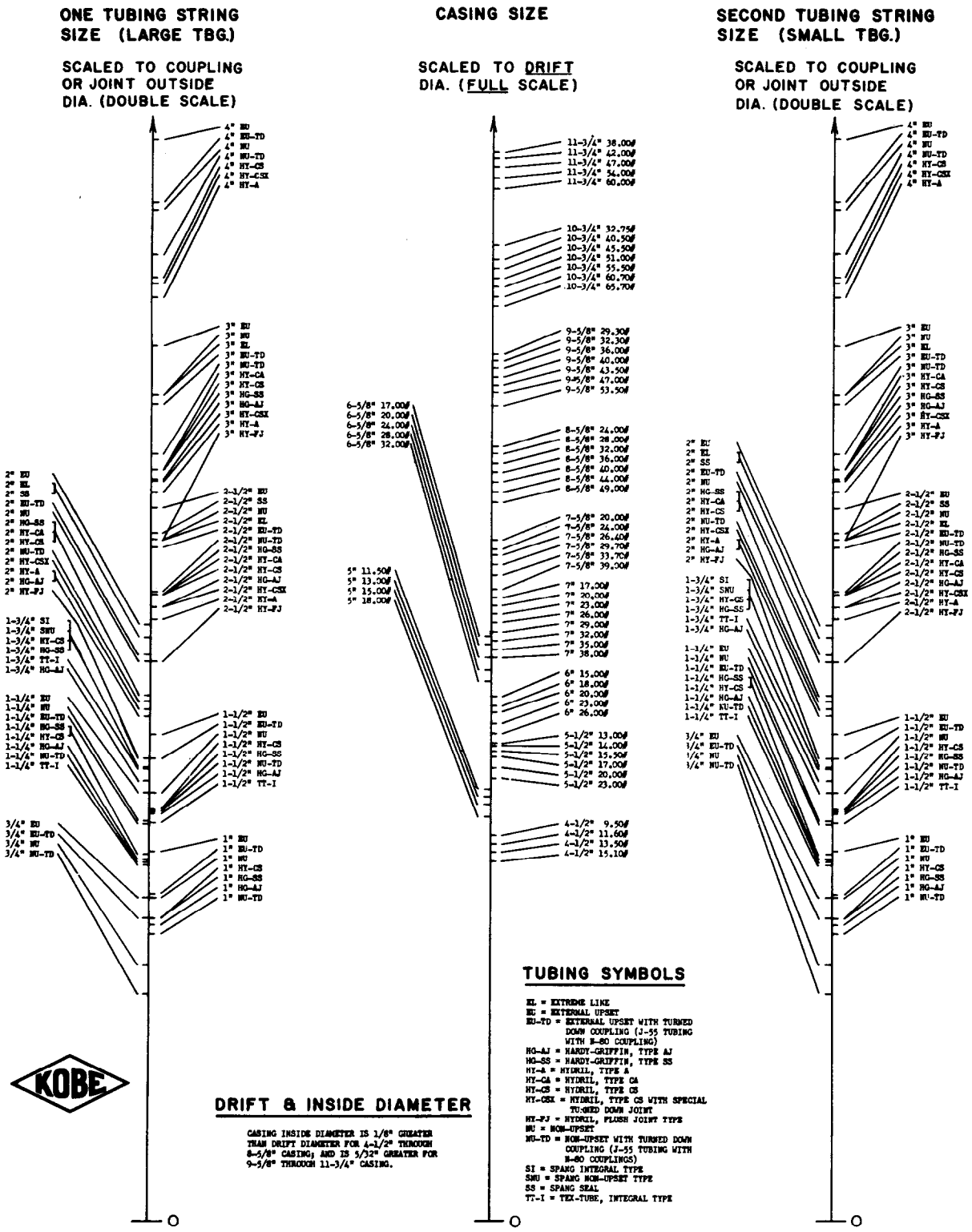
ALTERNATE ZONE PARALLEL FREE

FIG. 4

PRINT D

CLEARANCE NOMOGRAPH — DUAL TUBING IN CASING

FOR TWO INDEPENDENTLY RUN TUBING STRINGS
(NOMOGRAPH CAN ALSO BE USED TO DETERMINE
SINGLE TUBING IN CASING CLEARANCE)



DRIFT & INSIDE DIAMETER

CASING INSIDE DIAMETER IS 1/8" GREATER THAN DRIFT DIAMETER FOR 4-1/2" THROUGH 8-5/8" CASING; AND IS 5/32" GREATER FOR 9-5/8" THROUGH 11-3/4" CASING.

TUBING SYMBOLS

EL = EXTREME LINE
EU = EXTERNAL UPSET
EU-TD = EXTERNAL UPSET WITH TURNED DOWN COUPLING (J-55 TUBING WITH N-80 COUPLING)
HG-AJ = HARDY-GRIFFIN, TYPE AJ
HG-SS = HARDY-GRIFFIN, TYPE SS
HY-A = HYDRIL, TYPE A
HY-CA = HYDRIL, TYPE CA
HY-CS = HYDRIL, TYPE CS
HY-CSX = HYDRIL, TYPE CS WITH SPECIAL TURNED DOWN JOINT
HY-FJ = HYDRIL, FLUSH JOINT TYPE
NU = NON-UPSET
NU-TD = NON-UPSET WITH TURNED DOWN COUPLING (J-55 TUBING WITH N-80 COUPLINGS)
SI = SPANG INTEGRAL TYPE
SNU = SPANG NON-UPSET TYPE
SS = SPANG SEAL
TT-I = TEX-TUBE, INTEGRAL TYPE

PRINT E

string, and the lower zone intake is through the packer. Power oil for this pump is injected down the large string. Exhaust power oil and production is forced up the small outside string.

The free pump producing the lower zone is retrievable by merely reversing the power oil down the outside string, and the zones being produced by each unit may be reversed. If the lower zone is produced with the free pump no special equipment is required; however, if they are reversed a change is necessary in the free pump bottom hole assembly. All advantages of the parallel free pump are applicable here. These advantages include positive paraffin control, retrievability of the pump, etc.

Print D, Figure 3

The parallel free pump and casing free pump are utilized in this application. The parallel free pump is shown as being installed between the packers for clarity, but actually both pumps are installed above the upper packer. Production from the lower zone is through both packers. Power oil for the lower zone pump is down the long string, while exhausted power oil and lower zone production is up the small tubing. The upper zone is produced as a casing free pump with power oil pumped down the large string and exhaust power oil and production brought up the casing.

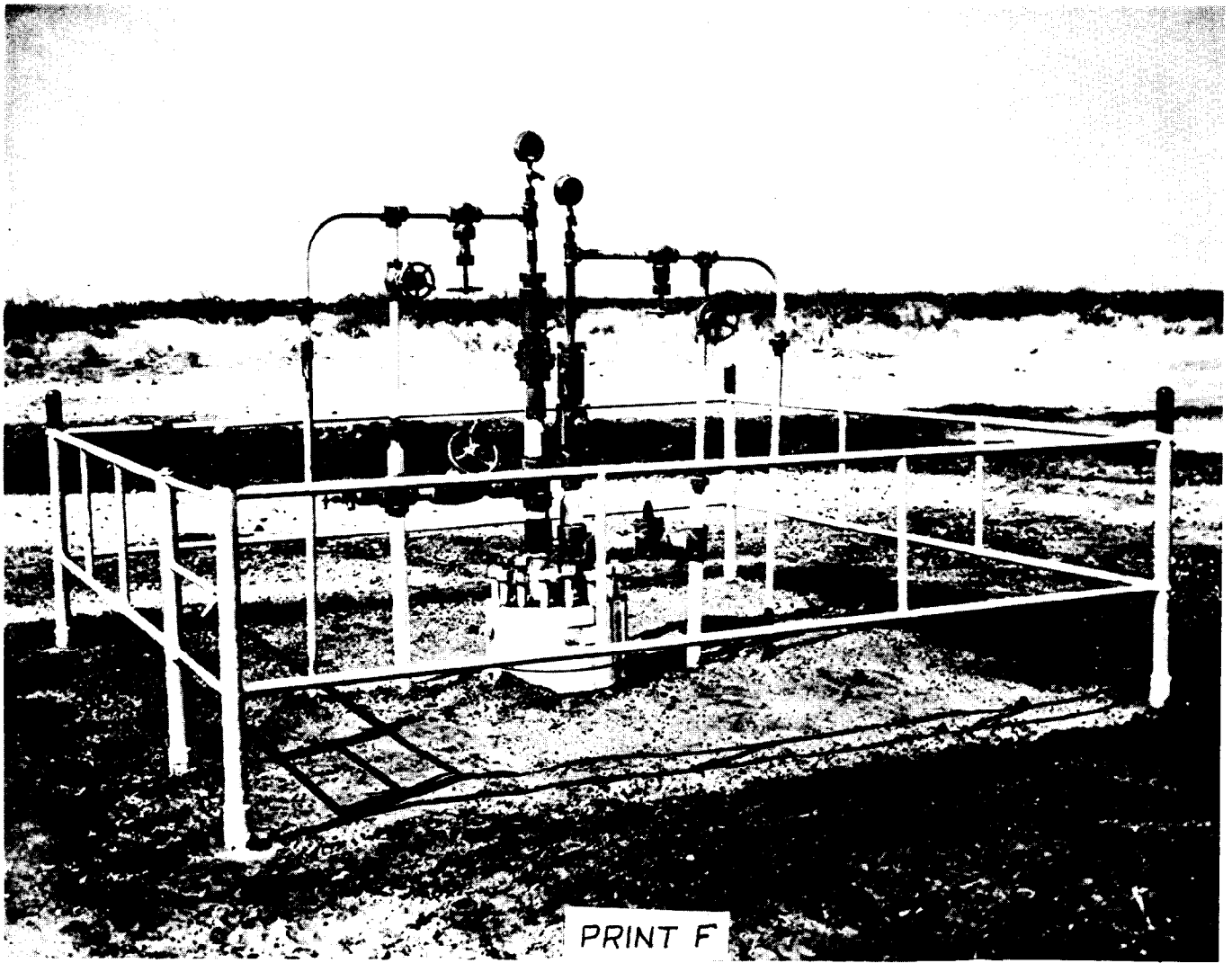
This application has the flexibility of the free pump for both zones. If venting of the upper zone is required parallel free pumps may be installed to produce both zones, but this production requires one more string of small tubing and the installation of one less packer.

Print D, Figure 4

The alternate zone parallel free installation, as shown in Figure 4, is an application which requires a special hearing in some states. The special bottom hole assembly is run on the large string and seated on the packer, and the small string is run independently and stabbed in. Although not shown here, intake above and below the packer is effected through a retrievable standing valve. Production from each zone is controlled by an adapter on the bottom of the pump: one adapter closes off production from the upper zone and opens the pump intake to the lower zone. By retrieving this pump and changing the adapter, production from the lower zone may be closed off and the upper zone opened to the pump intake. Power oil to operate the pump is injected down the large string, while exhausted power oil and production is pumped up the small outside string. Gas venting of the lower zone may be affected by the addition of a vent string through the packer, and gas venting of the upper zone is through the casing.

This application has the features of the free pump; however, it has the disadvantage of being able to produce only one zone at a time.

Prints C and D illustrate the adaptability and flexibility of hydraulic pumping to multiple zone production. There are other applications, such as alternate zone pumping



by lowering and raising, with the use of a hydraulic lift or ram, the pump intake through a packer set between the two zones. There are several installed as free pumps in tandem with a common power oil source, and the exhaust power oil for both pumps return to the surface with one zone's production (production from the other zone is produced through another route). The single engine operating two pumps -- each of which produces a separate zone -- has an application in which the production ratio can be predicted. This is an application of the double pump end pump with a single engine end. The application of hydraulic pumping to one zone with other zones in the same well bore being artificially lifted by other methods or flowing is being done in several places. In general, the type of application and displacement available is controlled only by the tubing strings which may be installed in the casing and the fluid characteristics.

Many data sheets and charts are available to assist in the selection of tubing string designs. Print E, "Clearance Nomograph - Dual Tubing in Casing," is one available to the industry. This type nomograph is used primarily for a quick check of possible casing and tubing combinations.

For a more detailed look, actual measurement should be used. In using the nomograph the point on the "large tubing" scale should be lined up with the corresponding point on the "small tubing" scale. Where this line intersects the "casing size" scale, the casings listed above this intersection may be used for the tubing combination under question. All casings listed below this intersection are too small.

There are probably as many different well head hookups as there are types of applications. Print F is one of the simplest and incorporates all the necessary features for this double fixed insert installation. In general, all well head hookups are fabricated from off the shelf items.

Conclusion

The simplicity of installation and operation characteristics of hydraulic pumping make it readily adaptable to the ever increasing depth and volumes of multiple zone completions.