Sub-Surface Two-Zone Pumping

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Economics

Many dually completed oil wells are flowing and may be expected to continue flowing for many years. The flowing life of other dual oil wells is relatively short for one or both pays. Some dual oil wells never flow and require artificial lifting equipment at the time of completion. Pumping equipment that would lift well fluids separately and simultaneously from dual wells was developed in 1947.

This pumping equipment was developed with two purposes in mind. First, it is designed to provide a means by which the operators of dually completed oil wells can pump one or both producing formations without co-mingling fluids. Second, it is designed to provide a means by which the operators of singly completed oil wells can recomplete their wells as dual producers. Great economic advantage can be obtained in many fields by producing two pays simultaneously through one well bore. The practical possibility of pumping two producing formations simultaneously offers substantial investment and operating savings compared with twinning wells, or producing a lower pay to depletion.

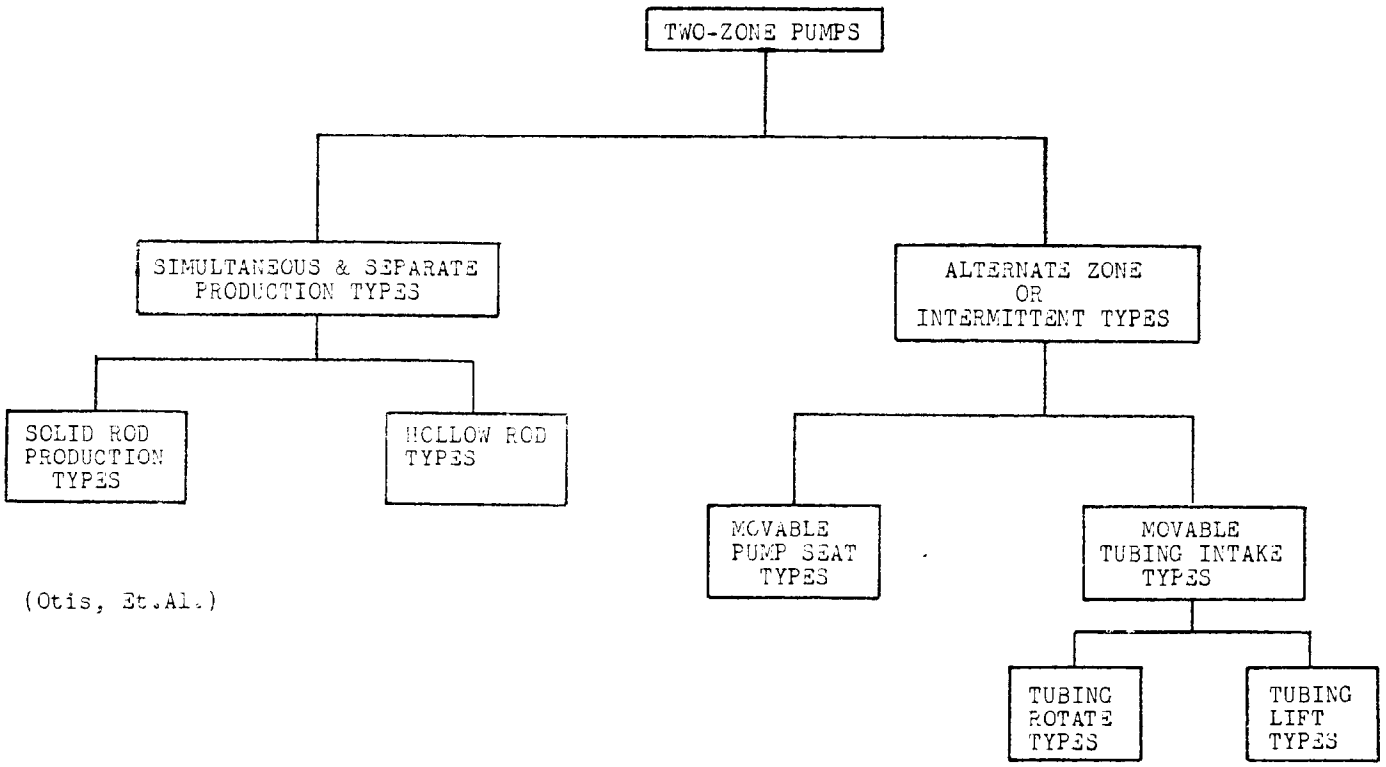
Present-day methods for the practicable and profitable production of dually-completed oil wells have progressed to such a degree that, as a matter of practical economics, operators are virtually compelled to review the possible advantages of two-zone production before starting additional drilling programs. This is logically evident when it is considered that usually, a second, known formation can be produced at a small percentage of the cost of drilling and completing a new well. A dual-completion, where possible, naturally eliminates the need for an additional outlay for pipe, rods, tubing, a pumping unit, pumping engine, and other capital equipment. Too, the development of another pay horizon by re-completing a single-zone well ofttimes is more desirable than re-drilling to deeper pays or drilling twin wells. These observations do not apply to new, flowing wells alone; for instance, even if a well is on the pump, the use of the sub-surface equipment described herein does not, as a general rule, entail the installation of any additional surface equipment or the use of additional rods, etc. A second flow line fitting must of course be made up at the casing outlet, but the operation of the Otis Two-Zone Pump does not require an additional stuffing box, polished rod, or pumping jack, nor are there any flexible lines, hollow polished rods, or other special fittings that require additional installation and maintenance.

There are a sufficient number of dual pumps in operation to prove that this sub-surface equipment will pump fluid from two horizons. Thus, when additional sub-surface equipment only is considered, it can readily be seen that the small per-well increase in operating costs is of little importance when compared with the great saving realized in the drilling and completion costs of two wells. This equipment is one of the most important recent production developments offered to the industry.

"What does it cost to produce a barrel of oil?" This is a question in the mind of every operator. The actual cost attributed to that barrel of oil many involve such costs as seismograph work, geological studies, land fees, drilling, completing, office and field operating costs, and many others. With the present trend in rising costs of both finding and producing oil, the oil companies must operate efficiently in order to maintain a fair profit. Each new tool or service offered must reduce costs or increase net profits, or both, to be successful. These are the primary objectives of the dual pump assembly. Not only does the dual pump meet these requirements, but it also conserves vital material such as casing, sucker rods, pumping units, engines, and other equipment.

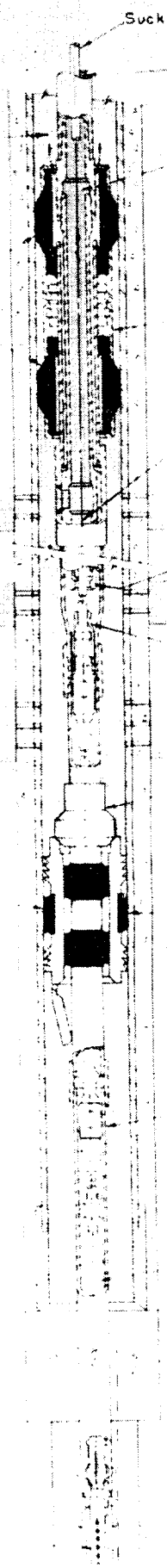
Structures

There are several possible structures of equipment available today. These structures differ in their basic operation. However, all mentioned here use a conven-



(Otis, Et.Al.)

CHART I



VIEW SHOWING COMPLETE TWO-ZONE PUMPING HOOK-UP

CHART II

tional pumping jack and a rod string to operate the sub-surface pumps. These two main structures are: (Please refer to Chart I).

1. Intermittent type: Employs one oil well pump and alternately produces one zone at a time by means of suitable sub-surface equipment.

2. Simultaneous and separate zone production types: There are two main sub-structures commercially available at the present:

A. Hollow Rod Type: This structure employs a string of hollow sucker rods to produce one zone and either the tubing-casing annulus or the tubing-rod annulus to produce the alternate zone.

B. Solid Rod Type: This structure employs a standard string of A.P.I. sucker rods and the tubing to produce one zone while the alternate zone is produced from the tubing-casing annulus.

This structure is by far the most practicable and it is here that the greatest use has been experienced. This structure will also be the basis upon which additional major developments of "dual pumping" will be based. It is, as a matter of fact, the type with which we will be concerned during the remainder of this article. All of the Otis Two-Zone Pump types fall under the Solid Rod Method of production.

There are four main assemblies of the Otis dual pump: (Please refer to Chart II). (1) A positive displacement pump to produce the upper pay, (2) a cross-over device within an annular style packer that has separate passages for the fluids from the two pays, the lower zone being crossed over into the tubing-casing annulus, and the upper zone taken directly into the tubing, (3) a polished rod attached to the upper plunger that actuates a lower pump and a pack-off unit that separates the two pays within the tubing, and (4) positive displacement pump to produce the lower pay.

An additional packer must be used in all dual wells to separate the pays. Although this packer is not considered a part of the pump proper, it is very important that the packer have certain mechanical features in order to be effective in dual pumping. These may be enumerated briefly as follows: (1) No part within the packer should move during the pumping cycle; (2) The packing elements should set positively with very little or no load being applied from the tubing string; (3) The slips should have a large contact area, and (4) The minimum I.D. of the packer should not be less than the tubing I.D.

The Otis Two-Zone Pump will produce oil from two separate oil sources and keep the two sources separated during the entire production cycle. A solid rod string is used throughout the pumping equipment. The lower zone production is pumped out of the tubing-casing annulus and the upper zone production is pumped out of the tubing at the surface through a regular pumping tee.

The stroke may be any length that is desired, including strokes up to 20 feet long. There is no practical dimensional length restricting the rod string as to the placement of the intake of each zone.. Installations with 40 feet between the seat of each pump have been made; likewise, an installation has been experienced

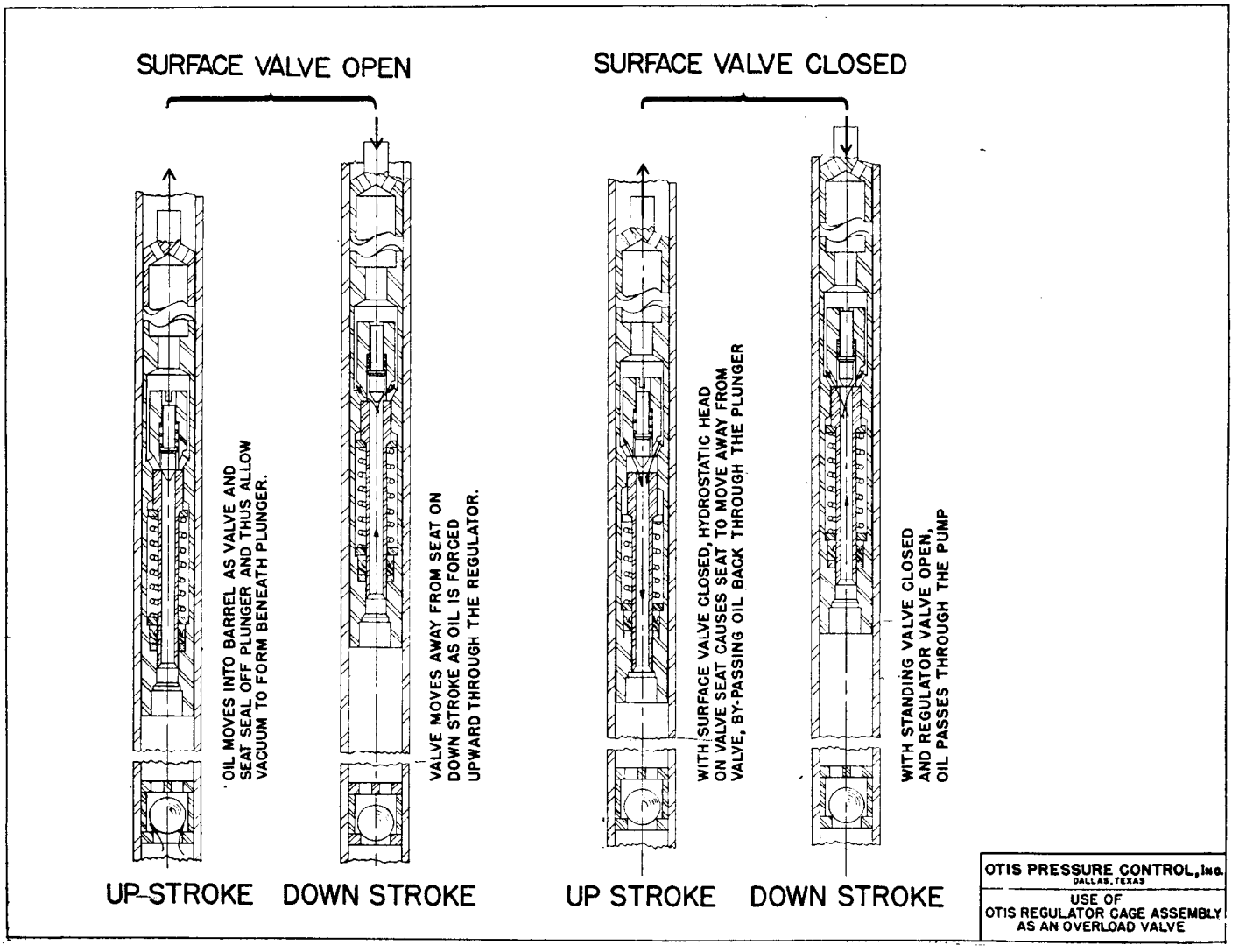
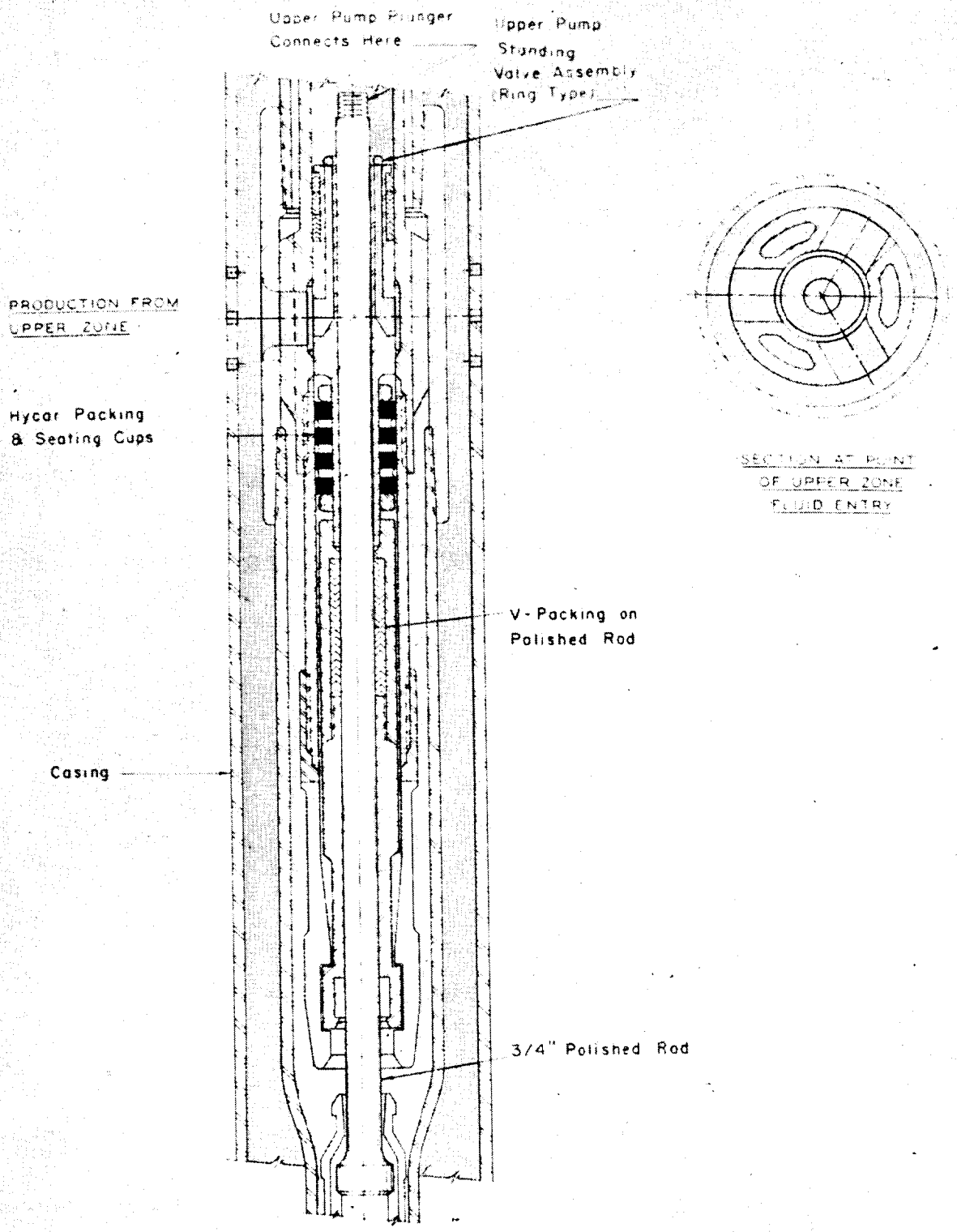


CHART III



SCHEMATIC DETAIL OF PACK-OFF
UNIT BELOW ANNULAR PACKER

PRODUCTION FROM LOWER
PUMP RISES AS SHOWN
INTO CROSS-OVER ASSEMBLY

CHART IV

CHART V
DUAL PUMP PLUNGER COMBINATIONS AND CRITICAL DATA

	Minimum Tubing I. D. (Nominal)	2½"	2½"	2½" or 2"	2"	2"
	O. D.	2-1/4"	2"	1-3/4" - 40	1-1/2"	1-1/4"
	Area, Sq In.	3.976	3.142	2.513	1.767	1.227
Upper Plunger	Displacement Area,, Sq. In.	3.536	2.700	2.061	1.325	0.785
	Displacement Diam., In.	2-1/8"	1-55/64"	1-5/8"	1-19/64"	1"
	Available Pump Type	Tubing	Rod	Tubing or Rod	Rod	Rod
	Area, Sq. In.	2.405	2.405	2.405	2.405	2.405
1-3/4"	% Capacity of Upper Plunger	68.1	89.2	116.1	182	352
Lower Plunger	Available Pump Type	Tubing	Tubing	Tubing	Tubing	Tubing
	Otis Type Designation for Upper Plunger	A or B	G or H	A or G	G or H	G or H
	Area, Sq. In.	1.767	1.767	1.767	1.767	1.767
1-1/2"	% Capacity, Upper Plunger	50.8	65.4	85.2	133	225
Lower Plunger	Available Pump Type	Rod	Rod	Rod	Rod	Rod
	Otis Type Designation for Upper Plunger	C or D	E or F	C or D	E or F	E or F
	Area, Sq. In.	1.227	1.227	1.227	1.227	1.227
1-1/4"	% Capacity, Upper Plunger	34.7	45.4	59.2	92.5	156
Lower Plunger	Avaliable Pump Type	Rod	Rod	Rod	Rod	Rod
	Otis Type Designation for Upper Plunger	C or D	E or F	C or D	E or F	E or F
	Area, Sq. In.	0.887	0.887	0.887	0.887	0.887
1-1/16"	% Capacity, Upper Plunger	25.1	32.4	42.8	66.9	113
Lower Plunger	Avaliable Pump Type	Rod	Rod	Rod	Rod	Rod
	Otis Type Designation for Upper Plunger	C or D	E or F	C or D	E or F	E or F

with a distance of some 2,180 feet between pumps.

Main Assemblies of Otis Two-Zone Pumps

The Otis Two-Zone Pump consists (as we have said) of four main assemblies. This is true for nearly every type of two-zone pump manufactured.

These assemblies employ, wherever possible, conventional pump parts made according to A.P.I. specifications. Because of the very theory of using two pumps and because the API specifications were not drawn to include two-zone pumps, there are a few parts with specifications other than A. P. I. This means that new connections of adequate strength had to be designed, and new materials of adequate strength and performance had to be adapted to meet deep-well pumping conditions.

Deep--Well is defined as: a single zone well pumping any quantity from below 7,000 feet, or a well producing 500 barrels of fluid from between 5,000 feet and 7,000 feet of depth.

When considering the loads encountered in pumping two zones at 5,000 feet or greater depths, you will readily understand that each two zone pump installation at or below these depths constitutes a deep well. To satisfy deep-well conditions, the Otis Two-Zone Pump has sufficient strength and durability to pump fluids within the limits imposed by the use of present day sucker rods.

The upper positive displacement type pump connects directly into two of the main assemblies. This upper pump may consist of one of two basic types of oil well pumps: It may be either a tubing type or a rod type of pump. These pumps always use metal plungers. The tubing type of pump may use either a common working barrel or a tubing-liner barrel. The rod type may consist either of a regular barrel tube or a liner barrel, and for the present time, the barrel is stationary with top and bottom seals and hold-downs.

The annular packer employs synthetic rubber cups to seal against the casing and prevent flow past the packer under very low or high pressure differentials. Likewise, this packer is designed structurally to withstand very high pressure differentials either internally or externally. It has built into it a cross-over device in the metal parts of the packer. This cross-over consists essentially of a horizontal tube arranged to by-pass a vertical tube. Attached below the cross-over is a nipple arranged internally to allow a pack-off unit to come to rest within it. Beneath this nipple is a set of outer clutch prongs for properly locating the pack-off unit.

The solid down-the-hole polished rod that connects the upper pump to the lower segment of sucker rods is 3/4" in diameter. Surrounding the rod is a standing valve and pack-off unit that uses A.P.I. sealing cups on the outside to separate the two pays within the internal nipple. Beneath the seating cups and located inside the pack-off is the packing which seals against the polished rod and forms a down-in-the hole stuffing box. This inside, or rod, packing is a self-adjusting type of V-Packing of a composition suitable for withstanding very high pressure differentials at elevated temperature for prolonged periods. Beneath this pack-off unit is a special, square-shouldered hold-down which is designed to come to rest in the recess of the outer clutch prongs. Above this pack-off unit is placed the annular ring-type standing valve for the upper pump. This valve has the unique feature of operating around the down-hole polished rod and is run and pulled on the rod string, and thus forms a true upper zone standing valve.

The lower pump may either be a tubing type of pump, or a rod type pump. The tubing type of pump may be as described earlier. The rod type of pump, with certain modifications made externally, may be a rod stationary barrel, a rod traveling barrel, and is always equipped with a bottom lock hold-down.

Equipment Selection

Having discussed the design and construction of the Otis dual pump, the next phase will touch briefly on equipment selection and application. When considering the use of a dual pump, several factors enter into the economic study of the operation which will affect the operator's decision to dually complete a well. These factors will usually be the same with the exception that one factor differs only in new-well and old-well practices. Some of these are outlined in Chart IV.

Chart IV
Economic Factors Influencing Dual Completions

1. Completion practice (involves materials and services):

A. New-Well Completion:

(1) Landing the casing, or "oil string" on top, or through the lower zone.

(2) Effecting a positive seal between the selected zones outside of the casing.

(3) Testing the casing, and the cementing operations encountered while accomplishing the first two operations.

B. Old Well Re-completion:

(1) Deepening to a new zone.

(2) Re-completing up the hole into a previously passed-up productive zone.

(3) Re-opening a previously non-commercial productive zone which may be produced commercially with the use of a dual pump.

C. Operations applicable to both new and old-well re-completions:

(1) Testing each zone independently for oil, water or gas production (This may be done in the drilling stages, or the re-work stages; however, the subsequent (interim) operations may have had an adverse effect on the productive zones. Therefore, it usually is advisable that this operation be performed after the casing is landed, said formation treatments, etc.)

(2) Sand-face or formation treatments. (This may be feasible prior to the productive testing, or at any time desired during the completion phase).

(3) Well bore clean-up may involve several operations; however, this operation is important for the successful operation of any dual completion, pumping or flowing.

2. Tubular program required for dual pumping.
3. Sucker Rod program required.
4. Surface equipment required:
   A. Pumping Unit, Gear Box, Engine, etc.
   B. Flow Lines required.
   C. Tankage and metering facilities required.
5. Operating practices which apply to the area.

These factors may actually be resolved into cost. Offsetting this cost, and affecting the application also is the expected return in terms of barrels of oil and cubic feet of gas, which may be converted into dollars and cents. This may be termed "additional pay out." After all, you, as production men, are accustomed to frequently looking at the size of the pot in a small, friendly game of poker during off-duty hours, are you not? Especially when some of your money is already in it, eh?

Now if we have studied the factors mentioned above and we have determined:

1. That a dual pump is feasible.
2. The depths at which we must pump.
3. The size of tubing available.
4. The size and weight (nominal) per foot of casing in which the packers must land.
5. The quantities of oil, gas, and water to be produced from each zone.

6. The surface equipment available.
7. The tubing sizes available for pumping.
8. The rod sizes available for operating the pumps.

Then we may select a two-zone pump. (Chart V).

We have now arrived at that point wherein we become involved in the calculations of a pumping well. I quote the **Practical Petroleum Engineer's Handbook**, by Mr. Saba and Mr. Doherty, third edition, 1949: "Lifting of well fluid by sucker rod pumping is a complex mechanical problem." This is true. However, the addition of a second oil well pump onto the rod string does not complicate our "complex mechanical problem." It merely causes us to abandon all of our convenient single pump charts (which have been carefully devised for us) and to revert back to the basic equations and use slightly different numbers in our calulations (i.e. the equations have not changed—only the numbers!)

In order to select equipment in a logical manner, it is necessary to predict, with a reasonable accuracy, the loads and stresses which may be expected while operating a two-zone pump. The calculated loads placed on the polish rod will determine the size of the pumping unit to be installed. The practicing theory is to install the largest unit with the longest stroke that will ever be needed to obtain the desired production from that individual well. The effective areas of the two plungers affect the loads placed on the rod string. These areas, for load purposes, may be added. The weight of the rods influence the load on the polished rod at the surface. The same consideration in regard to stress loads, peak torque, and other limiting factors will apply to dual installations. The capacity of the pump for the upper zone is reduced by the amount of the area of the rod which follows the upper plunger on each up-stroke. This "effective" displacement capacity of the upper plunger, for convenient calculation purposes, may be stated as an equivalent plunger diameter, and as such, may be used to calculate volumetric production. (See Chart V.)

Installation

Having decided upon the proper equipment, the well must be prepared for the dual pump installation. Once the well has been perforated or by other means opened to the pay zone, it is good practice that the well be cleaned thoroughly of any sand, scrap formation material, or other matter that it is possible to have removed. Also at this time, each zone should be accurately tested for productivity. As an added precaution, it is advisable that the operator scrape the pipe to remove any sedimentary deposits of drilling mud, cement, slurry mix, jell, bullets, burrs, or slag steel resulting from the use of a casing perforator. This is good, sound oil field practice regardless of the type of packer used. This is desirable because the operator is placing quite a financial burden on any packer, regardless of its cost, to assure a seal between the formations, and thus assure the producing success of his dual well.

A dual pump must be accurately and carefully installed. For instance, the distance between pump seats in the tubing string must be measured accurately and the correct length of rod string installed. The installation of a pump is described briefly as follows: It may be run inside 5" O.D., or larger, casing. Tubing of 2" diameter or larger may be used in the well. The upper pump seat, annular packer, cross-over fitting, tubing segment between the upper and lower pumps, and the lower pump seating shoe are made up in the tubing string and lowered to the desired depth in the casing. The lower packer is set, and a predetermined amount of weight is placed on the packer. The weight should be slightly greater than amount of force that the tubing string will be relieved of on the upstroke of the pump plungers. After the tubing is landed, preparations are made to run rods and the remaining portions of the two pumps.

The lower pump (or plunger) is attached at the lower end of the sucker rods. The length of the sucker rods to be run between the pumps must be tallied so that the upper and lower plungers will be spaced properly in each barrel. A special coupling is attached to the upper end of this segment of rods. The function of this coupling is to join the solid polished rod with the lower segment of sucker rods and to carry the rod pack-off unit and upper pump standing valve into their proper seat. The top of the polished rod is joined to the upper plunger or pump by means of a special cage. The top of the upper pump plunger connects to the sucker rods, which extend to the surface.

As the rods are lowered into the tubing, the lower pump passes through the upper pump barrel (or seat) and the clutch prongs of the hold-down unit. The pack-off unit and upper pump standing valve also pass through the upper pump barrel. As the special coupling passes the outer clutch prongs, the square shoulders of the special hold-down are stopped. This correctly positions and anchors the pack-off unit and the upper pump standing valve. As the rods are lowered further to the bottom of the normal down-stroke, the upper and lower pumps are landed in their seats. After the installation of a conventional stuffing box and polished rod at the surface, the dual pump is ready for operation.

Production

Production from either zone may be accurately controlled. This may be accomplished by various methods in addition to varying number and length of strokes:

1. Variation in relative sizes of pump plunger. (See Chart V.)
2. Actual disconnection of the lower pump by manipulation of the rod string.
3. Regulation of production below that of the pump capacity. The use of an overload valve has been adopted for pumps to provide a variable control over the volume of fluid produced through the pump. This traveling overload valve allows the produced fluid to be by-passed through the plunger on the upstroke and through the pump on the downstroke when the surface valves are closed. Under this arrangement a high potential zone can be completely shut in after it has produced its allowable.

Protection Against Paraffin

As a protection against an accumulation of paraffin in the tubing and in the annulus, paraffin scrapers are installed on the sucker rod string and a valve is placed in the tubing below the paraffin belt so that warm oil may be circulated at intervals as may be found necessary. The use of hollow sucker rods for the circulation of warm oil has been successful in some areas.

Well Servicing

Generally speaking, the frequency for pulling the rods for a dual pump is about the same as for single pumps. A pump work-over job takes a little longer than for a single pump, but only because two pumps must be serviced.

It has been considered advisable by some operators to leave the derrick in place so that the sucker rods can be hung in the derrick when the well is serviced. This practice makes it easier to keep the rods, tubing, and pump parts clean and free of sand and dirt.

Conclusions

Dual pumps have proved that dual wells can be produced without co-mingling the fluids from two separate horizons after the wells cease to flow. The successful operation of this equipment has served to

(Continued to bottom of page 32)

Sub Surface Two Zone Pumping, cont'd—

produce two horizons without the expense of drilling two wells.

There should be little doubt as to the initial savings made in drilling one hole and dually completing a multiple-zone well. It is believed that the era of dual pumping wells actually is in its infancy and will grow to take its place among the other standard producing methods in the petroleum industry.