Artificial Lift as Applied to the Multiple Completion Choke Assembly

By *KARL N. TUNSTALL*
Otis Engineering Corporation

INTRODUCTION

In seeking a more economical approach to the production of petroleum, the multiple completion choke assembly has emerged to decrease initial cost, lower lifting cost, reduce workover cost, lower the economic limit while increasing profit per barrel, produce oil which would not otherwise be recovered, and allow an economical means to evaluate questionable reservoirs. Artificial lift has been used above the choke in gas lift, rod and hydraulic pumping, and in plunger lift operations to widen its basic scope beyond the original concepts. Artificial lift created special conditions and required new rules to govern the allotting of reservoir fluids.

REGULATIONS

Every regulatory agency, in order to grant a multiple zone allowable, has two basic requirements which must be met: (1) to constantly prevent communication between separate sources of supply; and (2) to have prorating orifices resistant to erosive action. The check valve assembly (Fig. 1) remains in the tubing while blanking, allocating, and adjustments are made in the orifice head so that the stronger zone is not allowed to back flow into the weaker. The orifice head assembly, when installed, provides separate flow paths for each zone until that zone has been properly proportioned through its respective orifice. The production is then combined and jointly flows to the surface.

Downhole commingling has been allowed in most states on several bases: (1) production distribution curves, with the single point validation method; (2) limits tests, where tubing inlet pressure remains a constant during lift conditions; (3) percentile, based on ratio performance and referred to as subtraction; and (4) on a gravity base, as determined by °API on dissimilar crudes. The frequency rate on subsequent testing ranges from 60 days to one year.

Each means of allocating production is tailored for that type of artificial lift. This approach encompasses the fundamentals that it must be an accurate means of distribution, to satisfy the regulating body, but must also be the most economical method available so that the producer warrants continued use of the tool.

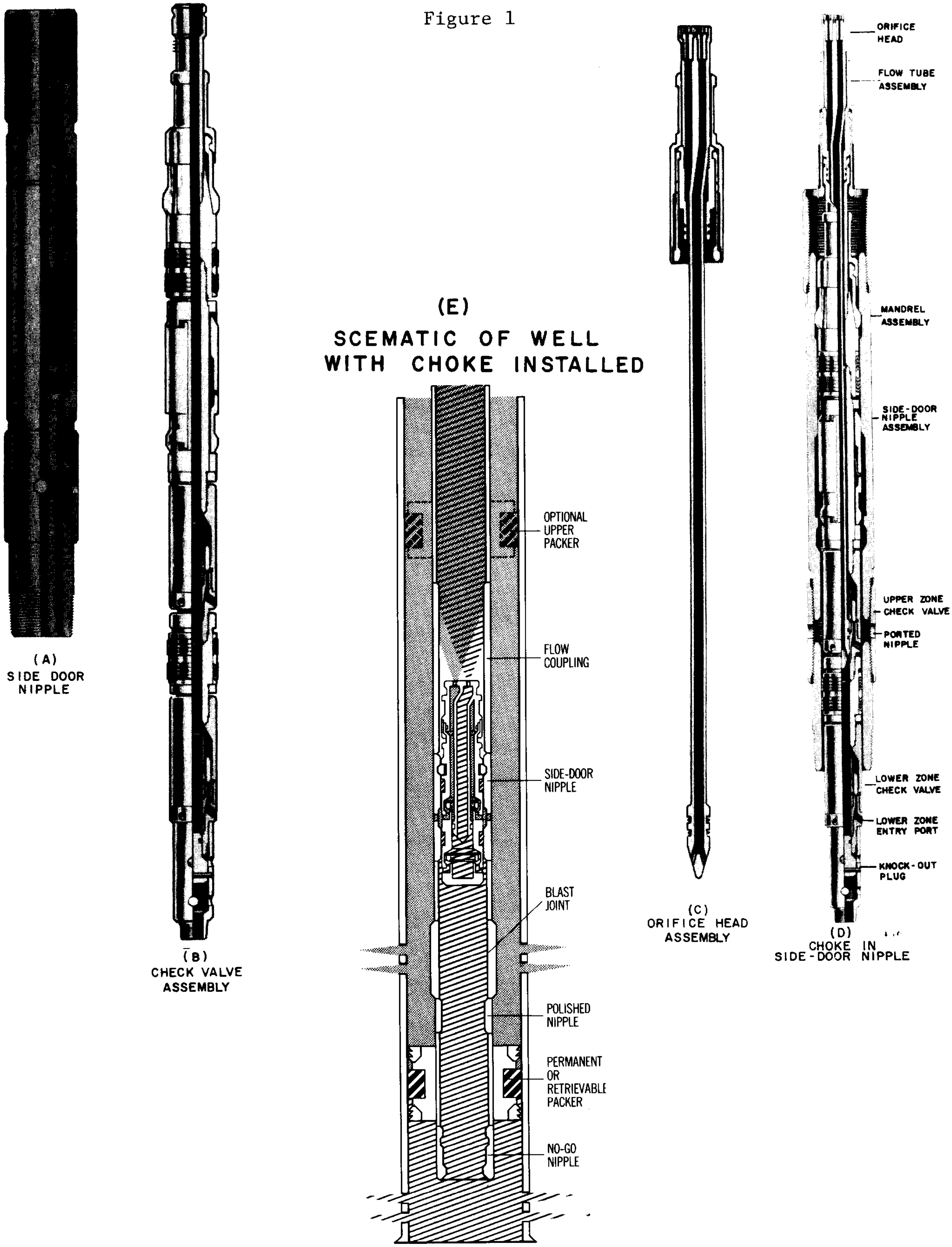
Oklahoma, Louisiana, Mississippi, New Mexico and North Dakota have allowed use of the tool, and the regulating agencies have existing field or general orders to permit its application. Kansas has indicated that an application in that state would meet with approval. Texas is still on an individual well basis, and no order of a general nature has been formulated. Overseas application has been limited to lifting one zone with aeration from another, but an economic limit situation is now in the process of consideration.

DISTRIBUTION CURVE

The production distribution curve (Fig. 2) serves as the most accurate and economical approach to allocate production in flowing wells and some gas lift wells. Every barrel and/or cubic foot of gas can be allocated back to the reservoir from which it was produced using a plot of production versus tubing inlet pressure. Its continuation as a valid means to disperse production can be ascertained by a single point check, i.e., validating method, since this plot indicates what the individual zones are capable of producing against varying back pressures immediately downstream of the tool. Tubing inlet pressure is normally used to differentiate the downstream pressure from flowing bottom-hole pressure.

The production distribution curve serves as a working tool to allocate production. It may be obtained by single zone plots which are added to obtain the combined, or may be obtained by

Figure 1



(A) SIDE DOOR NIPPLE

(B) CHECK VALVE ASSEMBLY

(E) SCEMATIC OF WELL WITH CHOKE INSTALLED

(C) ORIFICE HEAD ASSEMBLY

(D) CHOKE IN SIDE-DOOR NIPPLE

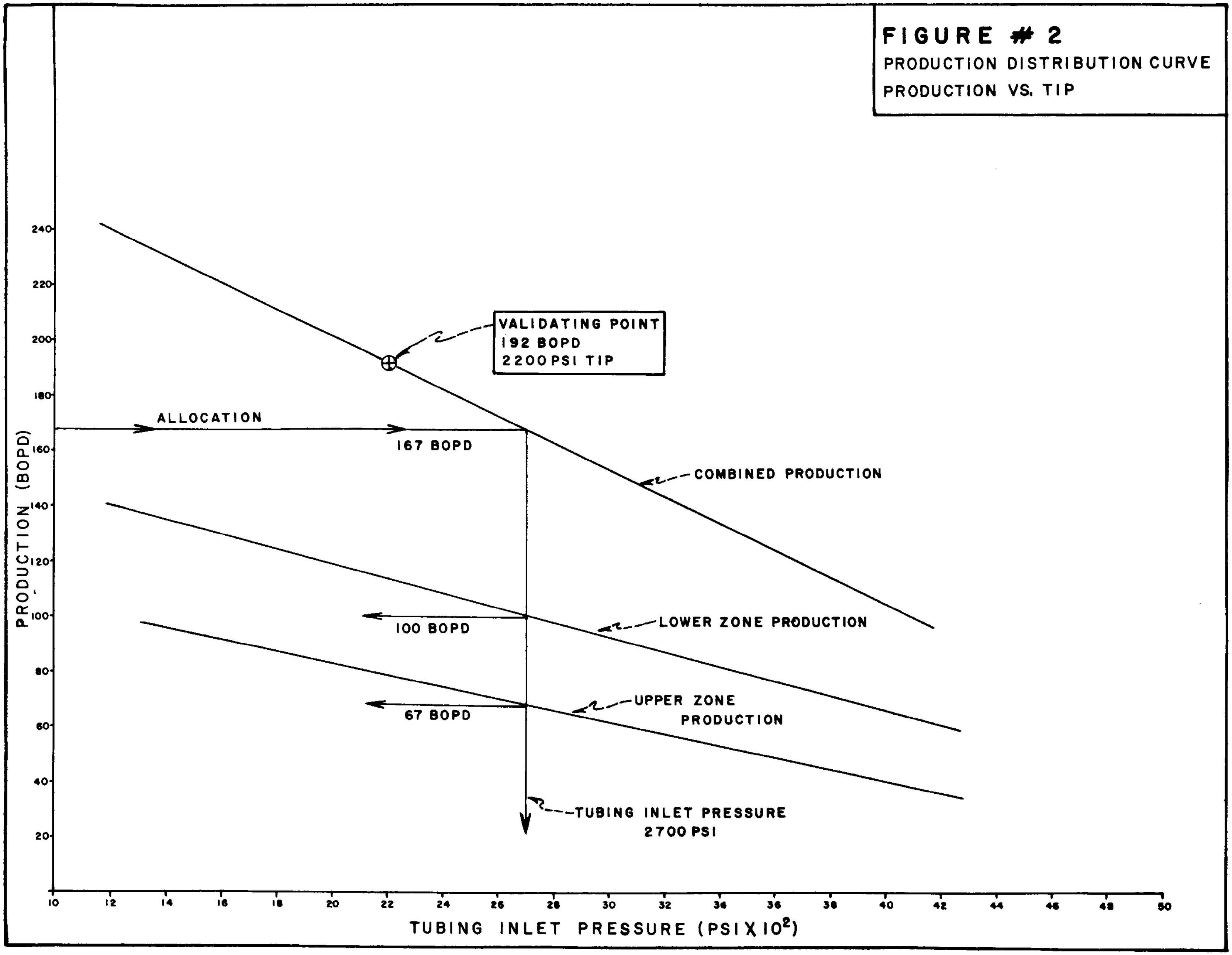


FIGURE # 2
PRODUCTION DISTRIBUTION CURVE
PRODUCTION VS. TIP

subtracting a single zone plot from the combined. Any combined production is merely the sum of the two or more contributing zonal rates at a particular downstream condition. This combined production does fix a tubing inlet pressure whereby the single point validation indicates any deviation.

The production distribution curve is a proof test of producing capabilities of one or more zones through fixed bean sizes as related to downstream pressures. As a comparative base on flowing wells a plot of pressure versus depth (Fig. 3) indicates that any design tubing inlet pressures may be used between the minimum tubing inlet pressure for the traverse of that fixed condition, up to a maximum of the flowing bottom-hole pressure, at desired rate, of the weaker zone. If the flowing bottom-hole pressure of the weaker zone is used for the design base, then the differential required to force compatibility will be the difference in flowing bottom-hole pressures. An operator can then produce his well at higher surface pressures, affording more versatility than would be the condition if choke design were calculated from the minimum tubing inlet pressure. It also allows for wide range surface control to meet allowable changes, capacity of production facilities and unofreseen shut-in periods.

A graphic example of the flow stream (Fig. 4) depicts dynamic conditions existing both upstream and downstream of the choke. The flowing bottom-hole pressure has a bbl/psi rate of change as a function of the zone's productivity index while downstream of the choke a much higher rate of change occurs which is a function of flow rate through the bean. The bottom-hole pressures range from static to the point at which critical flow takes place. Tubing inlet pressure variations are the same stream's capability to flow through a restriction at pressure ratios less than critical. Any additional decrease in downstream pressure neither increases production rate nor decreases flowing bottom-hole pressure. For any downstream condition this choke will produce only one rate, and will continue to do so until a change in mix, i.e. water oil ratio or gas oil ratio, or pressure occurs.

LIMITS TEST

Limits tests are set up by some regulatory bodies where the tubing inlet pressure remains a constant as in the case of rod or hydraulic pumping. If the tubing inlet pressure remains constant during testing of each zone individually, and can be returned to this same base when combined flow occurs, then production from each source will remain constant. This situation does not exist in flowing wells, but is a created condition below rod or hydraulic units when each zone is metered through its own choke.

Pumping installations have additional advantages over multiple zone pumping since the annulus is used to vent gas (Fig. 5) and the pump only encounters gas-free liquid. Gas locking of pumps, while pumping below a packer, has been virtually eliminated.

As many additional zones as desired or encountered may be added to the single artificial lift mechanism by merely adding additional prorating orifices. Several three zone rod pumping installations are now in operation. As in the case of some existing installations, it may be necessary to choke back a zone capable of flowing independently in order to take advantage of the benefits afforded by multiple zone lift with one pump, one tubing string, and still be able to vent produced gas.

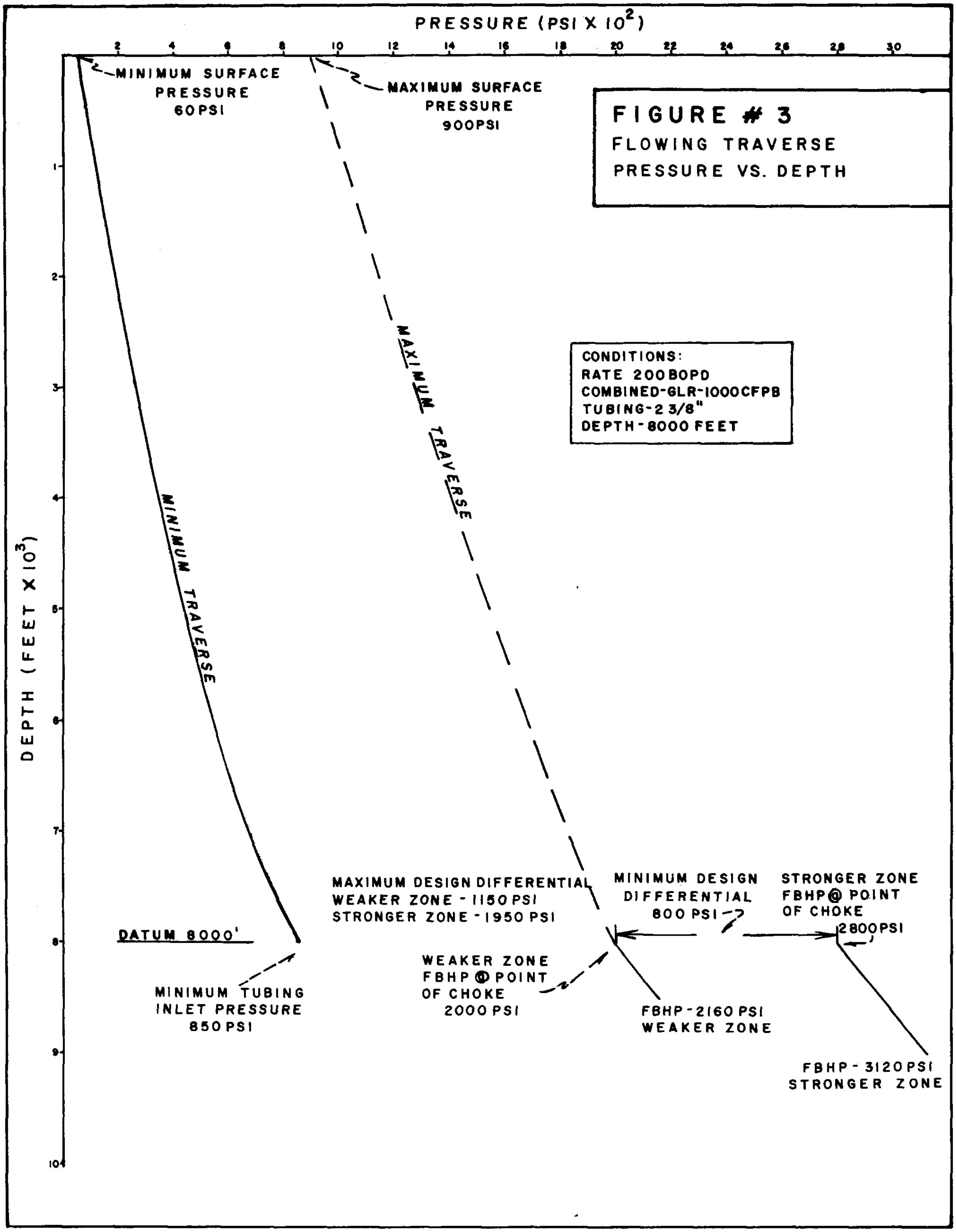
Hydraulic pumping has been used in conjunction with the choke but requires an additional string if the formation gas is to be vented. One operator had six zones commonly pooled for one allowable, but by regrouping and using the multiple completion choke assembly in conjunction with hydraulic pumping, had them separated as two sources of supply. After a rework to install the necessary down-hole equipment he now produces his well as a dual completion, and is receiving twice the single allowable rate.

EVALUATION OF QUESTIONABLE RESERVOIRS

To have a balance point which would warrant investigation of poor sands present in the well bore, a second zone need only produce one barrel per day for two years to allow a break even point. This cost comparison allows for both equipment needs and testing requirements. Any production in excess of the one barrel from a second zone would reflect a profit to the venture.

OTHER METHODS

Two isolated conditions which cannot be utilized under the wide applications of the first two methods, but deserve explanation since they do represent other valid means of allocation are subtraction and gravity proportionment.


PRESSURE (PSI X 10²)
2 4 6 8 10 12 14 16 18 20 22 24 26 28 30
DEPTH (FEET X 10³)
1 2 3 4 5 6 7 8 9 10
MINIMUM SURFACE PRESSURE 60PSI
MAXIMUM SURFACE PRESSURE 900PSI
FIGURE # 3
FLOWING TRAVERSE
PRESSURE VS. DEPTH
CONDITIONS:
RATE 200BOPD
COMBINED-GLR-1000CFPB
TUBING-2 3/8"
DEPTH-8000 FEET
MAXIMUM TRAVERSE
MINIMUM TRAVERSE
MAXIMUM DESIGN DIFFERENTIAL
WEAKER ZONE - 1150 PSI
STRONGER ZONE - 1950 PSI
MINIMUM DESIGN DIFFERENTIAL 800 PSI
STRONGER ZONE FBHP@ POINT OF CHOKE
2800PSI
DATUM 8000'
MINIMUM TUBING INLET PRESSURE 850 PSI
WEAKER ZONE FBHP @ POINT OF CHOKE 2000 PSI
FBHP-2160 PSI WEAKER ZONE
FBHP-3120 PSI STRONGER ZONE

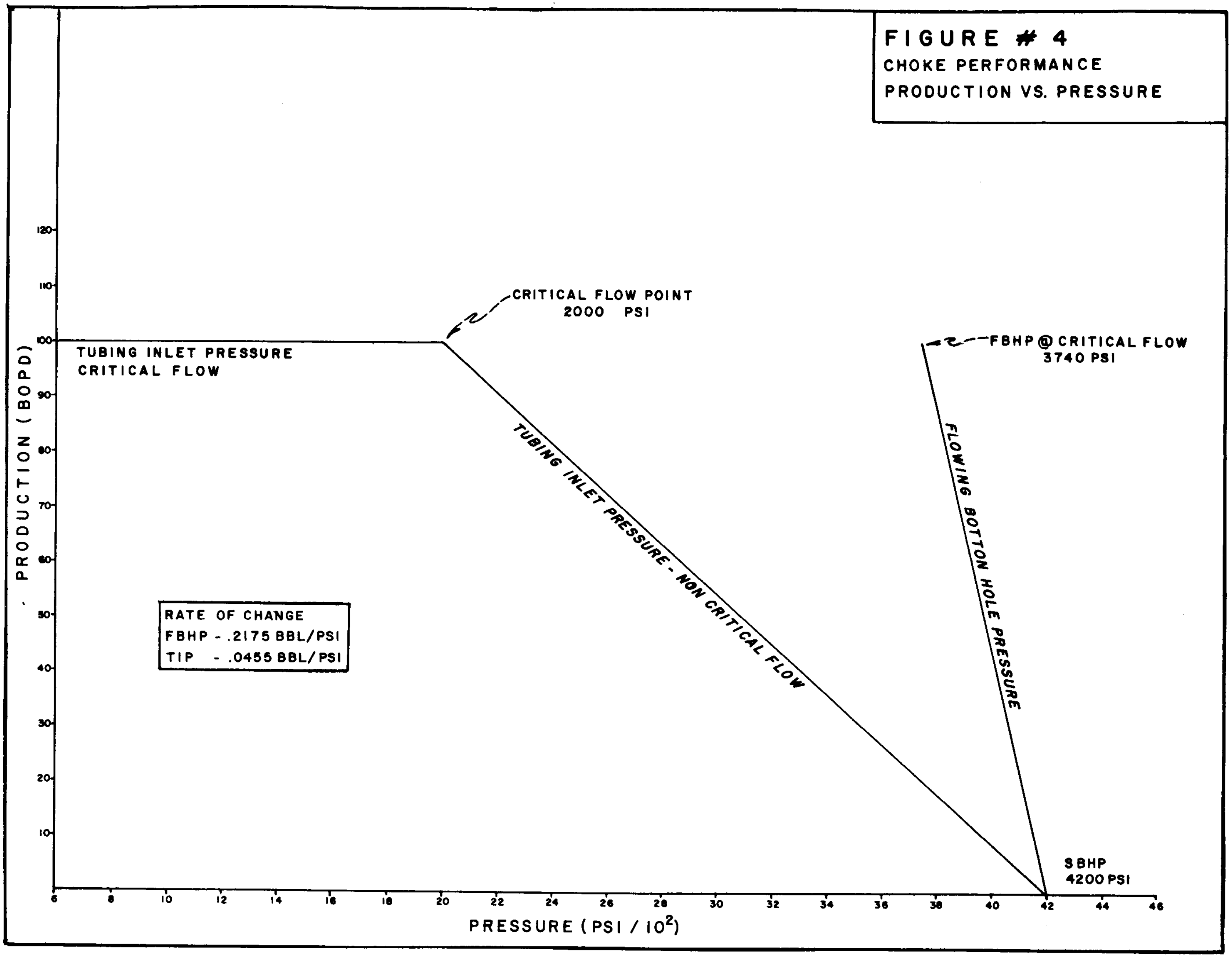


FIGURE # 4
CHOKE PERFORMANCE
PRODUCTION VS. PRESSURE
PRODUCTION (BOPD)
PRESSURE (PSI / 10²)
CRITICAL FLOW POINT
2000 PSI
TUBING INLET PRESSURE
CRITICAL FLOW
TUBING INLET PRESSURE - NON CRITICAL FLOW
FBHP @ CRITICAL FLOW
3740 PSI
FLOWING BOTTON HOLE PRESSURE
SBHP
4200 PSI
RATE OF CHANGE
FBHP - .2175 BBL/PSI
TIP - .0455 BBL/PSI

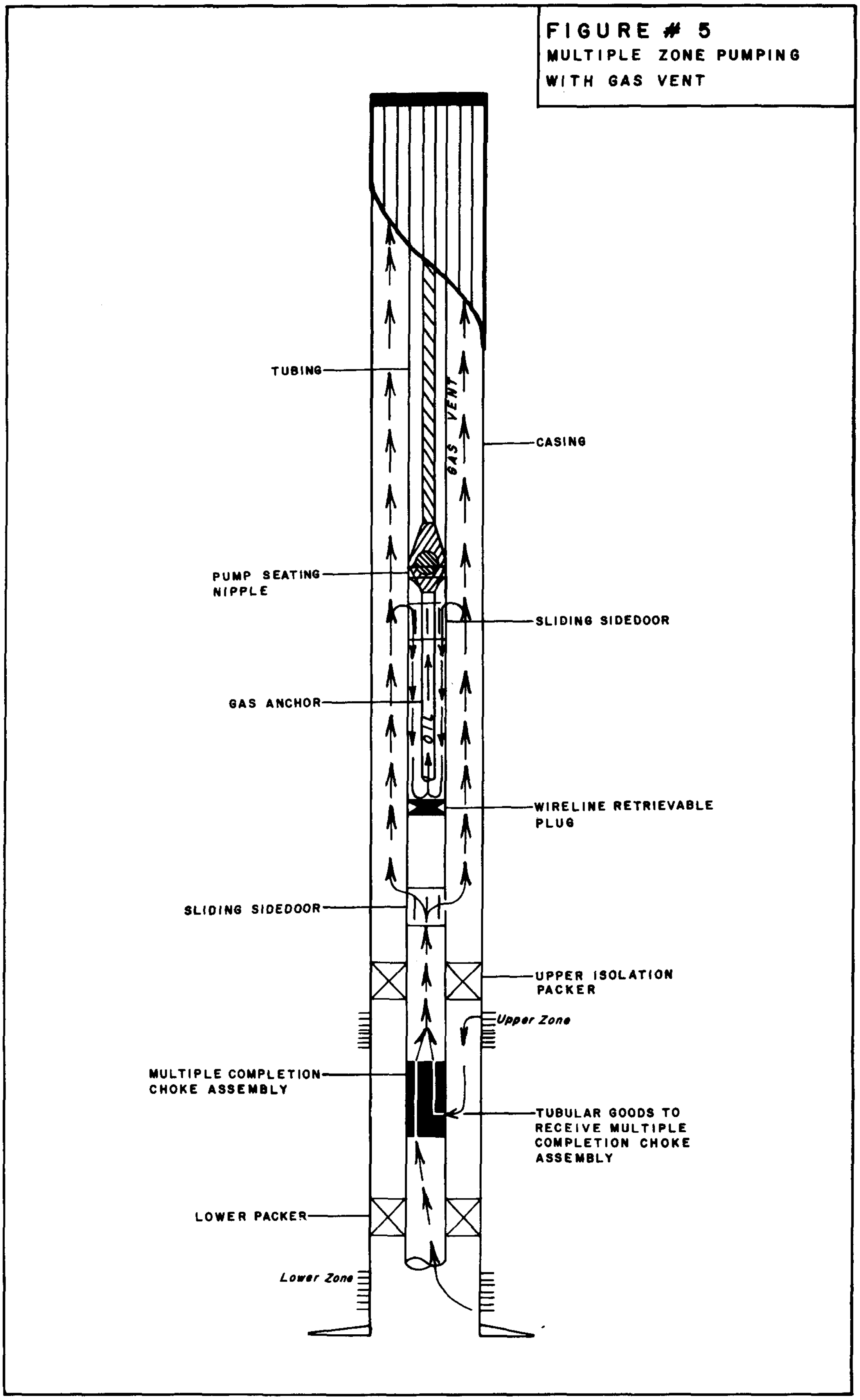
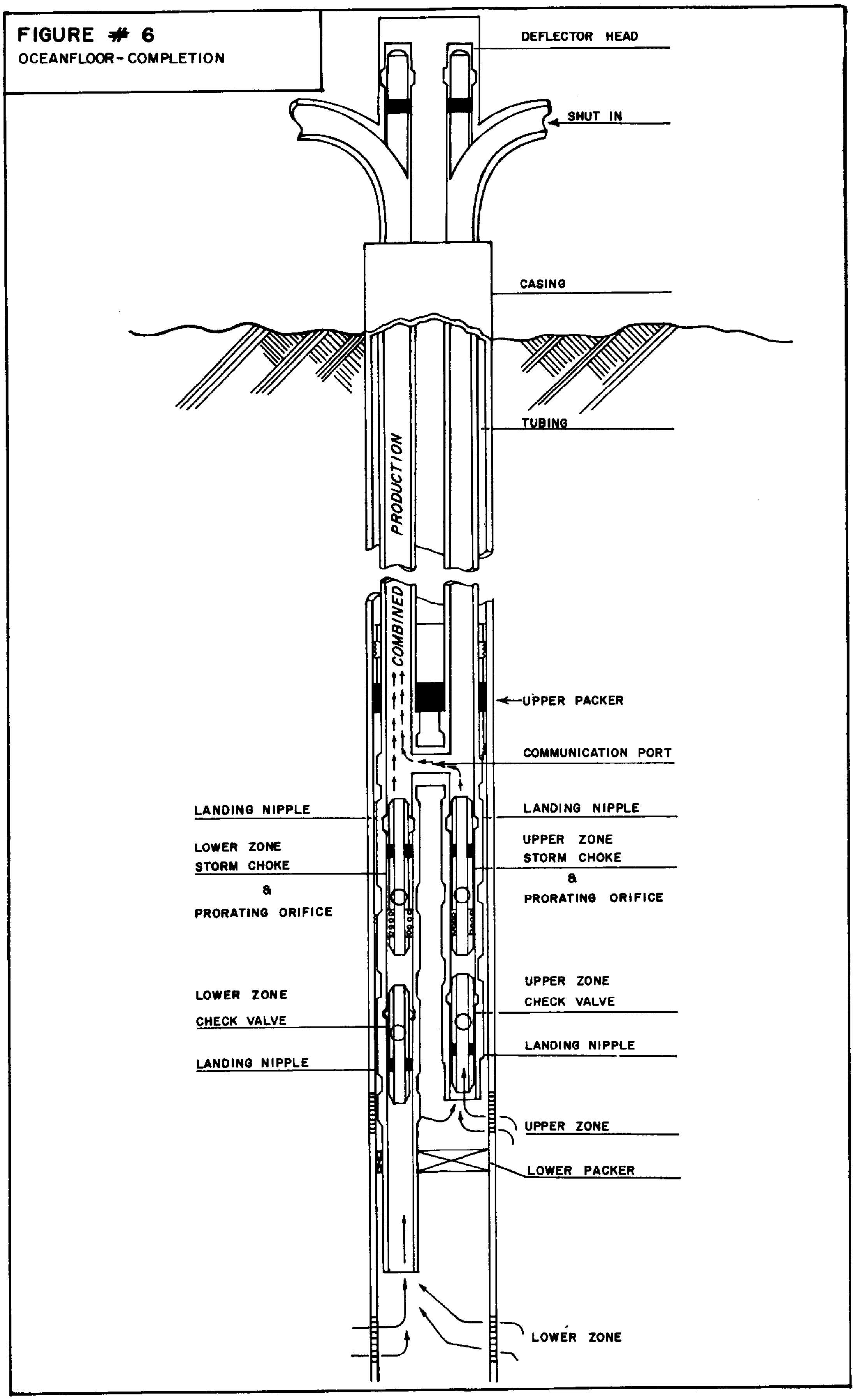


FIGURE # 5
MULTIPLE ZONE PUMPING
WITH GAS VENT
TUBING
GAS VENT
CASING
PUMP SEATING NIPPLE
SLIDING SIDEDOOR
GAS ANCHOR
OIL
WIRELINE RETRIEVABLE PLUG
SLIDING SIDEDOOR
UPPER ISOLATION PACKER
Upper Zone
MULTIPLE COMPLETION CHOKE ASSEMBLY
TUBULAR GOODS TO RECEIVE MULTIPLE COMPLETION CHOKE ASSEMBLY
LOWER PACKER
Lower Zone

FIGURE # 6
OCEANFLOOR-COMPLETION



The percentile base has been used in conjunction with plunger lift operations, and is another case of essentially holding the tubing inlet pressure a constant. Where its use is being applied, the reservoirs are of low permeability, and large changes in flowing bottom-hole pressure do not vary the producing rate appreciably. The zones demonstrate similar producing characteristics although one zone is incapable of flowing alone. It can, however, produce by assistance from the other, a high gas oil ratio zone.

In the plunger lift operation a workable cycle frequency is established for one zone, and held as constant as possible for combined flow. The ratio of single zone and combined establishes a percentile which is then applied for day to day variations in production. The operator may be able to establish a small increase in daily production by refinement of his combined zone cycle and this increase is allotted on the percentile base established under the closely aligned conditions.

Crudes of dissimilar gravities have been combined on a density base with a reasonable degree of accuracy. A plot of the composite specific gravities closely approaches the production distribution curve. The inaccuracy of this method, in crudes of similar specific gravity, would be limited by the measurement devices now in common field usage.

Other methods can be used and may be the future means by which crudes are separated. Some of these are gas-oil ratio, water cuts, surface recording bottom-hole pressure instruments, and possibly allocation based on surface information when our existing technology could permit the plotting of a distrubution curve, by computer, from surface well tests.

FUTURE

The tool has afforded many producers savings in varied applications in the past with new avenues of diversification being conceived regularly. One of the latest uses is in ocean floor completions (Fig. 6) where the operator uses two storm chokes in a dual purpose capacity as both his means of subsurface safety shut-in, and as a prorating orifice.

CONCLUSION

The past performance of the tool has been highly favorable, and can afford others the same advantages when more than one zone is discovered. The progress is linked to permission granted by each state's regulating authority, and that bodies desire or need to conserve dollars in production. Allocation accuracy will always revert to the rules that govern the toll, and to the integrity of the operators who seek and obtain permission for use.