Gas Lift In Dual Zone Completions

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ABSTRACT

This paper deals with the problems of gas lift design for a dually completed well. Gas lift flow valves are described. The limitations of small tubing and restricted annular areas are noted. Problems of flow valve design for small tubing are emphasized. Methods for gas lifting only one zone of a dual are explained. The merits of a separate injection gas source for each zone to be lifted, as compared with a common gas source for both zones, are discussed. Applications of concentric and parallel type dual gas lift installations are outlined. The advantages of retrievable gas lift equipment are mentioned.

INTRODUCTION

The increased trend toward dually completing wells has been brought about primarily by economics. The additional cost of drilling deeper and deeper wells, combined with enforced proration and offset obligations, have resulted in the operator exploring the dual producing problems. These problems include the prevention of commingling of the fluids and those associated with artificial lift. Dualing also permits the depletion of a marginal zone which could not payout on a single well completion basis.

Producing a dually completed well is no problem as long as both zones flow. After one zone ceases to flow, the operator is faced with abandonment of this zone or the installation of some form of artificial lift. Generally, gas lift installation design for producing only one zone is relatively simple. However, when both zones cease to flow, design becomes complex. The casing size primarily governs the selection of equipment which can be employed. If simultaneous artificial lifting of both zones of a dual is anticipated prior to drilling, 7" O. D. casing should be the minimum size considered in the drilling program of this well. This larger casing permits a greater number of gas lift equipment combinations to meet the operator's producing requirements.

Because the widespread need of artificial lift equipment for the increasing number of dually completed wells is relatively recent, extensive field data is not available for a detailed quantitative evaluation at this time. This paper presents the design problems and limitations of various combinations of dual gas lift installations and will assist the operator in the proper selection of dual gas lift equipment. The subject matter will be presented in the following sequence:

1. Gas Lift Flow Valves.
2. Limitations of Small Tubing and Restricted Annular Areas.
3. Gas Lifting One Zone of A Dual.
4. Gas Lifting Two Zones With A Common Injection Gas Source.
5. Gas Lifting Two Zones With Separate Injection Gas Sources.
6. Future Trend in Dual Gas Lift Equipment.
7. Conclusions.

GAS LIFT FLOW VALVES

Pressure Operated Valves

The most widely used flow valve in the industry is the pressure operated valve. This valve can have a pressure charge, a spring force, or a combination of the spring and pressure load holding the valve closed. The majority of these valves have a bellows which opens and closes the valve by a set pressure fluctuation opposite this bellows. The pressure opposite the bellows is generally the injection gas pressure, and by increasing or decreasing this injection pressure, the valve can be opened or closed from the surface.

A constant flow valve is a valve designed for metering the gas through a fixed orifice into the fluid column. These valves have a large port to utilize maximum back pressure effect from the tubing. A pressure operated valve with an unrestricted port is used for intermittent operation, which is sometimes termed "slug lift."

Fluid Operated Valves

The fluid operated valve is opened and closed by an increase and decrease in fluid head in the eductor tube. This is a pressure operated valve that is run in a special mandrel which enables the fluid weight in the eductor tube to provide the opening force opposite the bellows.

Differential Valves

The differential valve is operated automatically by changes in the fluid head in the tubing. The differential between the casing pressure and the fluid weight necessary to open the valve is controlled by a spring incorporated in the valve. The valve will remain closed until the fluid weight plus the spring force becomes greater than the casing pressure, at which time it will open. Gas injection continues into the fluid column until the fluid weight decreases, as a result of aeration, below that pressure necessary to hold the valve open.

Flow Valve Selection

When a common injection gas source is used to lift both zones of a dual completion, pressure operated valves are frequently used in combinations with differential or pressure-charged fluid-operated valves. This combination is desirable because two strings of pressure operated valves will often result in one zone using all the injected gas. Significant fluid weight effect can be achieved by running large ported, unbalanced flow valves. An intermitting valve with a ratio of 16 percent between the area of the port and the effective area of the bellows has an approximately 20 percent back pressure effect on the seat area. In other words, a 500 psi fluid build up above the valve will decrease the opening pressure of this valve by 100 psi. The tubing back pressure effect on a valve is an important consideration in the design of a dual well, where both zones are being lifted from the same injection gas source.

LIMITATIONS OF SMALL TUBING AND RESTRICTED ANNULAR AREAS

Capacity

Small tubing sizes and small annular areas between the macaroni and conventional tubing string result in high flowing gradient. According to Fanning's equation, the capacity of two different sizes of tubing for single phase fluid flow is a function of the ratio of the tubing diameters to the 2.5 power. A rate of 250 barrels per day through 1-1/4" tubing would be equivalent to approximately 1,000 barrels per day through 2" tubing. The multiphase vertical flow of an actual gas lift well is a more complex problem. An outstanding contribution for calculating the conditions encountered in this type of flow is offered in the A. P. I. paper, number 851-25-1, by Poettmann and Carpenter. This paper, published in A. P. I. Drilling and Production Practices, 1952, presents a pressure gradient traverse correlation for 2", 2-1/2", and 3" tubing sizes, based on field data compiled from flowing and gas lift wells.

An extrapolation of pressure traverses for 1-1/4" tubing, employing the method outlined in the A. P. I. paper, revealed the flowing gradients in 1-1/4" tubing to be extremely high. The resulting gradients indicate that a high injection pressure is necessary for nominal depths. If the operator desired 250 barrels of fluid per day from a low fluid level well, through 1-1/4" tubing, from a gas injection depth of 5,000 feet, a surface injection pressure in excess of 1,000 psi should be anticipated. The flowing gradient in small tubing, as compared to that in 2" or 2-1/2" tubing, becomes excessive for relatively low continuous producing rates and a reasonable surface injection pressure.

Annular flow results in considerable turbulence from the small tubing couplings and mandrels; therefore, an efficient intermitting installation through a small annular area is doubtful. By the use of large tubing and small macaroni strings, high rates of fluid production are possible by continuous flow through the tubing annulus from high productivity—high bottom hole pressure wells.

Setting Depths

To run the desired size macaroni in a tubing string already in the well, will often require a non-upset tubing. Small non-upset tubing strings are limited in the depth to which they can be run because of the weakness in the threaded section of the coupling. Should a packer be necessary on the macaroni string for efficient gas lift operation, a safety factor in tension must be considered for pulling this packer. This further reduces the already setting depth of a non-upset string.

Deposition Problems

Paraffin or scale deposition must be considered. Experience indicates that annular flow is not desirable for fluids which deposit paraffin, carbonates, or sulfates. The pulling of the macaroni can become difficult, if not impossible, as a result of this condition. This deposition can generally be reduced or eliminated by the proper chemical injected into the lift gas.

Problems of Flow Valve Selection

The decrease in the opening pressures of pressure operated valves with depths should be as great as possible. The high resistance to flow in a small annular area or macaroni string may cause the upper valves to open before the pressure can be transmitted to the desired operating valve. If the available kick-off injection pressure is low, making a significant decrease in valve setting pressures impossible, a choke installed downstream of the surface intermitter is desirable to prevent opening of the upper valves.

Selection of the proper flow valve port or choke size is most important for gas lifting through a small macaroni or annular area. It can be extremely critical if the injected gas supply is in a large casing annulus. Fluid operated or intermitting valves should generally be choked to prevent excessive gas passage. The increase in flowing gradient from excessive injection gas, imposes a back pressure in the small eductor tube which will reduce the fluid production. Differential valves with orifice equivalents varying from a 3/64" to a maximum of 6/64" have been employed with 1-1/4" to 1-1/2" tubing sizes for 3,000 ft. wells. Fluid operated valves with choke sizes from 4/64" to 8/64" have been run on 1-1/4" tubing strings to depths in excess of 6,500 feet. Ample gas passage has been experienced with these orifice or choke sizes. When a small annular or macaroni string supplies the injection gas to the valves 1/4" ported valves have proven satisfactory.

GAS LIFTING ONE ZONE OF A DUAL

Both concentric and parallel string types of installation are employed in lifting one zone in a dually completed well.

Concentric Strings

A small macaroni string inside 2", 2-1/2" or 3" upset tubing for gas lifting through the tubing represents the majority of dual gas lift installations. Flow valve mandrels which are commonly used with macaroni strings are shown in FIGURE 1. Oil or gas can be flowing from the casing annulas. This type of installation offers the following advantages: 1) Low initial installation cost because the valves can be run without disturbing the existing equipment in the well, 2) the valves can be economically replaced, for the same reasons, and 3) it is unnecessary to kill the flowing zone, thus reducing the hazard of possible damage, when working over the zone on gas lift. In the case of a dual in which high pressure gas is being produced from the casing annulus, a gas lift installation permits artificial lift without vibration. FIGURE 2 illustrates two concentric type installations.

The disadvantages of a concentric type installation are the same as those outlined in the small tubing section of this paper. If the operator anticipates future gas lifting of the zone producing through the tubing, these disadvantages can be partially offset

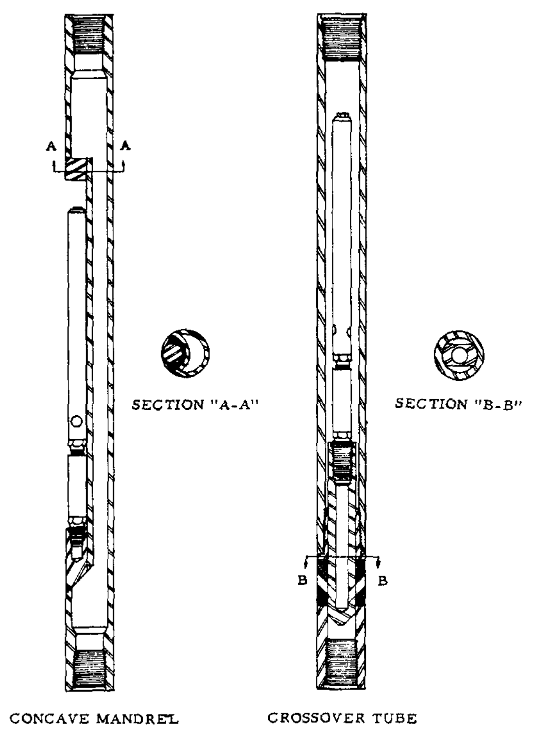

FIGURE I

by running at least 2-1/2" or 3" tubing in the well initially.

The concentric installation can be modified to permit the flow of a weak zone through the small tubing. Selection of conventional or casing flow mandrels for the larger tubing string will enable the operator to use the casing or the small tubing annulus for gas lifting the second zone. The disadvantages to this installation are: 1) the valves must be run initially with the larger tubing string, 2) both strings of tubing must be pulled to replace a flow valve, and 3) both zones must be killed for installation and workovers. These disadvantages can be partially offset by running eccentric retrievable valve mandrels on the tubing string, thus permitting the replacing of flow valves by wire line, after pulling the macaroni string.

Parallel Strings

A two-parallel string installation differs from a concentric type in that two tubing strings are run, side by side. These strings may be either strapped together or supported separately. When only one zone is to be gas lifted, the installation can be designed to permit the workover of that zone without disturbing the flowing zone. This can be accomplished by the use of a special detachable dual string packer which permits the running of each tubing string separately. The two parallel strings offer additional capacity over most concentric type installations. In large casing all the advantages of full open tubing are possible which permits paraffin cutting, the running of bottom hole pressure surveys, etc. The tubing centerlines can be kept strictly parallel through the mastergate valves by installing the dual wellhead equipment now being manufactured for this purpose.

Two parallel string installations can be designed for the three following combinations of flow and lift:

1. Producing both zones through the tubing strings by gas lifting one string with gas from the casing annulus. This is the most "universal" parallel string installation for gas lifting only one zone.

2. Injecting gas in one tubing string to gas lift the casing annulus while flowing through the second string. If the high productivity zone to be lifted is the upper one, the subsurface equipment cost will be greatly reduced by the elimination of a packer and crossover equipment.

3. Injecting gas in one tubing string for gas lifting the second string. This installation is especially suited to an oil-gas dual where the upper zone is gas. If the casing has a sufficient I. D. to utilize special retrievable equipment, flow valves can be replaced without disturbing the gas zone.

The disadvantages of the parallel strings over the concentric strings for gas lifting one zone. are: 1) the higher initial cost, 2) the necessity, in many types of these installations, of killing both zones and pulling both strings of tubing to replace valves, and 3) the greater possibility of a "fishing" job during a workover.

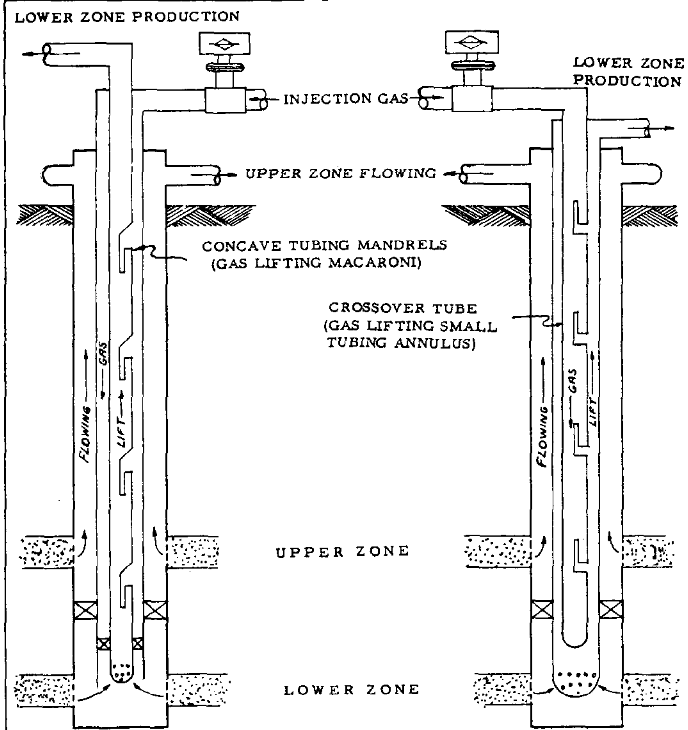

FIGURE 2

GAS LIFTING ONE ZONE OF A DUALLY COMPLETED WELL
CONCENTRIC TYPE INSTALLATION

NOTE: BY UTILIZING CROSSOVER EQUIPMENT, UPPER ZONE COULD BE LIFTED.

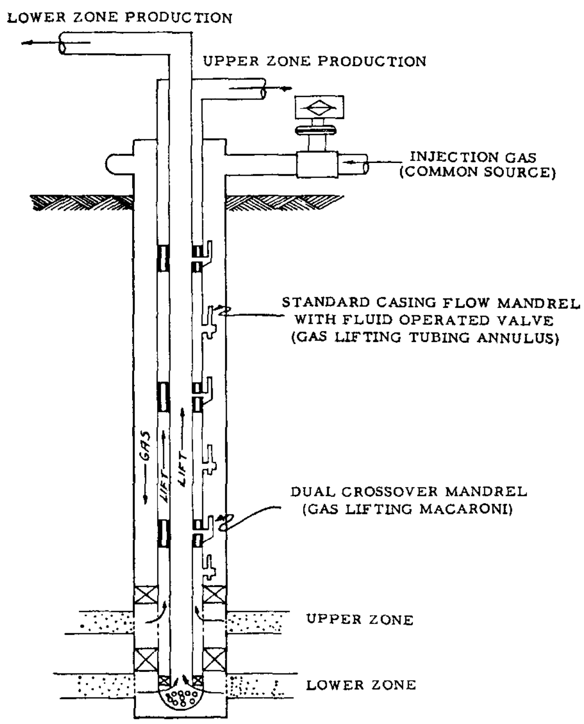

FIGURE 3

GAS LIFTING BOTH ZONES OF A DUALLY COMPLETED WELL
CONCENTRIC TYPE INSTALLATION WITH
COMMON INJECTION GAS SOURCE

GAS LIFTING TWO ZONES WITH A COMMON INJECTION GAS SOURCE

The advantage of utilizing a common gas source for lifting two zones is the low initial installation cost.

Design Consideration

The flow valve design is critical for a common injection gas source because of the problem of one zone starving the other for gas. Partial rectification can be accomplished by the use of a time cycle surface controller on the flow line of the zone using most of the gas. The surface controller can be set to shut-in the flow line of this zone several hours per day, thus allowing the starved zone to receive all of the injection gas during this period.

Concentric Strings

The concentric type installation FIGURE (3) can generally be installed for less initial cost than the parallel string type and is readily adaptable to small casing sizes. If the casing annulus is used for injection gas for an intermittent type installation, high injection gas fluid ratios are probable. Because of the spread, (which is the difference between the opening and closing pressure of conventional pressure operated flow valves), the cubic feet of gas passage per valve operation increases with pressure, casing size, and operating valve depth. The problems of intermittent design for small tubing in large casing are extremely difficult. The capacity of small tubing is not sufficient to provide the fluid slug necessary for a low gas-fluid ratio. Large valve ports permit excessive gas passage and are prohibitive to efficient gas lift operation. A small port or choked valve will remain open many minutes or possibly hours. The valve will not close before the necessary volume of gas passes through the small port opening to reduce the casing pressure to the closing pressure of the valve. These are extremely important considerations in the design of a small tubing and macaroni installation that is to be run in large size casing. Continuous flow design will generally give optimum performance in this type of installation. High rates of fluid production are difficult to obtain from a concentric type of installation even though the gas is injected down the annulus between the macaroni and tubing. This annular area may be sufficient to permit adequate gas passage. If the well is a part of a closed rotative system which requires gas storage, the small annular area is detrimental to the system.

For wells which can be casing flowed, the gas lift installation can be designed to permit removal of both strings of flow valves without pulling the tubing. By running eccentric type casing flow retrievable valve mandrels, the casing flow valves can be selectively retrieved and replaced by wire line methods, after the macaroni string has been pulled. This installation is extremely flexible in comparison with other types of installations using a common injection gas source.

Parallel Strings

Two full open 2" tubing strings with conventional pressure operated valves can be integrally run in 7" O. D. casing, FIGURE (4). The casing annulus will hold an adequate gas supply for the lifting of substantial rates of fluid from both zones. The higher initial cost of parallel strings over concentric strings and the hazardous round trip operation discourages many operators from running parallel strings. By a minor modification of an additional string, parallel or concentric, the operator is assured of controlled injection gas for the lifting of both zones. Retrievable eqquipment is available which permits the gas lifting of two zones by a common gas source with all valves selectively retrievable. Combinations of 1-1/4" line pipe strapped to 2" tubing are available for 5-1/2" O. D. casing.

GAS LIFTING TWO ZONES WITH SEPARATE INJECTION GAS SOURCES

Design Considerations

The three string installation is the gas lift engineer's choice for lifting two zones. The important advantage is that each zone has its separate injection gas supply. None of the disadvantages of the common injection gas source for lifting both zones are experienced in this type of installation. The flow valve design is as simple as that for a conventional single completion gas lift well with the exception that two strings must be considered. Both strings can be the intermitting type without encountering the problem of one zone taking most of the gas. Each zone can be operated and tested completely independently of the other zone.

The three strings can be any of a number of combinations of tubing sizes and can be completely concentric, combination of concentric and parallel, or completely parallel. The concentric strings offer greater flexibility in the case of a malfunction, because the macaroni or inside tubing can be pulled without removing the larger tubing. For this reason, the troublesome zone should be lifted by flow valves on an inside string. If all the strings are parallel, the complete installation must be pulled to replace one valve. However, higher producing rates may be obtained from the parallel strings than from the concentric strings.

The disadvantages of the three string installation are: 1) it has a high initial cost, 2) it is complicated to run and pull, 3) it presents more of a problem in the event of a fishing job, and 4) it requires a large casing size for certain desired tubing combinations. In wells which will permit normal wire line operations, the workover costs can be kept at a minimum by the use of completely wire line retrievable flow valves.

Three String Installations—Concentric

A completely concentric three string dual installation is prohibitive in small casing. It is necessary to use non-upset or flush joint tubing to obtain sufficient equivalent areas for satisfactory operation. An example of this type of installation would be a 1" macaroni inside 2-1/2" non-upset tubing inside 4" non-upset tubing run in 7" O. D.—23 lb. casing, FIGURE 5.

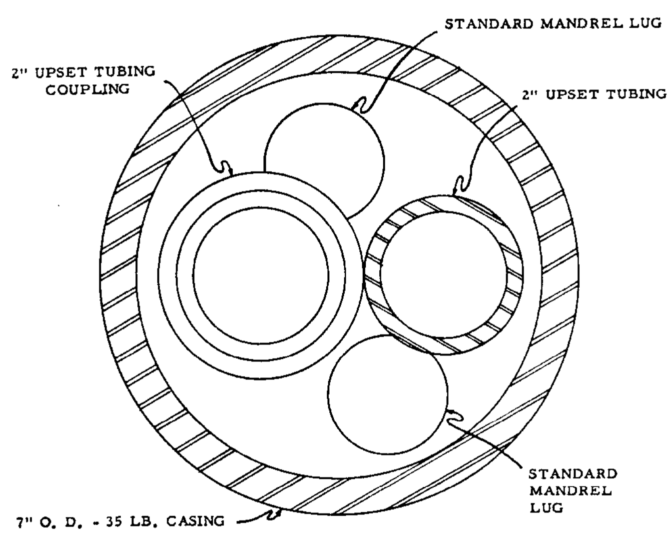

FIGURE 4

TWO PARALLEL STRINGS OF 2" EUE TUBING WITH CONVENTIONAL VALVE MANDRELS IN 7" O. D. ------35 LB. CASING

Injection gas in the casing and inside or outside of the macaroni would be two of several variations of the concentric three string installations. This type of installation is seldom considered because of the special packers and uncommon tubing sizes which are generally required.

Three String Installations—Combination of Parallel and Concentric

The operator can select one of four different designs for dually lifting two zones with a combination of parallel and concentric strings. The tubing sizes can be varied in each type of installation to increase the lifting efficiency and assure the required production. Injection gas in the casing and the tubing annulus or macaroni are the two types which will adapt to the majority of dual wells. FIGURE 6 illustrates injection gas in the casing and tubing annulus.

By injecting gas in one tubing string, two additional combinations are possible. Utilizing a concentric macaroni string permits flow valve replacement at a low workover cost. Many combination parallel and concentric type installations are now in operation in West Texas.

Three String Installations—Parallel

A three-parallel string installation with non-retrievable type flow valves can be designed to meet the producing characteristics of the zones to be lifted. Some examples are as follows:

1. Injecting gas in the casing and small tubing to lift the two tubing strings. An example of this type of installation, FIGURE (7), would be two 2" tubing strings and a smaller tubing string attached to special capsule by-pass mandrels. The smaller string supplies gas for the valves inside the special mandrels for gas lifting one string of 2" tubing. Conventional or concave mandrels with flow valves would be run on the other string of tubing, and the injection gas would be supplied from the casing annulus.

2. Injecting gas in one tubing string and a smaller tubing string to lift through the casing annulus and the other tubing. The installation is the same as the previous type with the exception of casing flow mandrels being substituted for the conventional or concave mandrels on one string of tubing. This installation is desirable when very high producing rates are required from one zone.

3. Gas lift with three string retrievable equipment. The most recent development in wire line retrievable flow valves for three string duals incorporates one 2" tubing string with two 1" line pipe strings strapped to the tubing, FIGURE 8. Retrievable valve mandrels can be obtained which permits gas lifting through one of the 1" strings with injection gas from the other 1" string. The tubing is lifted by injection gas from the casing. If both zones have a high productivity, the mandrels can be constructed to gas lift the tubing and casing by individual gas supplies from a separate 1" string for each zone. All flow valves are selectively retrievable from the full open 2" tubing string, and the

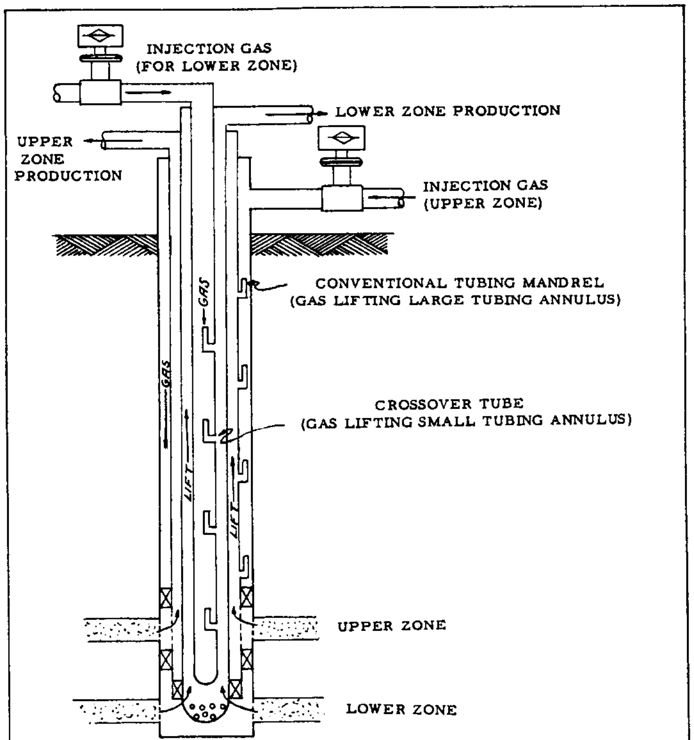

FIGURE 5

GAS LIFTING BOTH ZONES OF A DUALLY COMPLETED WELL COMPLETELY CONCENTRIC TYPE INSTALLATION WITH SEPARATE INJECTION GAS SOURCES

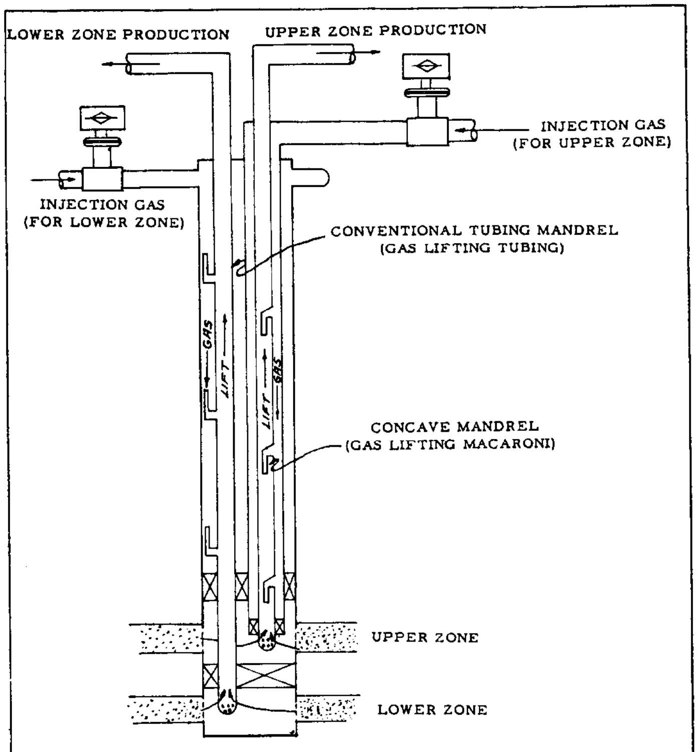

FIGURE 6

GAS LIFTING TWO ZONES OF A DUALLY COMPLETED WELL COMBINATION CONCENTRIC AND PARALLEL TYPE INSTALLATION WITH SEPARATE INJECTION GAS SOURCES mandrels are designed to be run in 5-1/2" O. D. —17 lb. casing.

FUTURE TREND IN DUAL GAS LIFT EQUIPMENT

If the trend of thinking continues in the direction of slim hole drilling and permanent type well completions, full open retrievable type gas lift equipment will be required for small tubing sizes, to be run in dual gas lift installations. Special equipment is now being manufactured which will permit the completion, workover, and recompletion of, not only the lower zone, but also the upper zone of a dual with both zones on gas lift. This eqquipment can be run inside of 5-1/2" O. D. casing. With the increasing development of special packers, cross-over tools and tubing wellheads, which provide full open tubing strings in dual installations, the gas lift manufacturers will strive to utilize these advancements by designing gas lift equipment which will provide greater flexibility and efficiency for dually lifted wells.

CONCLUSIONS

There is no one type of dual gas lift installation which will meet the producing requirements of every dual well to be artificially lifted. The producing problem of each well must be considered individually, and the type of gas lift equipment selected accordingly. The casing size limits the combination of tubing sizes which can be employed.

The flow valves selected must be capable of producing the reqired fluid with a reasonable injected gas-fluid ratio. Choke or orifice sizes must be evaluated for small tubing. A combination of fluid weight and pressure operated valves are generally required for satisfactory operation in a dual with a common injection gas source.

The flowing gradients in small tubing restricted annular areas are high; therefore, high injection gas pressures and low capabilities should be anticipated.

If future running of a macaroni string inside of the tubing for gas lifting is anticipated, at least 2-1/2" or 3" tubing should be run in the well initially.

The concentric string type installation costs less than the parallel type. In addition, the flow valves on the concentric macaroni can be economically replaced.

The parallel string type installation generally permits a larger producing capacity than the concentric type, but presents a more hazardous rnnning and pulling operation. Many types of parallel string installations offer the advantages of full open tubing.

Complete control of injection gas is assured from separate injection gas sources for each zone to be lifted. Although lifting two zones with a common injection gas source represents less initial investment, the cost of a workover resulting from one zone starving the injection gas from the other will generally offset this saving over separate injection gas sources.

The present trend in dual gas lift equipment is toward wire line retrievable flow valves. Retrievable equipment permits the replacement of a valve for only a fraction of the costs of round-tripping the tubing strings.

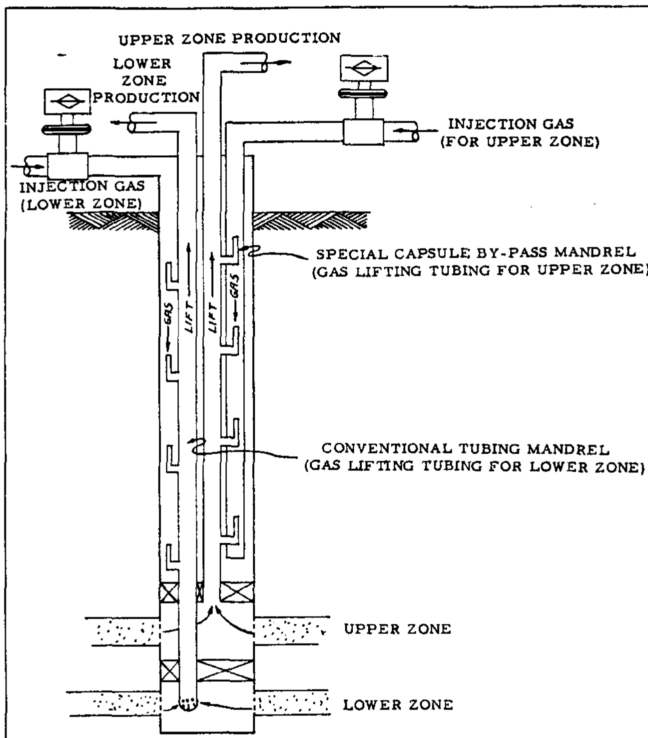

FIGURE 7

GAS LIFTING BOTH ZONES OF A DUALLY COMPLETED WELL
COMPLETELY PARALLEL TYPE INSTALLATION WITH
SEPARATE INJECTION GAS SOURCES

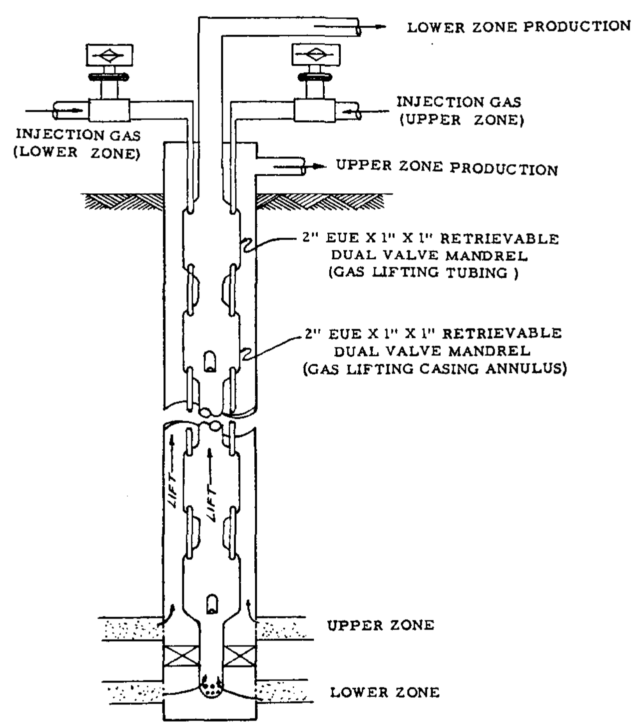

FIGURE 8

GAS LIFTING TWO ZONES OF A DUALLY COMPLETED WELL
THREE PARALLEL STRINGS EMPLOYING RETRIEVABLE
MANDRELS WITH SEPARATE INJECTION GAS SOURCES