Liquid Removal from Gas Wells-Gas Lifting with Reservoir Gas

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INTRODUCTION

The problem of liquid collection in gas wells causing a reduction of production has plagued gas well operators for several years. Many solutions to this problem have been attempted, with varying degrees of success.

The most common procedure is to open the well to atmosphere and blow the collected fluid out. This method is inefficient, first, because during the blowdown period the gas flow is at a peak and therefore the liquid inflow into the area surrounding the well bore is increased; second, the gas usage to produce the fluid is excessive because of lack of positive control, both in the frequency and the duration of the blowdown.

An improvement on this method is a differential pressure controller, which senses a pre-set differential between casing and tubing and actuates a timed blowdown valve. With exact adjustment this system can reduce the inefficiency of the blowdown, but it does not correct the excessive liquid inflow problem.

Several other methods, such as free piston, bottom-hole stand pipes, bottom-hole chokes have also been used with varying degrees of success.

NEW SYSTEM

During the last few years a new system has been developed. This system utilizes a down-hole controller, (Subsurface Liquid Diverter,) and gas lift valves.

Physical Configuration (see Fig. 1)

A. Gas production conduit (usually the annular space between tubing and casing),
B. A fluid production conduit (usually the tubing string), connected to a low pressure disposal facility,
C. A fluid control valve (Subsurface Liquid Diverter),
D. Gas lift valves,
E. Surface pressure regulators.

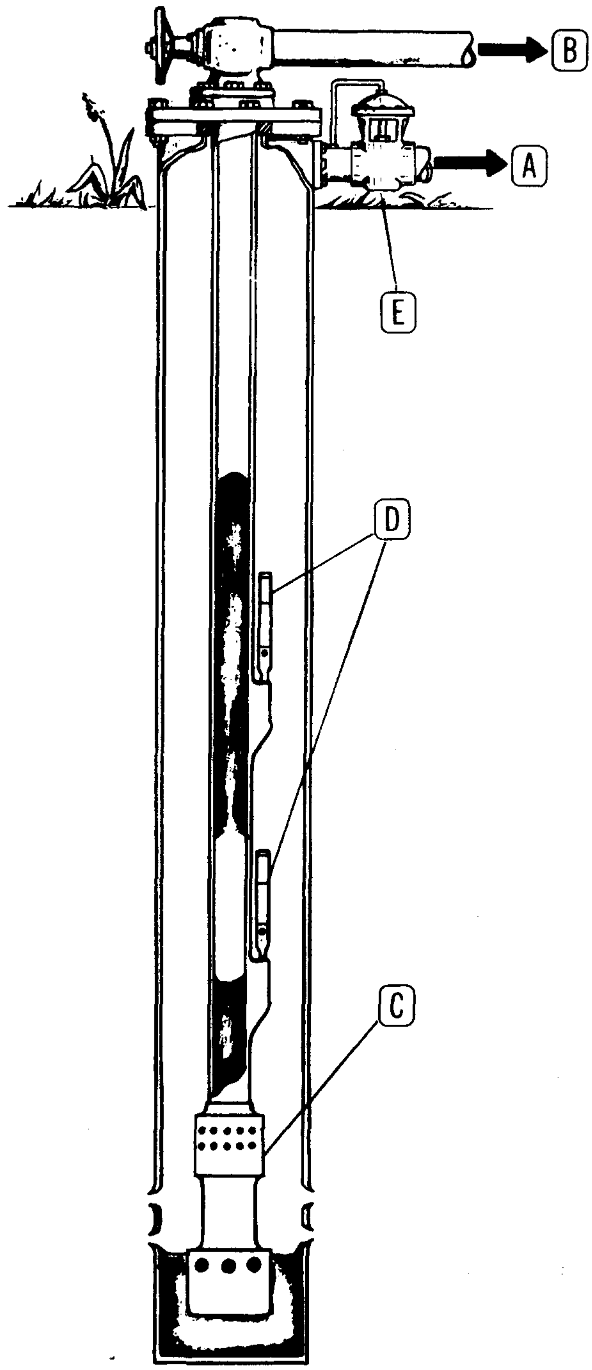


FIGURE 1

This new system is more efficient because:

(1) It automatically controls the liquid level at the perforation depth (i.e., at the source of the problem),

(2) It stabilizes the flowing bottom-hole pressure at a minimum pressure for maximum gas production,

(3) The lift gas usage is positively controlled by the gas lift valves,

(4) The lift cycle frequency is regulated by the well liquid inflow,

(5) The formation is not subjected to excessive flow rates.

In addition to primary use of unloading gas production wells, the system has been utilized to produce high GOR oil wells. It allows the operator to produce this type of well by using the energy of the reservoir gas to lift the liquid to the surface and eliminates the expense of surface equipment.

A further extension of the system has been in gas storage wells, which also have liquid accumulation problems during the withdrawal phase of operation.

Operation of System

As the gas is produced, the liquid is carried from the formation into the well bore. Since the stream velocity in the annular space is not sufficient to keep the liquid entrained, it falls back and collects in the bottom of the well. The subsurface liquid diverter opens and allows the collected liquid to flow into the tubing. The tubing is connected to a low pressure system at the surface so it is maintained at a lower pressure than the gas stream.

The gas lift valves are the tubing-pressure operated type and remain closed until enough liquid has collected above them to actuate them. At this time the gas lift valves open and admit gas from the annulus which lifts the liquid to the surface. The system components operate independently.

The Subsurface Liquid Diverter operates in a semi-continuous manner, and the gas lift valves operate intermittantly.

OPERATION OF SUBSURFACE LIQUID DIVERTER (SLD)

Basically the SLD (see Fig. 2) is a valve that is operated by liquid column balance.

The reference liquid contained in the tubing acts on the lower side of the diaphragm and moves the valve toward the closed position. The liquid in the gas stream acts on the opposite side of the diaphragm and counterbalances the reference liquid, which allows the valve to move toward the open position. Since the well liquid is diluted with gas, it is less dense than the static reference liquid and an additional force is supplied by the control spring, which is adjustable to compensate for variations in well liquid density.

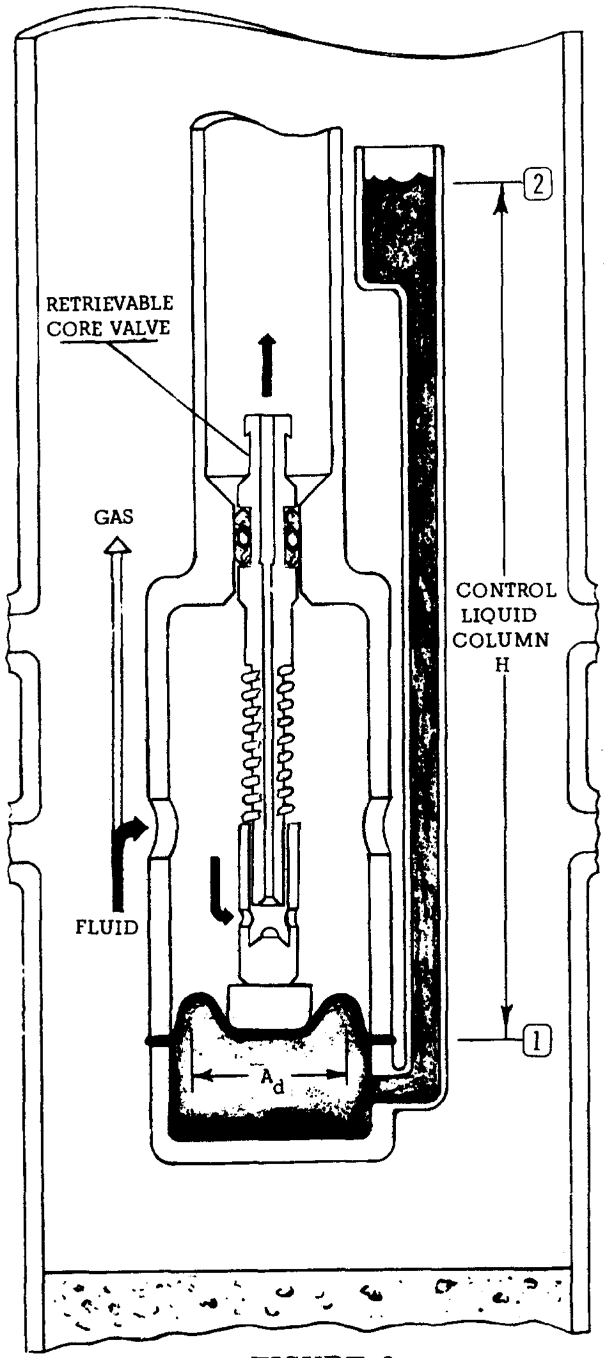


FIGURE 2

With the valve in the closed position the net force acting on it is in the upward direction. As liquid collects in the annular space surrounding the SLD, the net force is reversed and the valve opens. With the valve open, the liquid is diverted into the tubing. When sufficient liquid has been removed from the annular space, the net force is again reversed and the valve closes. These net force changes can be evaluated using force balance equations for the open and closed positions of the SLD.

Average Pressure Gradient

In order to simplify these equations the concept of average pressure gradient is used. This concept is illustrated in Fig. 3. The SLD senses any pressure difference between Level 1 and Level 2 (i.e., P_1 - P_2). From an analysis standpoint, this pressure change can be caused by a uniform column of liquid-gas mixture, or a combination of a liquid column and a gas column with a specific interface. The actual condition as shown by operating systems is somewhere between these two models. But, since the density of the liquid under well conditions is difficult to determine and since operational tests indicate that there is no well-defined interface under flowing conditions, the use of the average gradient concept simplifies the calculations involved.

Adjustment of SLD For Particular Well Conditions

The SLD has seven (7) design variables that can be adjusted to accommodate the well conditions.

(1) △P—The average pressure drop across the SLD can be adjusted within a range by the location of the gas lift valves. An approximate value of △P should be determined in order to select the other variables.

(2) CHOKE—This choke should be sized to permit the maximum desired flow rate with minimum △P. This choke has a stabilizing effect on the core valve, so the smallest size consistent with the flow requirements will produce the best results.

(3) A —The area of the core valve controls the spread (difference between opening and closing gradient). This seat size is selected in conjunction with the △P to be compatible with change in gradients that occur within the well.

(4) h—The liquid column height can be changed by using different length units.

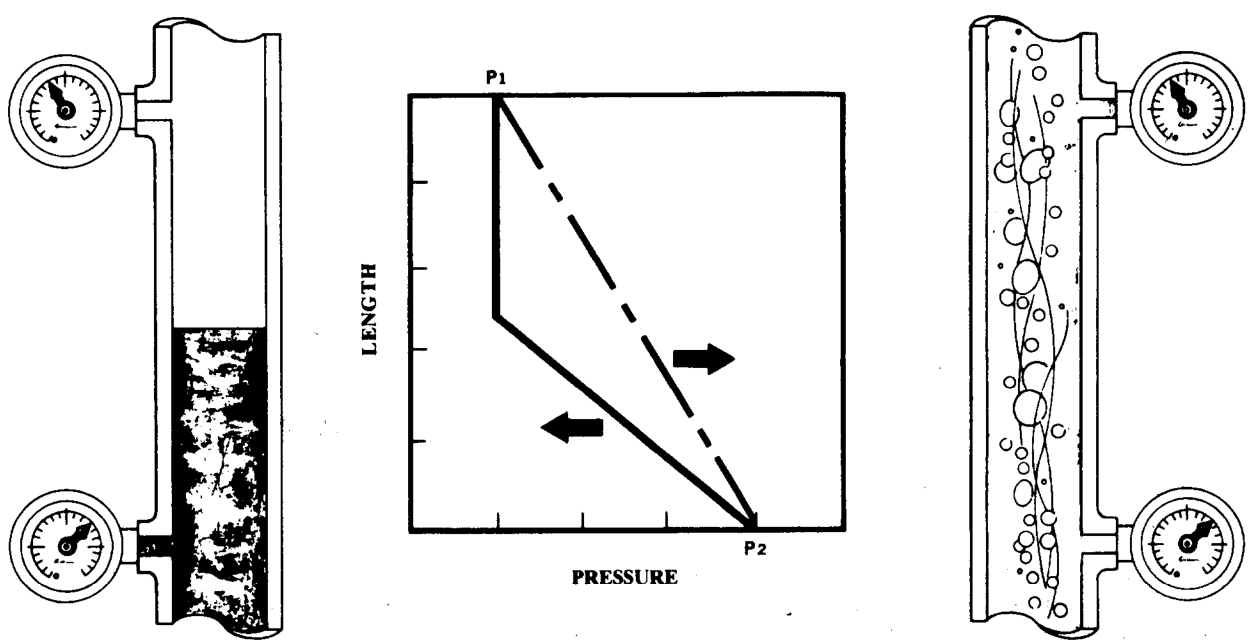


FIGURE 3

(5) A —The total daiphragm area (which is composed of multiple diaphragms) can be changed by specifying the number of diaphragms in the SLD.

(6) G —The reference liquid that is used should have a density equal to the well liquid under static conditions; if it is less dense it will ultimately be displaced by the well fluid which will alter the adjustment of the unit.

(7) F —The control spring force provides the necessary balance to cause the valve to open and close on the desired average gradients.

The choke, control spring, and valve and seat are contained in the wire line retrievable

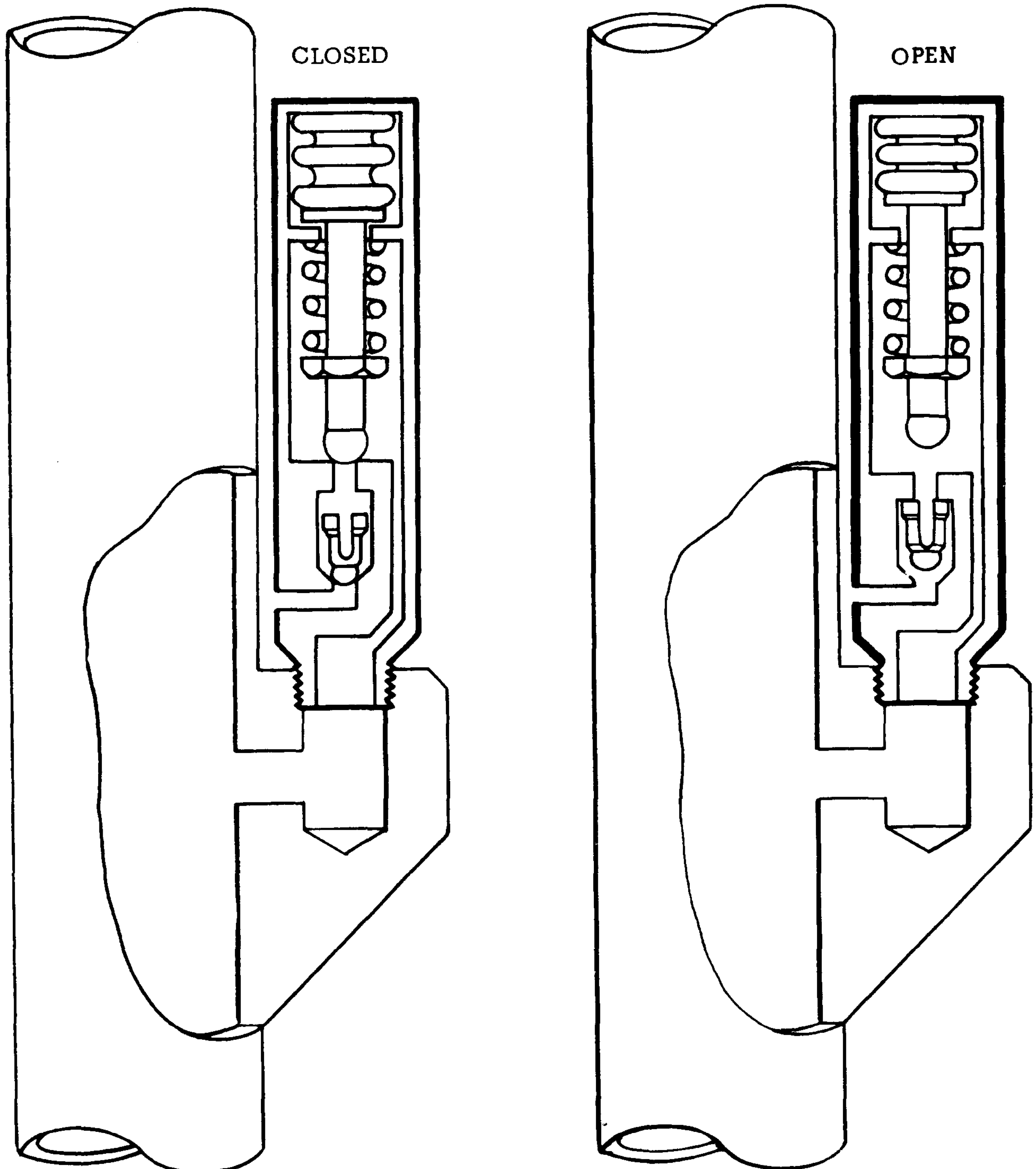


FIGURE 4

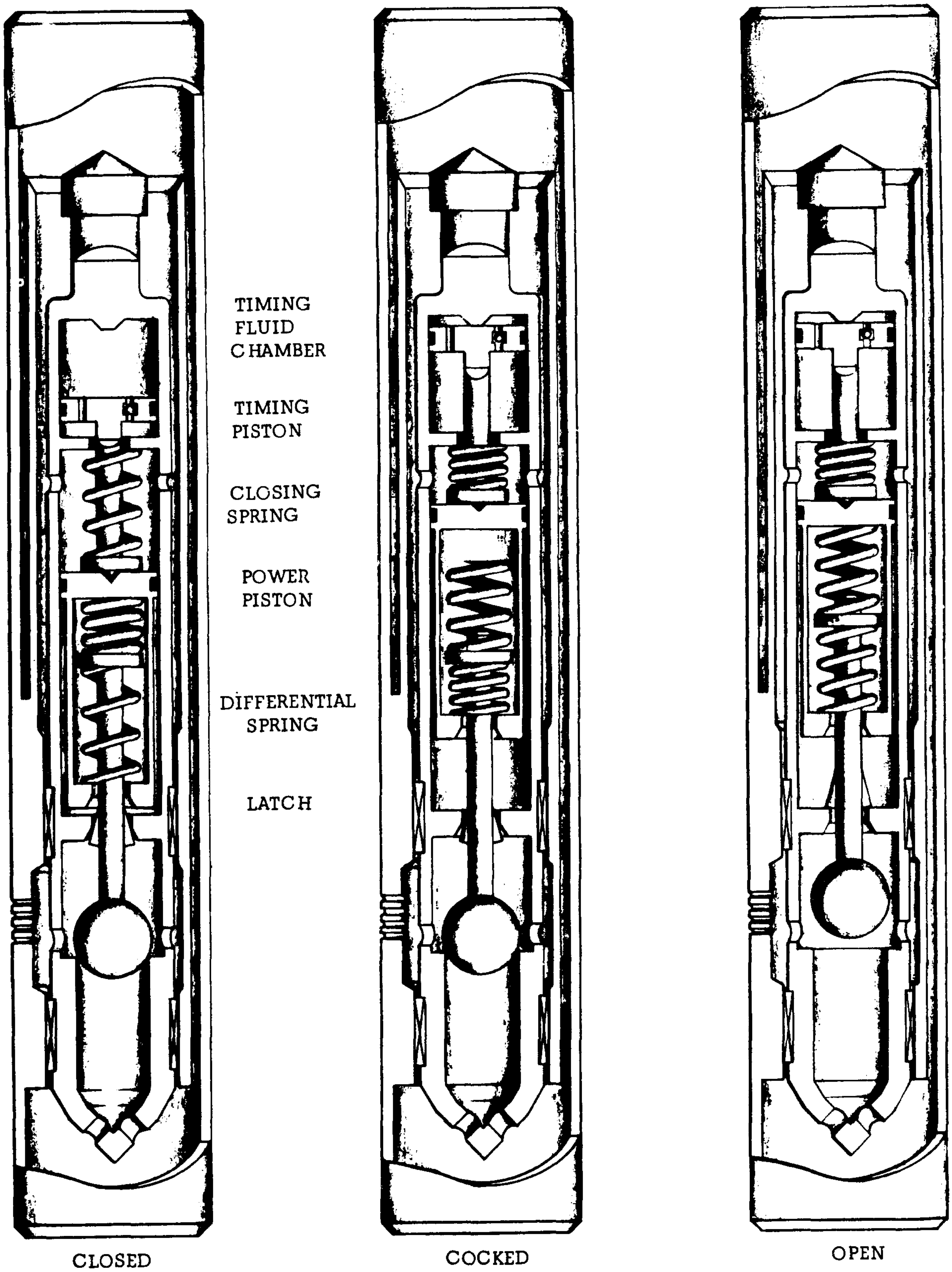

TIMING
FLUID
CHAMBER
TIMING
PISTON
CLOSING
SPRING
POWER
PISTON
DIFFERENTIAL
SPRING
LATCH
CLOSED
COCKED
OPEN

FIGURE 5

core valve, so that these control features can be easily adjusted after the SLD is installed in the well.

THE GAS LIFT SYSTEM

The gas pressure may vary over a wide range due to changes in desired production rate or fluctuations in line pressure. Therefore, the gas lift system must be capable of functioning within the wide range of operating pressures. This requirement limits the types of gas lift valve that can be used.

Fluid Operated Valve

The fluid pressure sensitive gas lift valves (shown in Fig. 4) are relatively insensitive to casing pressure changes, if a large bellows-to-seat ratio (R) is used. To obtain a large R , a small valve port is necessary, which is contrary to the large gas flow capacity requirement of intermittent gas lift. To overcome this deficiency, multiple valves are used.

Time Controlled Valve

The new time-controlled gas lift valve also meets changing pressure requirements. A brief explanation of its operation shows how this gas lift valve combines fluid actuation with an unrestricted valve port necessary for intermittent lift.

The operation of the time-controlled valve is initiated by a pressure difference between the casing and tubing, with the valve in a closed position (see Fig. 5). This pressure difference causes the timing piston to move up and compress the differential spring. When the differential spring has been compressed to a pre-determined force, the off-time delay has been completed and the valve is ready to open. When sufficient fluid head has collected in the tubing to augment the differential spring, the valve snaps open and is latched in the open position. Once the valve has opened, the pressure across the timing piston is equalized and the timing spring causes the piston to move downward. This downward travel is regulated by the fluid transfer through the timing piston ports, and is the predetermined injection cycle time. When the timing piston reaches the bottom of its travel it releases the valve latch and the valve closes. The valve is then ready to repeat the cycle.

SUMMARY

(1) The differential opening feature permits control by fluid load,
(2) The full open feature eliminates undesirable throttling action,
(3) The injection timing is independent of tubing or casing pressure,
(4) Correct adjustment of the timing cycle results in maximum gas lift efficiency.

SYSTEM DESIGN AND INSTALLATION

In order to design the system for optimum results, the operating pressure and depth, gas production rate, fluid production rate, etc., should be taken into consideration. The actual design procedure, which is relatively simple, is beyond the scope of this paper.

In the usual installation procedure, the well is "killed" by pumping in a compatible fluid and the equipment is run on the tubing string. In cases where killing the well is undesirable, the equipment can be installed under pressure using the "snubbing" technique.

The retrievable core valve or the swabbing core is installed in the diverter before running the tubing. To utilize the retrievable feature of the core valve, the tubing size must be 1-1/4 in. nominal (1.380 in. ID) or larger.

APPLICATION

The SLD system has application in a variety of wells, which can be classified as follows:

(1) Producing gas wells,
(2) High gas fluid ratio oil wells,
(3) Gas storage wells.

Each type of well requires a slight variation of the design to cope with its particular characteristics. However, there are certain minimum gas pressure and volume requirements that must be satisfied in order to insure a successful gas lift operation. These requirements are primarily a function of well depth. The curve of gas liquid ratio requirements (Fig. 6) specifies the average gas usage at increasing depths of lift. Figure 7 shows the minimum surface casing pressure required for increasing depths.

OPERATIONAL EVALUATION

To evaluate the operation of the system, usual production tests can be conducted. In a gas well the most important factor is gas production.

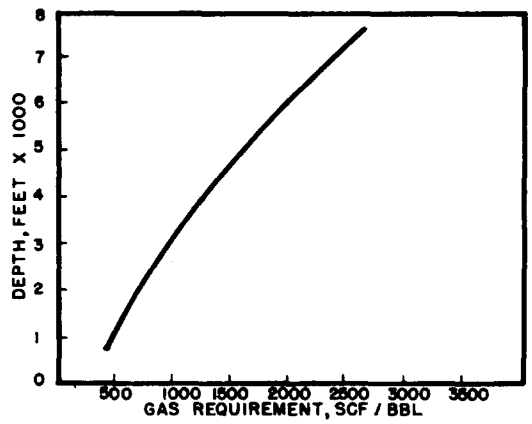


FIGURE 6

Depth of SLD Ft.	Min. surface casing pressure, psi
1000	200
2000	230
4000	315
6000	425
8000	480
10000	650

FIGURE 7

When the system is operating correctly, a stable or increasing production rate should be obtained. A second factor is the lift gas consumption. This can be evaluated by measuring (1) the total liquid produced from the tubing and (2) the lift gas used to produce this liquid. The resulting gas liquid ratio can be compared with the average GLR required for intermittent lift, as shown in the empirical curve (Fig. 6).

A two-pen pressure recorder at the well head provides a continuous record of the number of lift cycles and changes in the gas pressure. The uniformity of the lift cycles and the stabilization of the gas pressure indicate good operation.

In addition to the above, a bottom-hole pressure measurement in the tubing can provide positive data on the operation of the entire system. By observing the fluid inflow between cyles, the operation of the SLD can be determined. The operation of the gas lift valves is evaluated by measuring the opening pressure of the valves and also observing the cycle pattern.

An acoustical well sounder can be used to determine the liquid level in the casing, which should be near or at the SLD. The above-mentioned instruments have been used to evaluate the performance of this system in gas wells, high ratio oil wells, and gas storage wells.

Figures 8, 9 and 10 illustrate operational data on example installations of each category.

CONCLUSIONS

To date, this subsurface liquid diverter system has been applied successfully as follows:

(1) To automatically remove liquids from gas wells (this generally results in increased gas deliverability),

(2) To automatically produce high ratio oil wells using formation gas with a nominal equipment investment,

(3) To automatically remove liquid from aquifer storage wells when produced at relatively high withdrawal rates.

The system has been improved considerably with the development of the time controlled gas lift valve.

The system has operated efficiently using fluid operated gas lift valves; however, the use of the new time-control gas lift valve has greatly increased the system's flexibility and efficiency.

NOTE: The surface pressure record shows no indication of intermitting lift while the pressure bomb in the tubing indicates a uniform intermitting lift cycle.

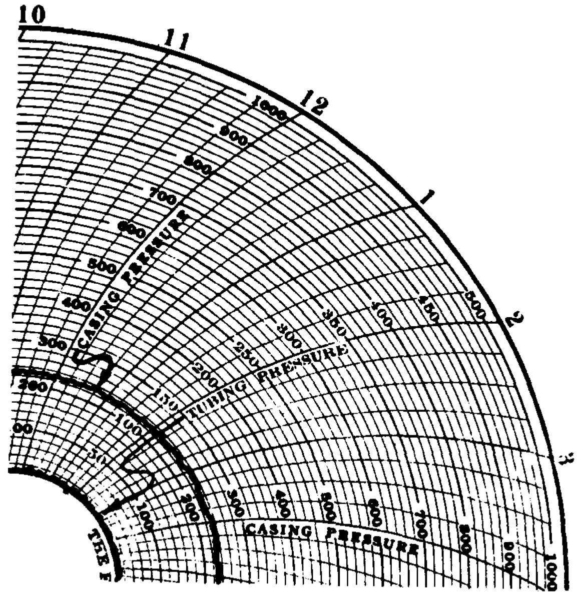
Installation:

Casing	7" - 24 lb.
Tubing	1-1/2 NU
Depth	2740

Production:

Gas	300 Mcf/D
Fluid	Composition-Salt Water
	Amount per cycle 0.5 BBL
	per day 30
Lift Gas	500 ft ^{3}/cycle

Gas Production Prior to SLD Installation - 100 Mcf per day using a timed blow down



SURFACE PRESSURE

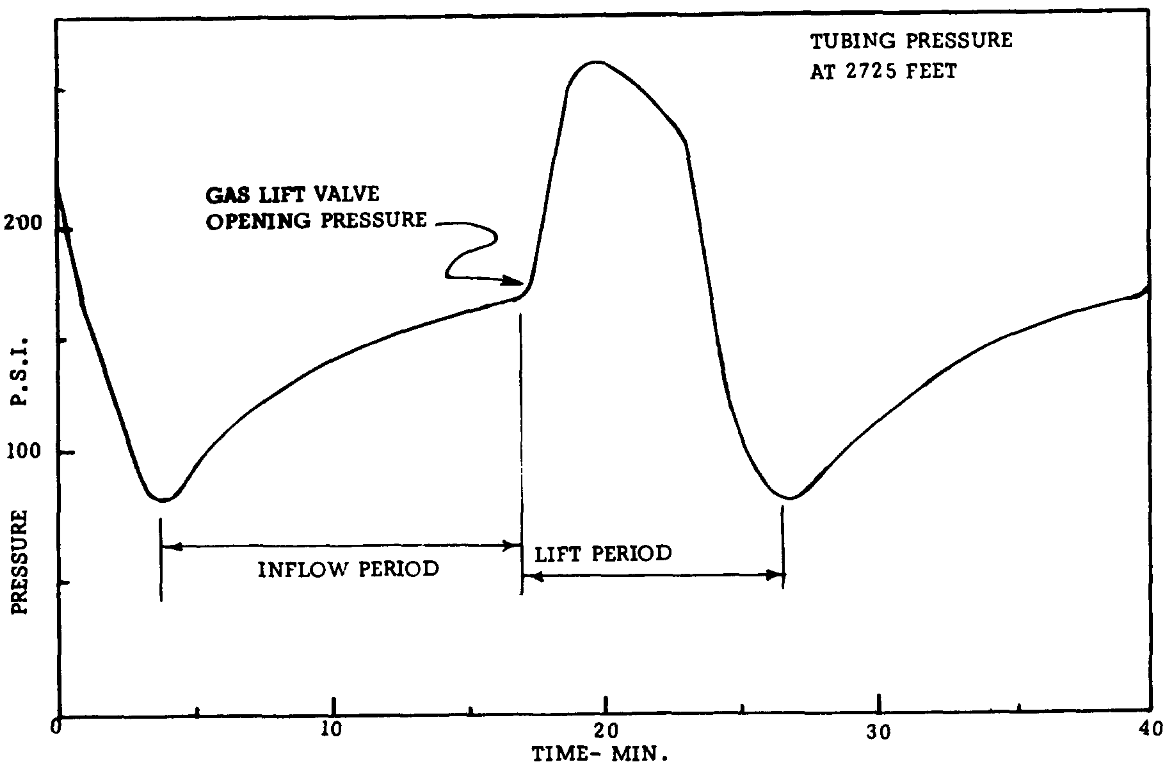


FIGURE 8

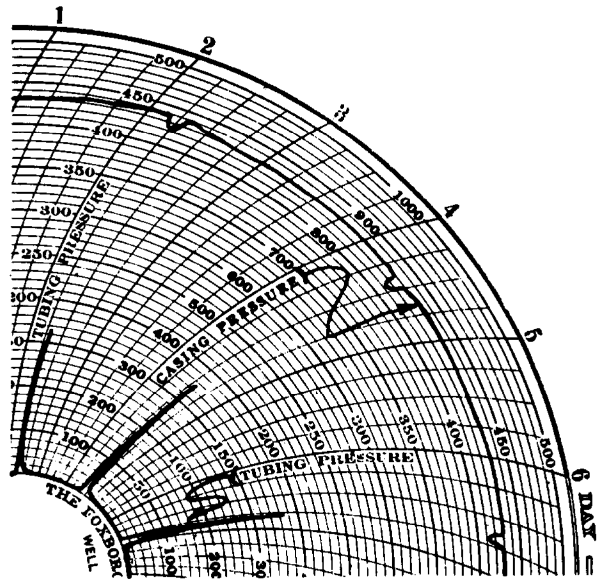
Installation:

Casing	4-1/2" - 11 lb.
Tubing	2-3/8 EU
Depth	6380

Production:

Gas	700 Mcf/D	
Fluid	Composition - Condensate 58° API	
	Amount	3.2 BBL/Cycle
		32 BBL/D
Lift Gas	5900 ft ^{3}/cycle	

Gas Production Prior to SLD Installation - 600 Mcf/D declining to 400 between manual blowdown cycles (3 day internal)



SURFACE PRESSURE

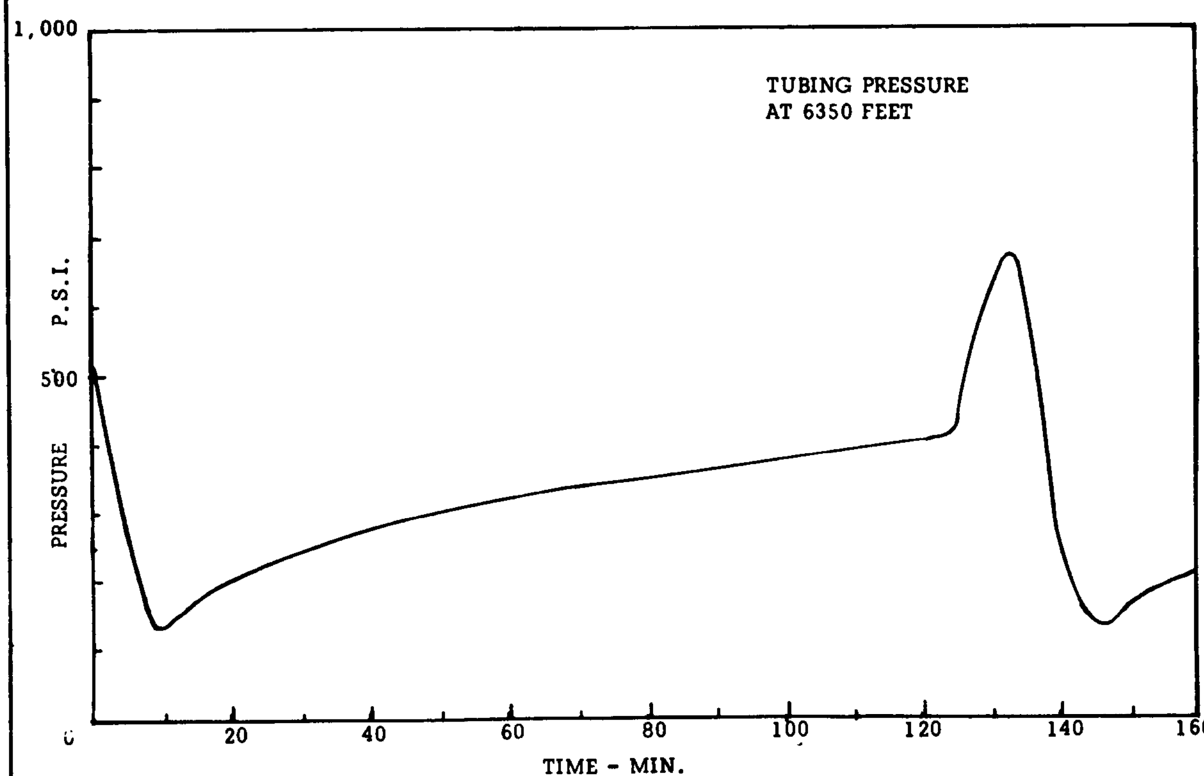


FIGURE 9

Installation:

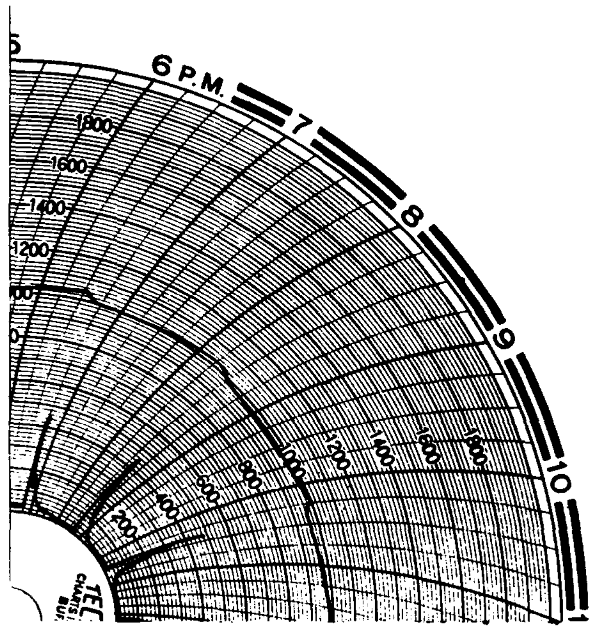
Casing	5-1/2" , 20#/ft
Tubing	2-3/8" OD
Depth	12,008 ft

Production:

Gas	2360 GOR
Oil	30 BPD
Water	20 BPD

Production prior to SLD Installation:

Gas	2360 GOR
Oil	18 BPD
Water	12 BPD



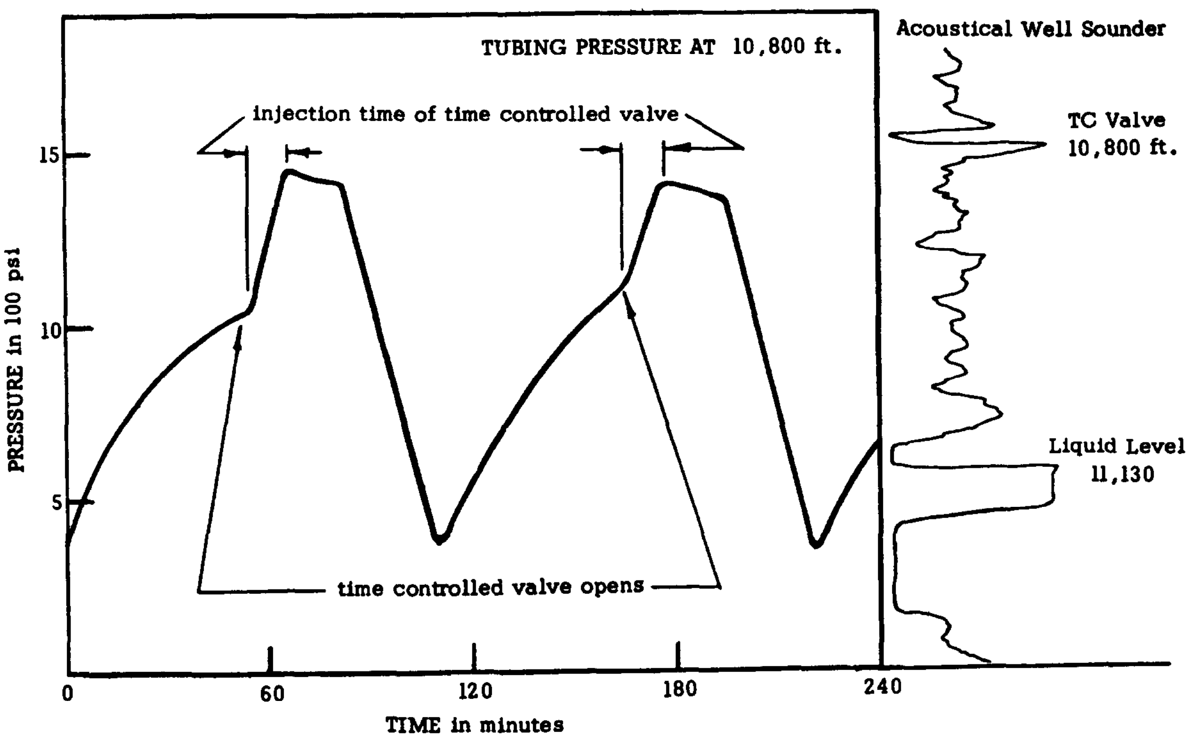


FIGURE 10