THE TECHNOLOGY OF ARTIFICIAL LIFT METHODS

Volume 2a
Introduction of Artificial Lift Systems
Beam Pumping: Design and Analysis
Gas Lift

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The University of Tulsa

contributing authors

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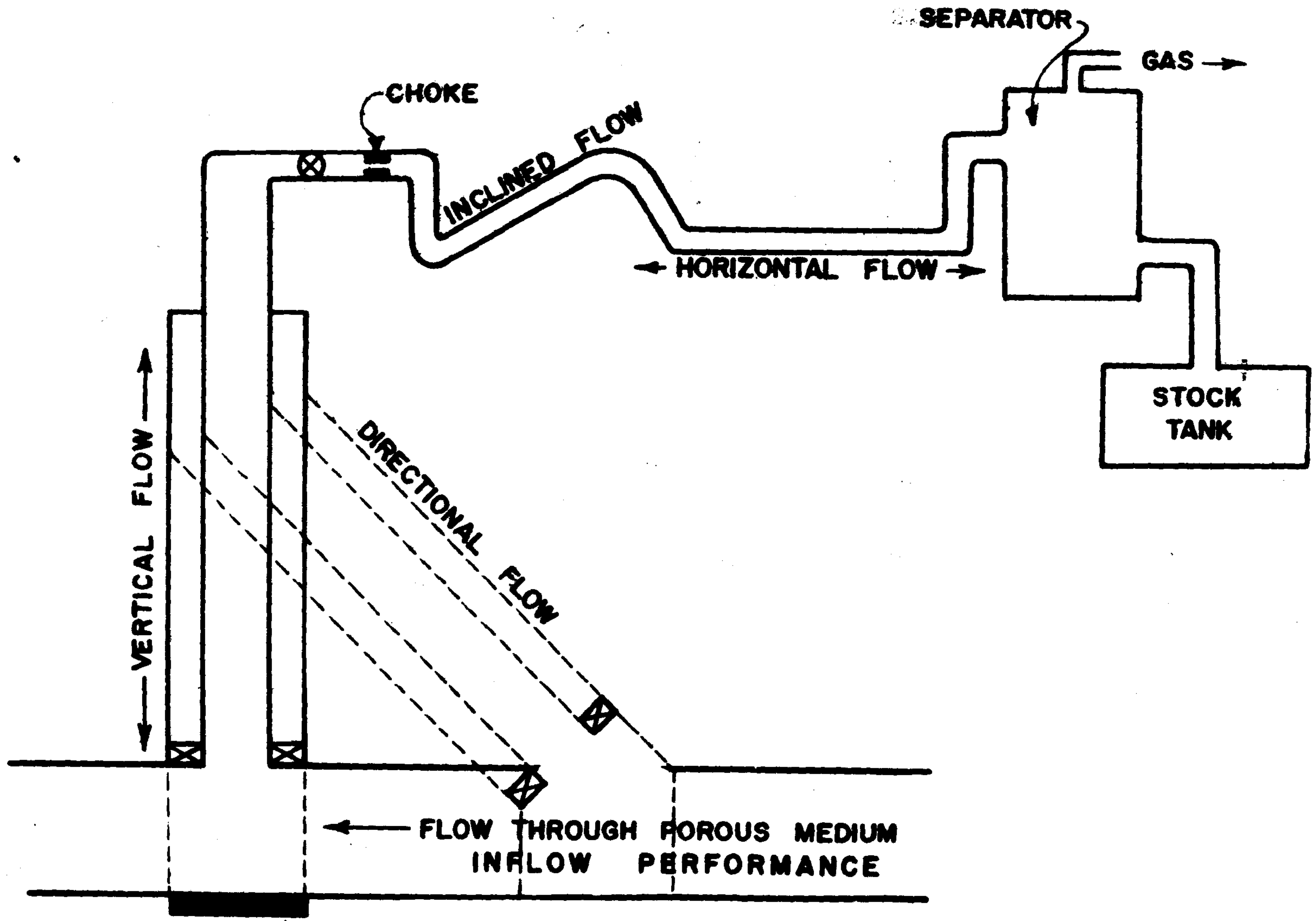
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CHOKE
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HORIZONTAL FLOW
STOCK TANK
VERTICAL FLOW
DIRECTIONAL FLOW
FLOW THROUGH POROUS MEDIUM
INFLOW PERFORMANCE

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Volume 2a

Preface

For the first time, all the artificial lift methods are presented in one volume. Volume 2 is published in two separate books, Vol. 2A and Vol. 2B, and is complete with sufficient charts, curves, etc. to plan, design, analyze, and compare all artificial lift methods. Volume 1, published in 1977, gives all the preliminary information needed to use Vol. 2. Volume 1 includes (1) the inflow ability of the well, (2) multiphase flow in pipes, and (3) the flowing well. Although not absolutely necessary, Volume 1 should be studied and used in conjunction with Volume 2. Volume 3, which is also available, includes over 2,200 flowing pressure traverse curves for multiphase vertical flow and horizontal flow, gas production, gas injection and water injection curves.

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Volume II offers sufficient flexibility to be used as a text or to be used by the engineer in industry in designing installations. Example problems are worked and numerous class problems are included. Eventually, an answer guide will be available.

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Kermit E. Brown

Contents

Chapter 1

Artificial lift systems

1.1 INTRODUCTION

This text will discuss the various types of artificial lift systems available today. More and more wells in the world are being placed on artificial lift, and the number will continue to increase. The selection of the most suitable type of artificial lift for a well or group of wells can be difficult or easy, depending upon the conditions.

Generally, more than one method of lift can be used. Each method of lift may be classified from excellent to poor in accomplishing the objective. Depending upon the economic considerations, two types of lift (one used later) may possibly be prescribed for a group of wells.

For example, in a "depletion" type reservoir, high initial production rates may be needed, but decreasing pressures and declining inflow capability may require a low rate in the future. In this case, an initial installation of continuous flow gas lift or electrical submersible pumping may be changed to intermittent gas lift, sucker rod pumping, or hydraulic pumping at a later date, or vice versa.

The following list probably represents the relative standing of lift systems based on the number of installations throughout the world. This differs from field to field, state to state, and country to country.

(1) Sucker rod pumping (beam pumping)
(2) Gas lift
(3) Electrical submersible pumping
(4) Hydraulic pumping
(5) Jet pumping
(6) Plunger (free piston) lift
(7) Other methods

As these methods are discussed, complete design procedures will be given along with numerous example problems.

In addition, other methods are continually being developed and tested. A short discussion on the ball pump and the gas-actuated pump are also given. The ball pump was tried many years ago, and new interest has recently sparked additional development of this lift method. The ball pump uses spherical flexible balls that pass down one tubing string and return through another in order to eliminate the slippage of gas past the liquids. Gas is used as the source of power.

The gas pump has been in the experimental stage for many years. Several field trials have been performed and are installed at the present time. The pump uses gas to actuate a downhole pump and can be used in conjunction with gas lift. In particular, gas lift unloading valves may be used to reach the pump.

Rothrock presented Table 1.1, showing the distribution of 518,867 oil wells based on a 7% sampling from 200 operators with information on 37,100 wells.[1]

TABLE 1.1
CRUDE PRODUCING WELLS (JAN., 1977)

Category	Number	Percent
Rod pumping	409,974	85.21
Gas lift	51,964	10.80
Electrical submersible	9,738	2.02
Hydraulic	9,470	1.97
Total U.S. artificial lift	481,146	100.00%
U.S. flowing oil wells	37,721	
Total U.S. producing oil wells	581,867	

Of the 518,867 wells, 481,146 or 92.7% are being lifted artificially. These are further broken down into 85.2% rod pump, 10.8% gas lift, 2% submersible, and 2% hydraulic. Approximately 383,000 of the artificial wells are strippers (producing less than 10 B/D). Assuming that 100% of the stripper wells are on rod pump, then Table 1.2 shows a re-distribution of the remaining wells.

TABLE 1.2
ARTIFICIAL LIFT WELLS (LESS STRIPPER WELLS)

Category	Number	Percent
Rod pumping	26,974	27.48
Gas lift	51,964	52.95
Electrical submersible	9,738	9.92
Hydraulic	9,470	9.65
Total wells	98,146	100.00%

Table 1.2 shows that the largest percentage of the wells are on gas lift after eliminating stripper wells. Gas lift predominates on offshore wells but, according to Rothrock, is not keeping pace with other lift methods in areas other than offshore.

Submersible pump use is increasing rapidly in West Texas and in some Rocky Mountain areas. Rothrock noted that hydraulic pumping is not growing at the rate of other methods. However, jet pumping is now taking 50% of the hydraulic market, and its popularity will probably continue to grow.

Table 1.3 breaks down total maintenance cost into failures, failure rates, cost per failure, total cost, and percent of each failure spent for well servicing. Also included are costs and rates for well workover.

Two main types of downhole equipment failures are pumps and rods. Each pumping well has a 57% chance of pump failure and a 44% chance of rod failure each year. These rates are additive so each well will average 1.01 failures/year.

Costs to maintain these wells total $346,000,000, including $230,000,000 for well servicing. Remaining expenditures translate to approximately 34,000,000 feet of rods and 31,000 bottomhole pumps needed for replacement of worn out equipment plus an additional repair of 180,000 pumps.

Submersible pump failure rates apparently are decreasing based on the 7% sample. Repairs to submersibles by manufacturers are running considerably less than in previous years.

The survey indicates that failure incidence in hydraulic pumps is increasing. Again, this may be due to the small number of hydraulic pumps contained in the survey. In any event, the growth of the hydraulic piston pump market appears to be declining and jet pumping is on the increase.

Gas lift failure rate is the lowest of any form of artificial lift (21%) but costs of individual failures are high compared to the average of all failures. A high portion of these costs, however, is attributable to high cost of service units, crews, and related equipment.

Various lift methods are compared in Chapter 9. Comparisons are quite difficult, but some choices of lift methods are obvious. One example is high volume wells where either electrical submersible pumping or continuous flow gas lift should be considered. Very deep lift must look at hydraulic pumping with installations presently pumping from 15,000 to 18,000 feet, with rates of 300 to 500 B/D. Although these pumps are set at these depths, the effective lift depth may be less. Effective lift refers to that depth to which the flowing bottom hole pressure will support the producing fluids. For example, if the flowing bottom hole pressure is 700 psi and the average fluid gradient is 0.30 psi/ft, the 700 psi will support the fluid 700/.30 = 2333 ft. Therefore, if the pump is set at a total depth of 15,000 ft, it is really only lifting from 15,000-2,333 = 12,667 ft and theoretically could be set at that depth and produce the same amount of fluids (neglects tubing well-head back pressure).

Availability of certain power sources will influence the decision on type of lift. All these factors are discussed in detail in Chapter 9.

1.11 Purpose of artificial lift

The purpose of artificial lift is to maintain a reduced producing bottom hole pressure so the formation can give up the desired reservoir fluids. A well may be capable of performing this task under its own power. In its latter stages of flowing life, a well is capable of producing only a portion of the desired fluids. During this stage of a well's flowing life and particularly after the well dies, a suitable means of artificial lift must be installed so the required flowing bottom hole pressure can be maintained.

Maintaining the required flowing bottom hole pressure is the basis for the design of any artificial lift installation; if a predetermined drawdown in pressure can be maintained, the well will produce the desired fluids. This is true regardless of the type of lift installed.

In gas lift operations, a well may be placed on continuous or intermittent lift. In continuous flow, the flowing bottom hole pressure will remain constant for a particular set of conditions, while in intermittent flow the flowing bottom hole pressure will vary with the particular operation time of one cycle of production. In this latter case, a weighted average flowing bottom hole pressure must be determined for one cycle and, hence, for a day's production. Economics enters into the design of any lift installation.

Many types of artificial lift methods are available: beam-type sucker rod pumps, piston-type sucker rod pumps, hydraulic oil well pumps, electrical submergible centrifugal pumps, rotating rod pumps, plunger lift, gas lift, and others. The advantages and disadvan-

TABLE 1.3
DOWNHOLE COSTS TO MAINTAIN U.S. PRODUCING OIL WELLS (YEAR 1977)

	Failure rate	Number of failures	Average cost, $	Total cost, $	Percent well servicing
Subsurface rod pumps	.57	210,277	1,078	226,657,000	60
Sucker rods	.44	164,118	729	119,665,000	79
Submersible pumps	.35	3,390	7,679	26,030,000	15
Hydraulic pumps	1.86	16,397	2,445	41,411,000	40
Gas lift	.21	11,490	4,153	47,713,000	78
Tubing	.12	62,623	1,837	115,027,000	73
Casing	.021	11,043	16,005	176,742,000	51
Total failures	.92	479,878	1,570	753,245,000	61
Workovers	.20	105,145	10,686	1,123,532,000	58
Total maintenance cost				1,876,777,000	59