Evolution of Gas Lift

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INTRODUCTION

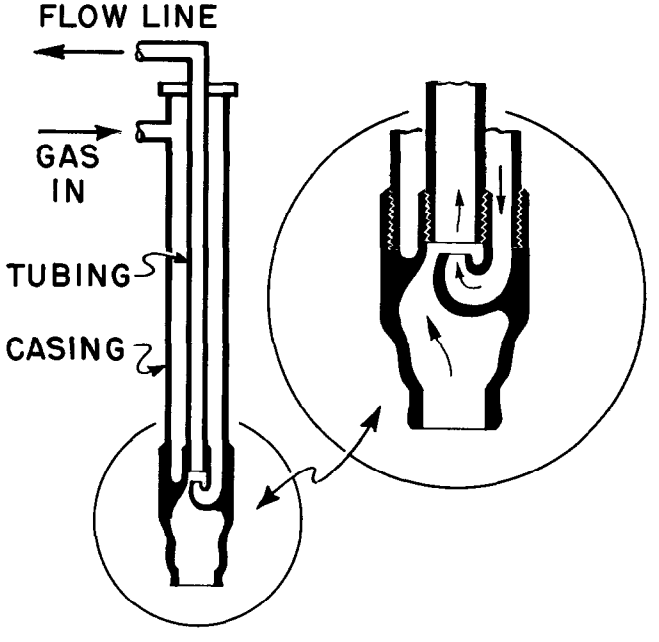
The concept of gas-lift and/or air-lift principles is not new. The application of utilizing compressed air as a means of lifting liquids was first used by Carl Emanuel Löscher (German Mining Engineer) in 1797. He made some laboratory experiments and described his invention in a pamphlet entitled "Aerostatisches Kunstgezeug."

However, it was not until 1846 that the first practical application of air-lift was attempted by an American named Cockford who lifted oil from some wells in Pennsylvania. Actually some controversy exists as to the final practical application, with Shaw[18] giving a date of 1864 with a description as found in Eaton's Petroleum.

The first United States Patent (No. 47,793) for an "oil ejector", was issued to A. Brear on May 23, 1865. (Fig. 1) Since that time more than 25,000 patents have been issued on gas lift and related equipment.

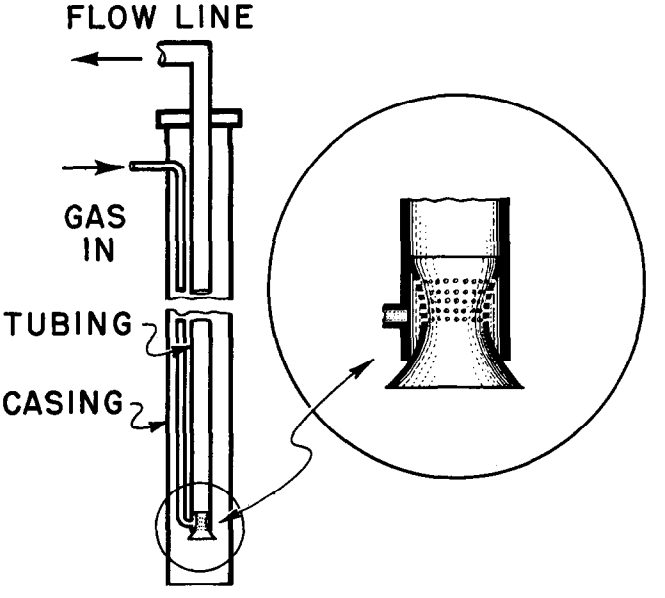
After 1865, the idea did not revive until a patent was issued to J. P. Frizell on October 19, 1880 (Fig. 2). His work was done without any knowledge of the previous work along this line.

Again without knowledge of previous inventions, in 1885, Werner Siemens made use of air lift to drain a mine shaft in Berlin. Also, in 1885, Laurent of France



BREAR OIL EJECTOR
(MAY 23, 1865)

FIG. 1.



FRIZELL METHOD OF RAISING WATER
(OCT 19, 1880)

FIG. 2.

and, in 1886, Goudry of France made use of a similar air-lifting device called an "emulseur" for pumping sulphuric acid.

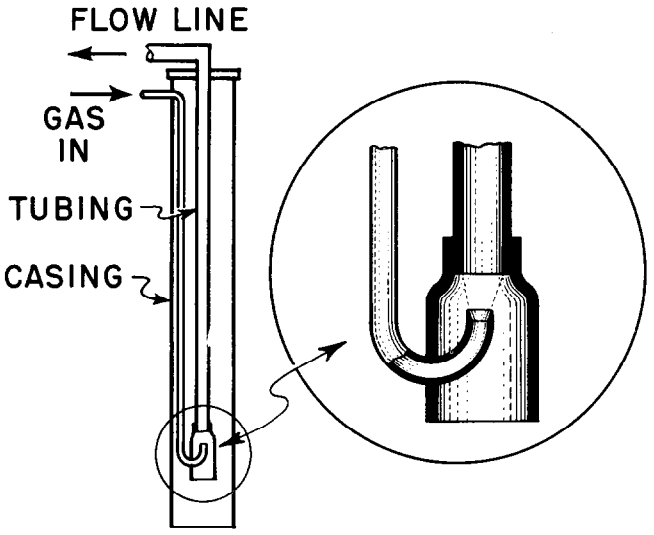
Actually all the previously mentioned methods of air lifting were at that time referred to as air lift pumping. The first use of the term air lift was mentioned in patent number 487,639 as issued to Dr. Julius G. Pohle on December 6, 1892 (Fig. 3).

After examining the early patents, Pennington[11] gave Dr. Pohle credit for being the inventor of air lift. Actually, though, the principle was patented prior to this time under air lift pump. It is noted, however, that Dr. Pohle is the first to apply the term "air lift."

CLASSIFICATION OF GAS LIFT ERAS

It might be possible to classify gas and or air lift into six eras beginning at the time of the first practical application.

1. Prior to 1864: Some laboratory experiments performed with possibly one or two practical applications.
2. 1864-1900: This era consisted of lifting by compressed air injected through the annulus or tubing. Several flooded mine shafts were unloaded. Numerous



POHLE PROCESS OF ELEVATING LIQUIDS (DEC. 6, 1892)

FIG. 3.

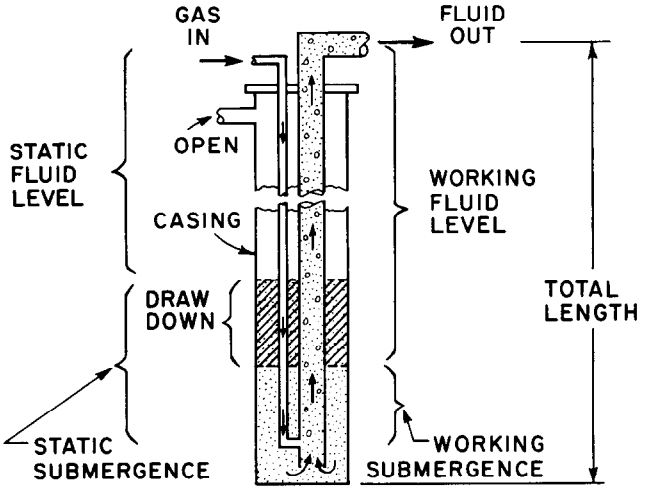
patents were issued low foot-pieces, etc.

3. 1900-1920: Gulf Coast Area "air for hire" boom. Such famous fields as Spindle Top were produced by air lift.

4. 1920-1929: Application of straight gas lift with wide publicity from the Seminole Field in Oklahoma Cf Fig. 4 for early gas lift nomenclature.

5. 1929-1945: This era included the patenting of about 25,000 different flow valves. More efficient rates of production as well as proration caused the development of the flow valve.

6. 1945-1961: Since the end of World War II, the pressure operated valve has practically replaced all other types of gas lift valves. Also in this era many



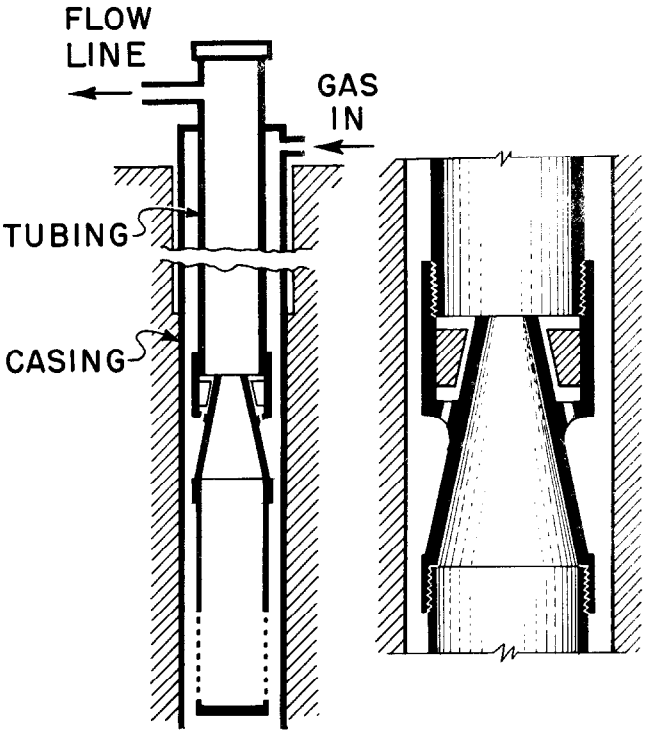
EARLY GAS LIFT

FIG. 4.

additional companies have been formed with most of them marketing some version of a pressure operated valve. Recent slim hole completions and dual installations have greatly popularized the concentric gas lift valve which has been developed since 1953. At present several companies are considering the development of a concentric valve.

ADVANCEMENT OF GAS LIFT

1. Straight Gas Lift: This particular method of lift employed no gas lift valves, and the fluid in the casing or tubing had to be depressed until gas could enter the bottom of the tubing. Thus, excessive kick-off pressures were required, and earlier lift emphasized the foot-piece on bottom.



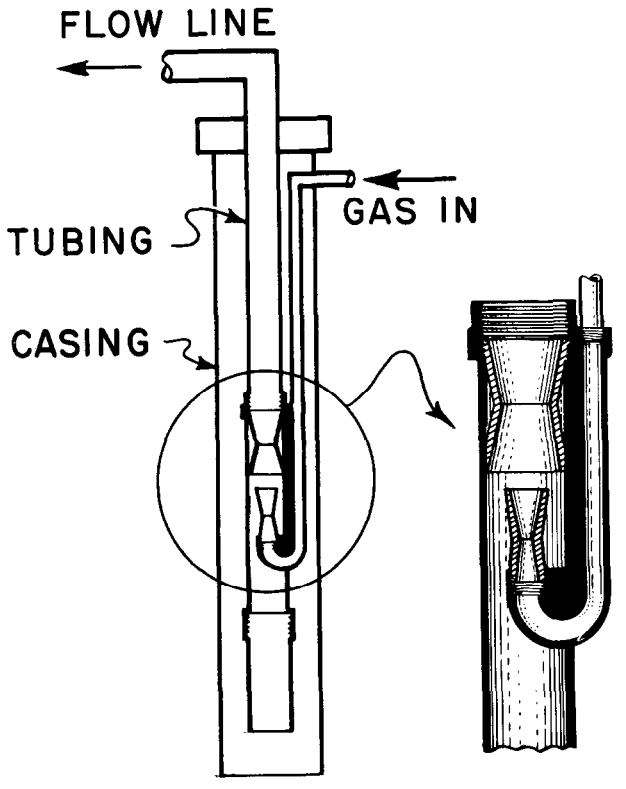
FERTIG EJECTOR (DEC. 16, 1884)

FIG. 5.

2. Jet Collars (Fig. 10): The excessive kick-off pressures required by straight gas lift were reduced considerably by placing holes in collars higher up the tubing string. However, once these holes were uncovered, there were no means for closing them off. Excessive gas was used, while the practice of punching, by wire line methods, buttons into the tubing string is quite common today.

Inserted brass nozzles consisting of 1/4 in. bushings with tapered holes were screwed into threaded holes drilled either into the collars or into the pipe and allowed a damaged nozzle rather than a foot-piece to be replaced.

3. Kick-off Valves (Figs. 12, 13, 14): The kick-off valve was the first valve designed to close as the next lower valve was uncovered. The earlier kick-off valves were designed to operate on 10-20 psi differential until



HARRIS AIR OR GAS-LIFT FOR FLUIDS (JAN. 11, 1898)

FIG. 6.

the development of the spring loaded differential valve which operated at or near 100 psi differential. The kick-off valve received its name from being used to kick off a well that would then flow from its own source of power.

4. Flow Valves: After the kick-off valves, came the development of flow valves that emphasized more and better control. These valves included mechanical valves, velocity valves, wire line actuated valves and the development of pressure operated valves. More modern developments have seen a center set drop valve first being developed, then the wire line retrievable valves being developed. Eventually, was developed a side-pocket retrievable valve that allowed selective retrieving of any valve in the string. The latest development of a concentric valve has helped greatly in slim hole completions and macaroni installations.

CHRONOLOGICAL ORDER OF AIR LIFT PUMPING AND AIR AND/OR GAS LIFT

The following tabulation is an attempt to list, in chronological order, some of the historical events and patents as applied to air lift and/or gas lift:

1797: Laboratory experiments by Löscher.
1846: Possible first practical application in lifting oil in Pennsylvania by Cockford.
1864: Possible first practical application as given by Shaw.
1865: A. Brear patent issued, "Oil Ejector," Patent (47,793) (Fig. 1).
1884: Patent issued on Fertig Ejector (Fig. 5).
1884: J. P. Frizell, patent issued, "Method of Raising Water," Patent No. 309,214 (Fig. 2).
1885: Werner Siemens used air lift to drain a mine shaft in Berlin.
1885: Laurent of France air pumped sulfur.
1886: Goudry of France air pumped sulfur.
1892: J. G. Pohle, patent issued, "Process of Elevating Liquids," Patent No. 487,639 (Fig. 3).
1895: J. E. Bacon, patent issued, Patent No. 542,620.
1898: Patent issued on Harris Air or Gas Lift for Fluids (Fig. 6).
1898: W. L. Saunders, patent issued, "Air Lift Pump," Patent No. 597,023.
1898: S. W. Titus, patent issued, "Apparatus for Using Compressed Air to Elevate Water," Patent No. 11,675.
1898: Experiments in Small Pipe by Professor E. Josse of Germany.
1899: M. T. Chapman utilized compressed air to blow oil from wells at Corsicana, Texas.
1900: Robert Stirling introduced the air-lift in the Baku field of Russia.

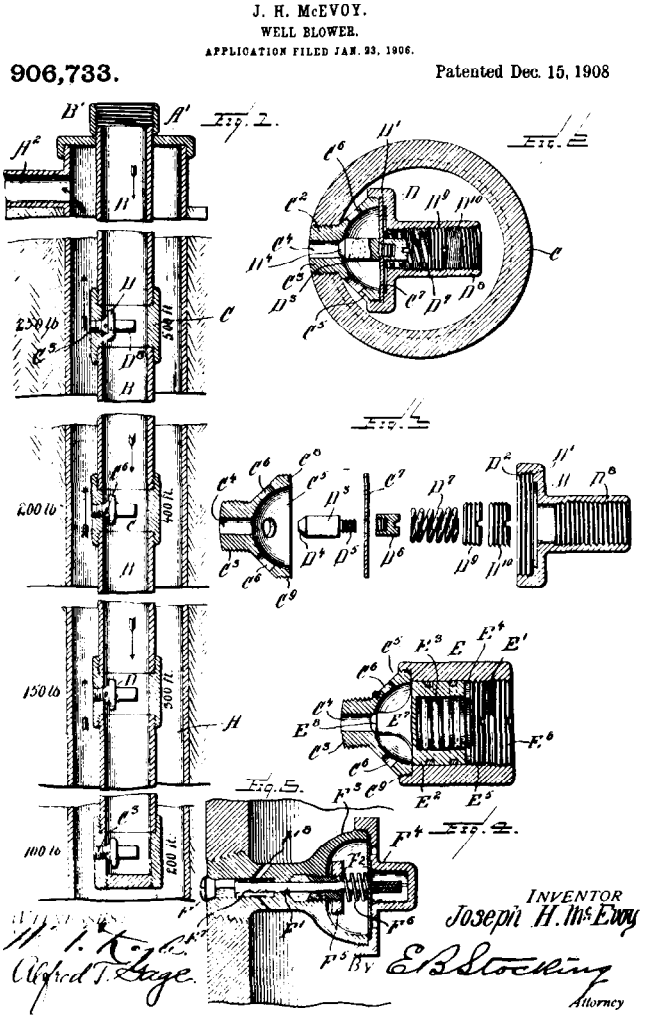


FIG. 7.

May 5, 1931. M. P. BURKE 1,803,837

GAS LIFT MEANS

Filed March 28, 1927 4 Sheets-Sheet 1

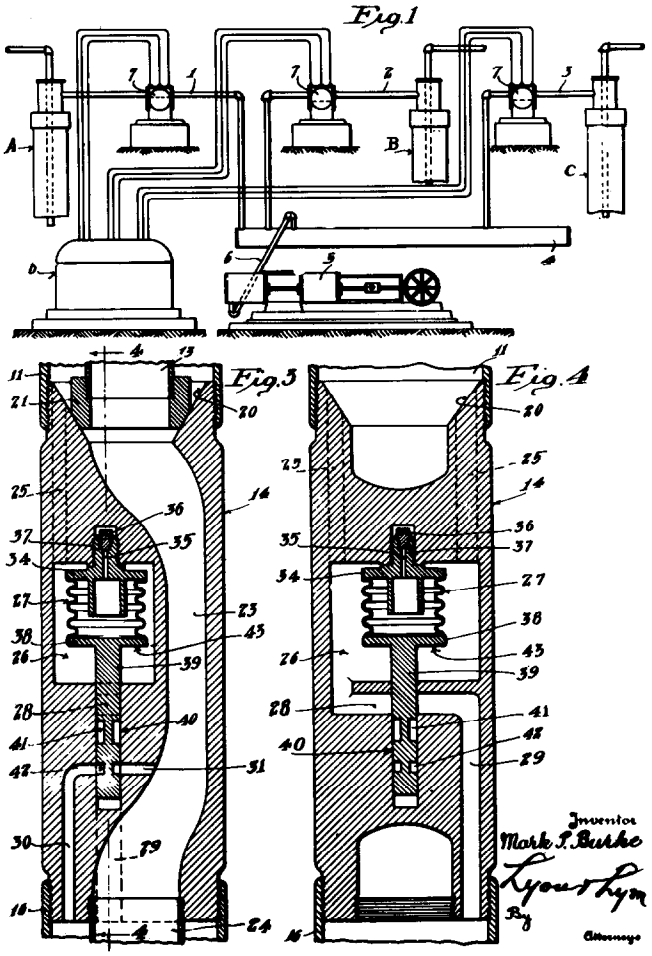


FIG. 8a.

1901: Spindle Top (first oil field of the Gulf Coast) — Air lift was introduced in 1901 and continued for more than 20 years. The old Spindle Top Power Company built a plant whereby "air for hire" was available.

Before 1904: Sour Lake Field, Texas, placed on air lift.

Before 1904: Batson's Prairie, Texas, placed on air lift.

Before 1904: Evangeline, Jennings, Louisiana, placed on air lift.

Before 1904: Mamou, Louisiana, placed on air lift.

1904: Humble Field placed on air lift.

1906: W. B. Harris, patent issued, "Air or Gas Lift for Fluids," Patent No. 814,601.

1908: Joseph H. McEvoy - Patent No. 906,733. Patented December 15, 1908; filed January 23, 1906. First pressure actuated valve, also first method patented using step down pressures (Fig. 7).

1909-13: Kern River Field in California employed air lift.

1909: F. G. Kimball, patent issued, "Air Lift Pump," Patent No. 939,270.

1911: G. J. Davis and C. R. Weidner conducted numerous laboratory tests on air lifting water, the results being published in 1914 by the University of Wisconsin Experiment Station.

1914: Philip Jones, patent issued, "Process of Pumping Oil Wells," Patent No. 1,102,152.

1915: The Old Dominion Mine at Globe, Arizona, was dewatered by air-lift. As much as 10,000,000 bbls of water was removed in a one-month period.

1915: Air lift applied for lifting sulfur in Louisiana.

1915: H. Frasch, patent issued, "Mining Sulfur," Patent No. 1,152,499.

1916: E. A. Watts, patent issued, "Pump", Patent No. 1,202,932.

1917: L. T. Edwards, patent issued, "Method and Apparatus for Lifting Water," Patent No. 1,213,170.

1917: S. F. Shaw dewatered a small copper mine at Panuco, Mexico, to a depth of 310 feet.

1919-20: S. F. Shaw dewatered the Tiro General Mine at Charcas, S. L. P., Mexico, to a depth of 1170 ft.

1920: H. T. Abrams, patent issued, "Automatic Valve for Air Lift Pumps," Patent No. 1,343,190.

1922: The Jermyn mine of Jermyn, Pennsylvania, was dewatered through two 24-in. holes extending to a depth of 240 ft at a rate of 410,000 to 480,000 BPD.

May 5, 1931. M. P. BURKE 1,803,837

GAS LIFT MEANS

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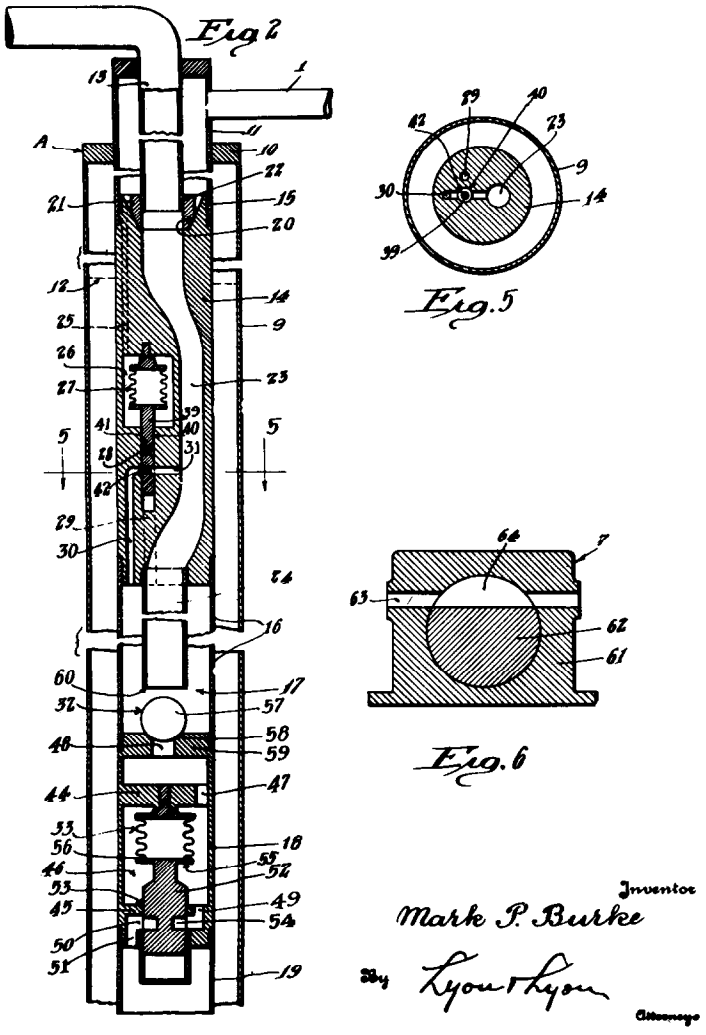


FIG. 8b.

1923-24: Smackover Field, Arkansas - Air-lifted to a depth of 2300-2600 ft, lifting up to 10,000 BPD per well.

1924: At the University of Wisconsin, C. N. Ward and L. H. Kessler conducted additional tests on air-lifting.

1925: Goose Creek, Texas - Compressed air from compressors used to air-lift 400-600 psi 2500 ft.

1925: Hull Field, Texas - Compressors used to compress air to 500-550 psi for lifting.

1925: Powell Field, Texas - Compressors to compress air.

1925: Wortham Field, Texas - Compressed air used for lift.

1925: Tonkawa Field, Oklahoma - Gas-lift utilized.

1925-26: The Jones method of recycling gas was introduced in California and made a start in introducing gas instead of air as a lifting medium. Some gas lifting was done in the Tonkawa and Braman fields of Oklahoma.

Nov. 4, 1930. M. T. ARCHER 1,780,808

INTERMITTENT GAS LIFT PUMP

Filed April 25, 1928

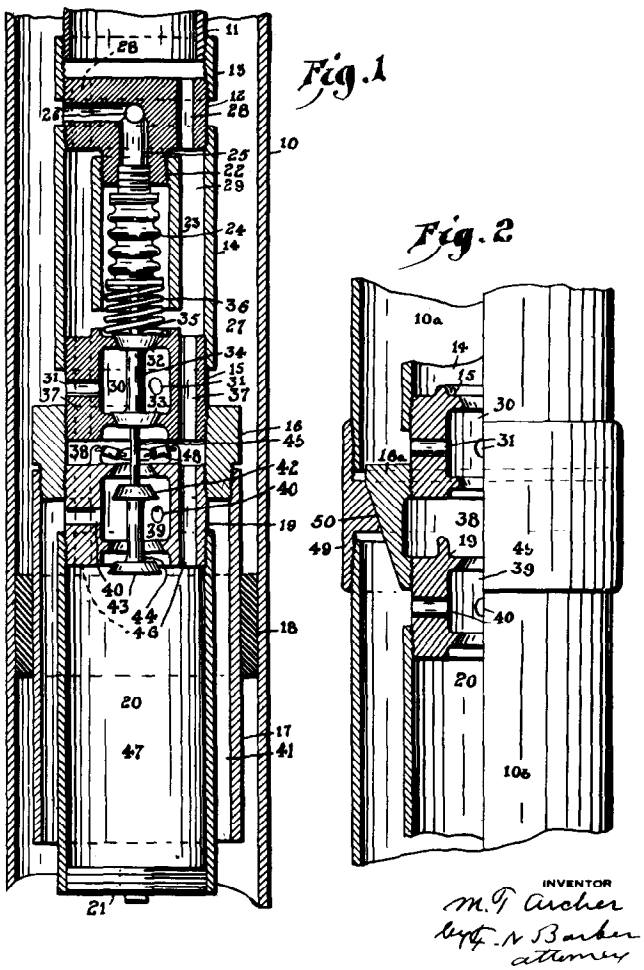


Fig. 1

Fig. 2

INVENTOR

M. T. Archer

by A. N. Barker

attorney

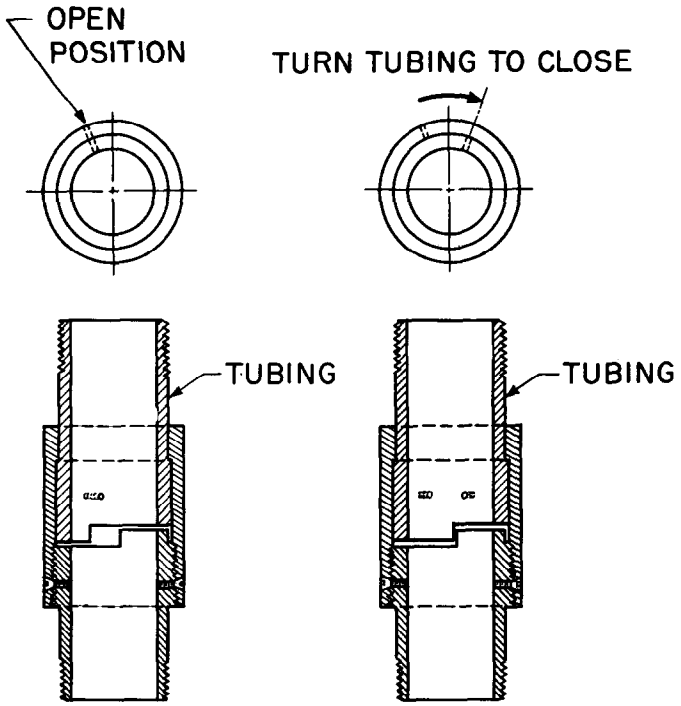
FIG. 9.

1926: In Texas and Louisiana air lift was adopted to lift sulfur from domes.

1926: The gas-lift method was applied in the Seminole Field of Oklahoma, and S. F. Shaw contributed tremendously in making a study of gas-lift in this field.

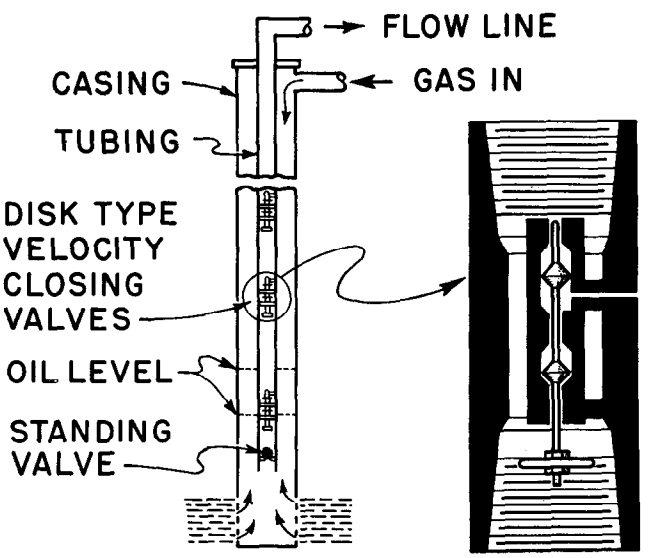
1926-30: Intermittent flow was first introduced in the Seminole Field, and at the same time intermittent flow was introduced in California.

1928: Burbank Field, Oklahoma - Employed straight gas-lift.



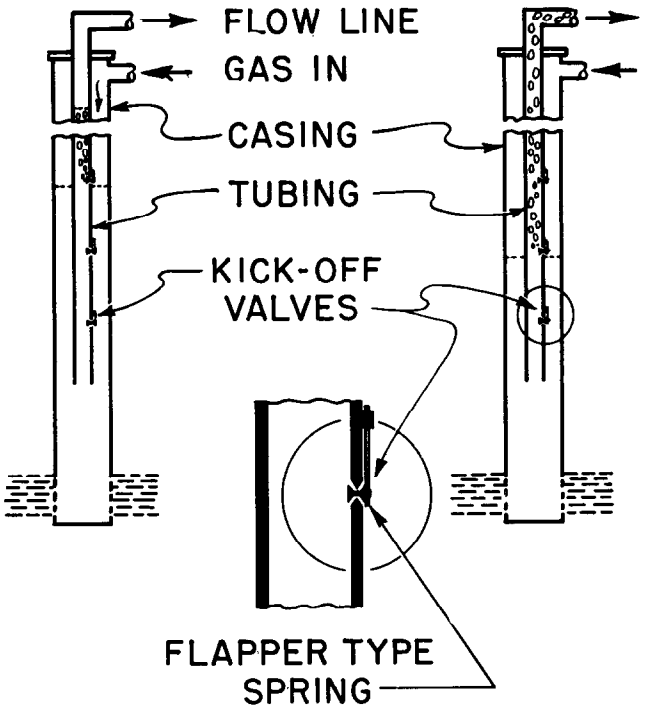
JET COLLAR

FIG. 10



VELOCITY CONTROLLED VALVES

FIG. 11.



KICK-OFF VALVES

FIG. 12.

1929: Bristow Field, Oklahoma - Employed straight gas-lift.

1929: Jet collars and buttons were used in straight gas lift to lessen the kick-off pressure. The introductory date is unknown (Fig. 10).

1929: Velocity controlled valve introduced by Bryan (some 20,000 were installed) (Fig. 11).

1930: Oklahoma City Field - Kick-off valves were first introduced here. The continuous injection of gas through kick-off valves on wells that would flow naturally was called "jetting" (Figs. 12, 13, 14, 14b).

1930: M. T. Archer - Patent No. 1,780,808; filed April 25, 1928; patented November 4, 1930. This is also a patent on a bellows gas lift valve and, while issued before Burke's patent, was filed after Burke's. It was not a pressure charged valve, but rather functioned between the Δ of the lift pressure gas and the fluid to be lifted (Fig. 9).

1930: Kick-off valves used - Mid-Continent in St. Louis Field.

1931: M. P. Burke - Patent No. 1,803,837. Patented May 5, 1931, filed March 28, 1927. This was in reality the first bellows pressure charged gas lift valve. In his patent Burke mentioned the use of a standing valve arrangement to keep the lift pressure gas off the formation during the period of gas injection (Figs. 8a and 8b).

1932: H. C. Otis - Patent No. 1,916,070. Filed December 27, 1932; patented June 27, 1933. Although this is a gas lift patent, it is related to a side door choke. Over 3000 wells were gas lifted in Oklahoma. These wells were duals, and a gas zone was used to lift an oil zone. Formation gas was also used to lift single zone wells as shown in Fig. 15.

1932: Kick-off valves and various types of flow valves have been utilized from the beginning of the East Texas Field until the present time.

1934: First spring loaded differential valves placed on market - Bryan's SDX and Merla's Type A were marketed at about the same time (Figs. 16, 17).

1935: First Bellows valve introduced by Bryan.

1935: First removable gas lift equipment developed by Bryan (Fig. 19).

1936-37: Gas-lift centrifugal pump combination was practiced in the Oklahoma City Field. Gas-lift-hydraulic pump combination was also used in Oklahoma City Field.

1938: Nixon marketed the large ported wire line mechanically controlled valve (Fig. 18).

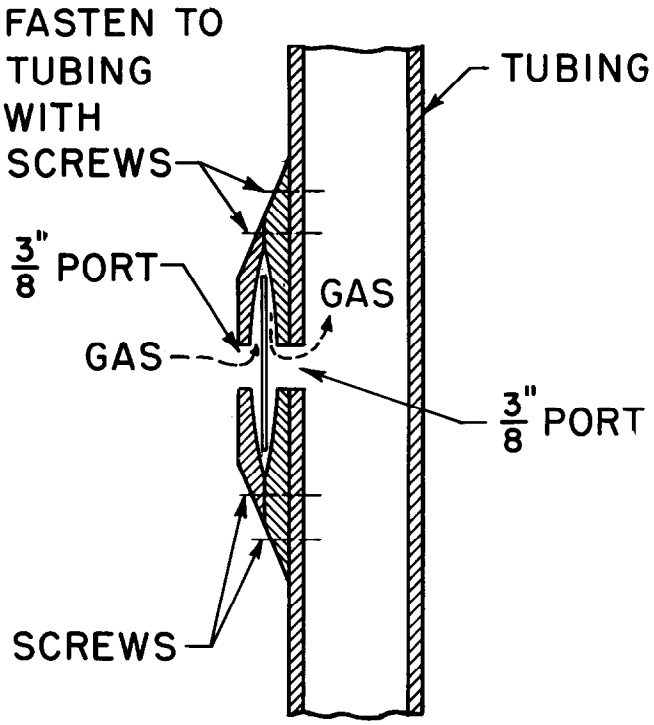
1939: T. E. Bryan - Patent No. 2,179,226. Filed August 24, 1936; patented November 7, 1939. This patent relates to a spring loaded, pressure actuated gas lift valve. This was the first patent on a bellows type fluid operated gas lift valve (Fig. 20).

1939: T. E. Bryan - Patent No. 2,145,918. Filed December 21, 1936; patented February 7, 1939. This was the first patent granted on a wire line retrievable gas lift valve (Fig. 21).

1940: Patent issued to Boman Thomas on Specific Gravity Differential Valve (Fig. 22).

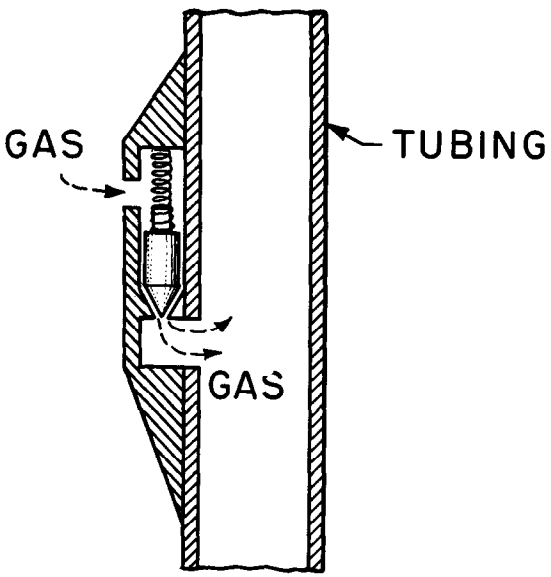
1941: W. F. Grisham - Patent No. 2,236,137. Patented March 25, 1941; filed February 25, 1938. First pressure charged diaphragm actuated gas lift valve. "The grandaddy of all pressure charged valves." See Figure 23.

1944: W. R. King - Patent 2,339,487. Patented January 18, 1944; filed May 25, 1940. While the King valve was given credit for being the first pressure charged



FEATHER KICK-OFF VALVE

FIG. 13.



TAYLOR KICK-OFF VALVE

FIG. 14a.

gas lift valve, actually the patent was a method patent utilizing the pressure valve, in conjunction with a surface control means, to inject a measured volume of gas into the well for each intermittent cycle (Figs. 24, 25, 26).

1946: H. C. Otis - Patent No. 2,393,404. Patented January 22, 1946; filed November 13, 1941. First patent granted utilizing wire line methods for perforating and packing off the perforation for gas lift and other well operations.

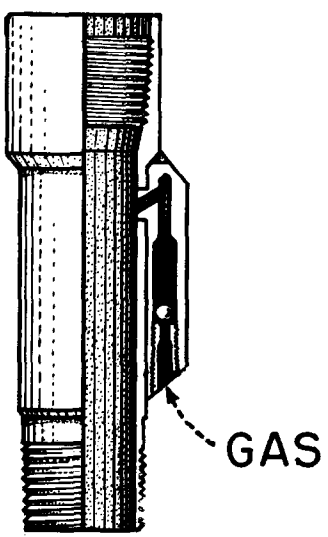
1949: T. E. Bryan - Patent No. 2,179,226. Patented January 7, 1949; filed August 24, 1936. This was the first patent on a fluid operated bellows valve.

1949: First set of concentric retrievable valves run in series, 1949, Placedo, Texas.

1949: Halbert Gas Lift Valve - Utilizes a scored bakelite float such that all valves above the casing fluid level are on their seat and closed, but are passing gas as permitted by the scored float. Valves not yet uncovered by fluid are open.

1949: Bryan BPU-2, double seated valve (for increased pressures on working down the hole).

1953: L. L. Cummings - Patent No. 2,642,889. Filed March 19, 1951; patented June 23, 1953. This is the first major change in gas lift valves in many years. It features a sensitive balanced valve, using a resilient material as the valve and actuating means. Its concentric construction makes it desirable for modern day gas lift (Fig. 27).



TAYLOR KICK-OFF VALVE

FIG. 14b.

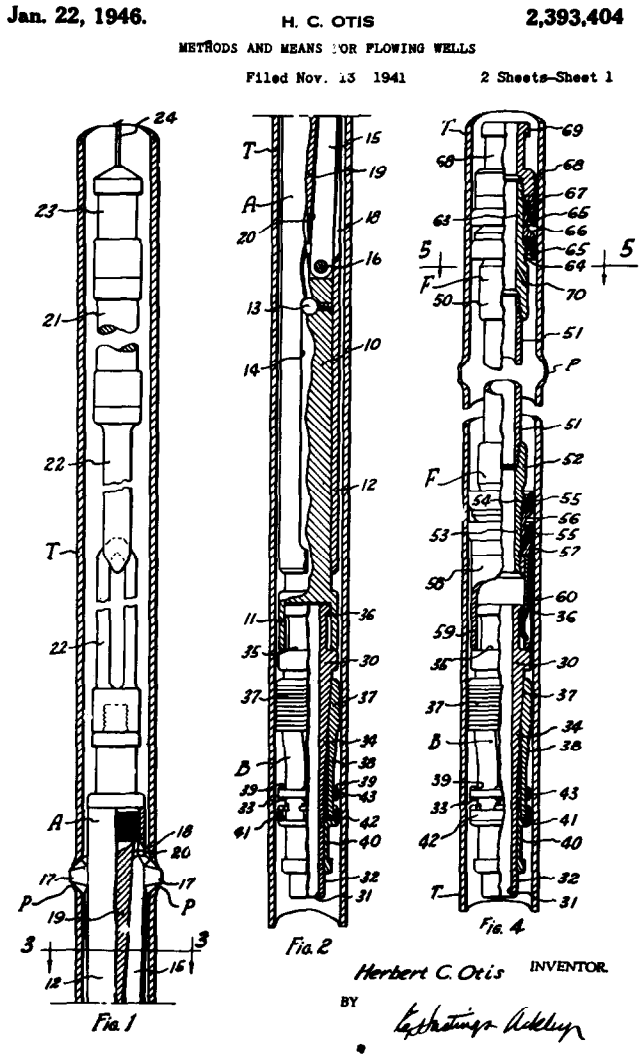


FIG. 15.

1953: Howard, McGowan, and Moore patent on Side Pocket Mandrel and means of installing a valve. Filed 1948.

1953: Walton patent issued on pilot operated bellows valve. Filed August 10, 1946.

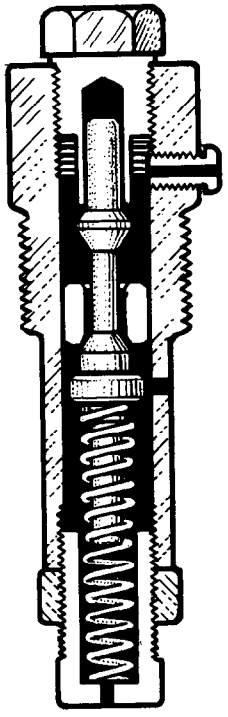
There are many interesting events that occurred during the earlier days of gas lift. A few of the more significant happenings and discussions are presented here:

Foot-pieces

In the early days, the "foot-piece" (point where gas entered casing and/or tubing) received much widespread publicity, and various claims were made by manufacturers of these devices.

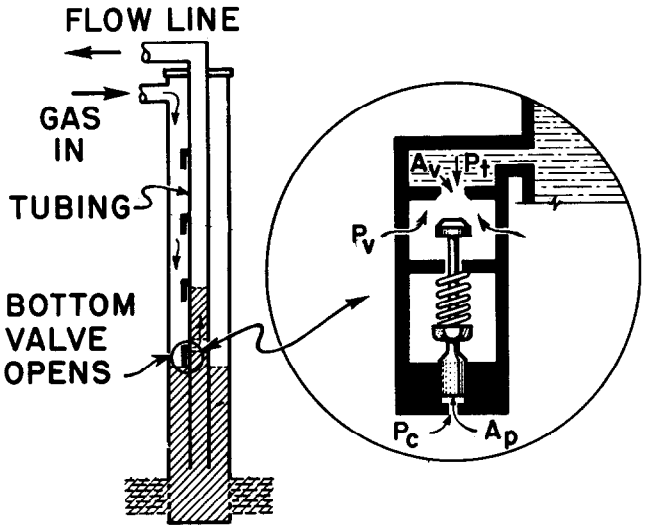
In 1927, Pennington[11] advanced the theory that a foot-piece that would finely divide the air bubbles would be more efficient. For example, the exposed surface of a 1-1/4 in. bubble is 4.90 sq in. and contains 1 cu in. of air. If this same cu in. of air was divided into bubbles of 1/8 in. diameter, the surface area would be 49 sq in. and would thereby do ten times as much work since frictional work is proportional to the frictional contact areas.

Davis and Weidner[3] conducted numerous experiments on foot-pieces and concluded that the type of foot-piece has very little effect on the efficiency of the air-lift pump if the air is introduced in an efficient manner and if the full cross-sectional area of the eduction pipe is realized for the passage of the liquid.



BRYAN DIFFERENTIAL VALVE

FIG. 16.

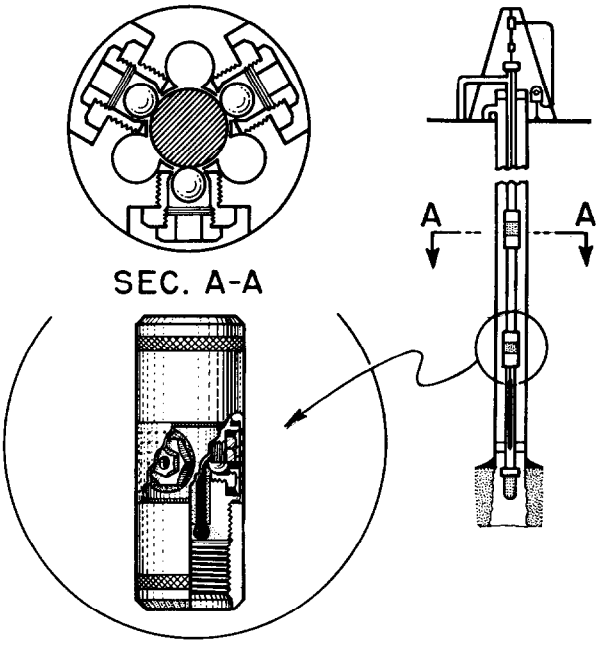


SPRING LOADED DIFFERENTIAL VALVES

FIG. 17

Tapered Tubing

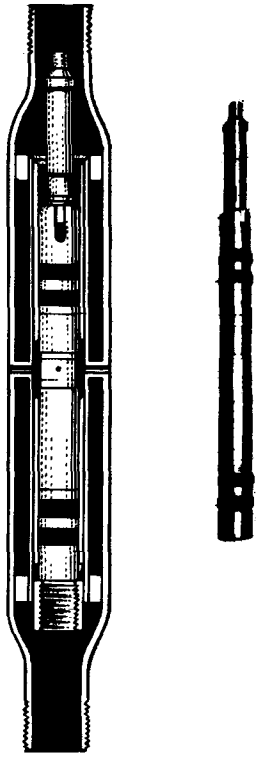
Considerable emphasis was given to tapered tubing strings in early gas lift and is still practiced today to a very limited extent. Pierce and Lewis offered a general discussion on the use of tapered tubing strings. Briefly, the idea was to enlarge the tubing strings toward the top of the hole so the velocity could be lowered and, thereby



MECHANICALLY CONTROLLED VALVES

FIG. 18

FIRST RETRIEVABLE VALVE



BRYAN DROP VALVE
FIG. 19.

reduce friction and in turn reduce the size of tubing at bottom so the velocity could be increased to minimize slippage. Although the argument seems somewhat sound, its practical application is rather unsound, and the utilization of slim hole completions practically eliminates its usage today.

Air for Hire

In the days of Spindle Top (1901) many "air for hire" plants were constructed with individual operators realizing a profitable business. Air was sold at so much per well per day, or a well was blown (lifted) for a percentage of the oil. A figure given by Osgood[8] was 10 per cent in a large well (7500 BPD) to 40 per cent in a small well (250 BPD).

Gas lift and air lift, in the early days, were striving for maximum production regardless of all else, and generally, the only criterion for efficiency was the total oil production.

Seminole Era

Gas-lift received its first big boost from the Seminole Field, because the results there were widely publicized. And this publicity led to gas-lifting in some Texas fields as well as several foreign fields such as Venezuela and Romania.

In the Seminole Field, air-gas lift was responsible for 70 per cent of production. A peak production of 527,000 BPD was reached whereas, without gas lift, the field could never have reached 200,000 BPD.

Air Lift Condemned

Air-lift at one time was condemned by many men of the oil industry because it resulted in overproduction and a corresponding low market. Of course, no voluntary proration was practiced, and the air-gas lift received the blame, although it was known that a piece of equipment could not be blamed for overproduction.

Pressure Operated Valves

The earliest patent on an automatic flow valve, utilizing a step down pressure method to permit "working" down the well, was obtained by Joseph H. McEvoy (Fig. 7). As quoted from the patent,

> In the operation of this invention it will be observed that the face of the valve exposed to the pressure outside of the air tube is much

Nov. 7, 1939. T E BRYAN 2,179,226

WELL FLOWING VALVE

Filed Aug. 24, 1936 2 Sheets-Sheet 2

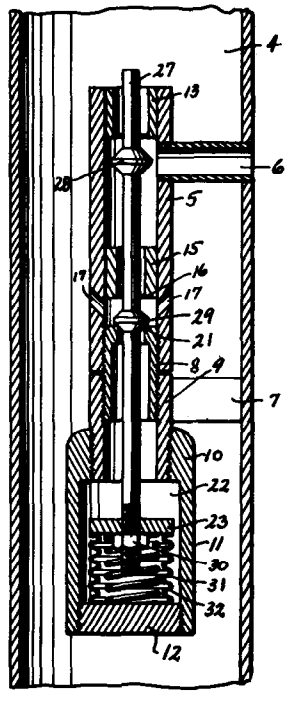


Fig. 4.

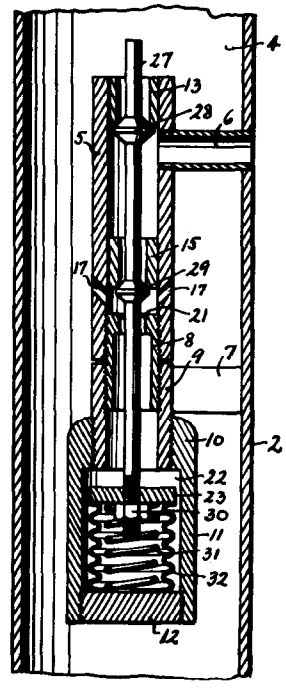


Fig. 5.

Inventor
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By J. Vincent Martin
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Attorneys.

FIG. 20.

Feb. 7, 1939. T. E. BRYAN 2,145,918

GAS LIFT APPARATUS

Filed Dec. 21, 1936 2 Sheets-Sheet 1

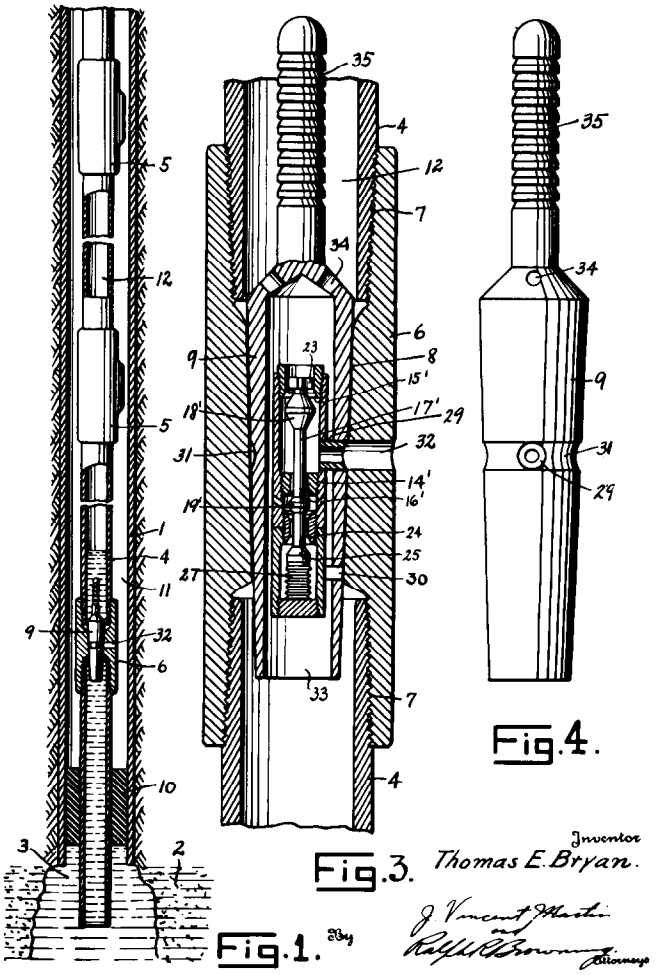
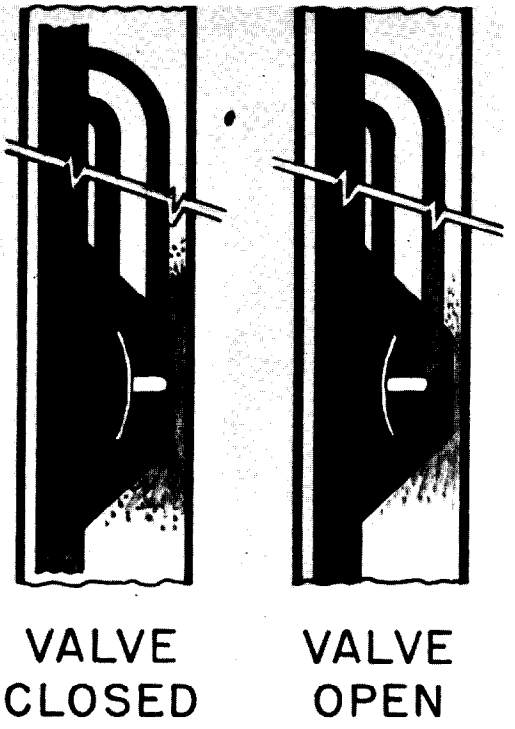
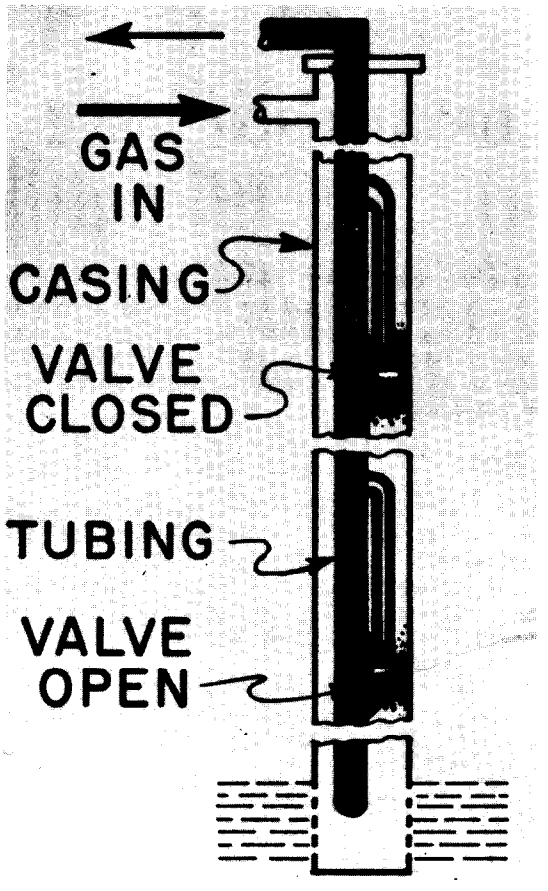


FIG. 21.

less in area than that of the diaphragm exposed to the interior pressure, there being a difference of approximately one to sixteen. As a result of this construction the exterior pressure of the liquid in the well has little or no effect upon the operation of the valve due to the small exposed area thereof and in the opening movement assists the diaphragm when the requisite pressure is applied thereon from the interior of the air pipe. The pressure required to open the valve and lift the liquid decreases downwardly corresponding to decreasing lengths of pipe section, for instance, the valve disposed at 500' from the top of the well discharges at a pressure of 250 lb. This pressure also lifts the body of liquid above said valve so that when the pressure is relieved this first valve closes. The next valve is shown disposed at 400' below the first valve and adapted to discharge at a pressure of 200 lbs, which also lifts the 400' of liquid and being less than the pressure required to open the first valve and does not affect the same . . .





SPECIFIC GRAVITY DIFFERENTIAL VALVE

FIG. 22.

March 25, 1941. W. F. GRISHAM 2,236,137

FLOW VALVE

Filed Feb. 25, 1938

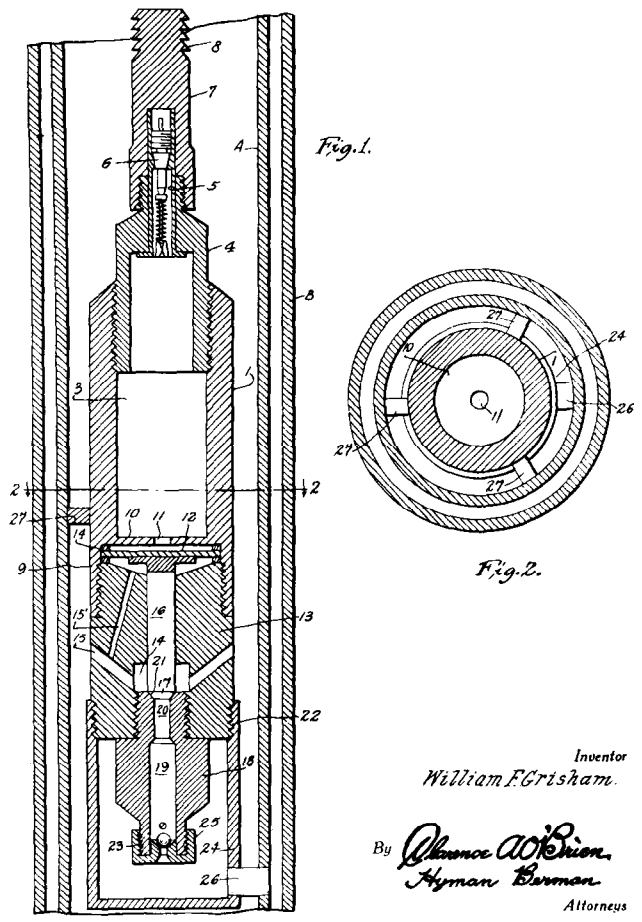


Fig. 1.

Fig. 2.

Inventor
William F. Grisham.

By Clarence A. O'Brien
Hyman Berman
Attorneys

FIG. 23.

Another step forward in the pressure operated valves uses the W. F. Grisham valve (Fig. 23) with a patent filed in 1938 and issued in 1941. This is the grandaddy of our present type bellows gas lift valves, and the only difference is that a diaphragm instead of a bellows was used.

The W. F. King patent on a bellows valve was issued in 1944. This was actually a method patent in which a gas volume control type intermitter was used in conjunction with a string of pressure operated gas lift valves. The basic idea of the patent was to have a surface control means for injecting, at predetermined cycles, a measured volume of gas into the well. The valves were to open and pass the same measured volume of gas under the liquid load to lift it in the most efficient manner. For many years, this patent controlled the use of our present day bellows valves, but because a patent is good for seventeen years, the patent recently expired.

From these early bellows valves many other bellows valves were developed. For instance, one of the first problems on the King valve was a means of protecting the bellows: it utilized a lead seal to keep excessive well pressures from damaging the bellows (Fig. 26). Most present day bellows valves are somewhat similar to the King valve except that a different means of bellows control is utilized.

One of the latest developments in pressure operated valves was the Cummings valve (Fig. 27). This particular valve is concentric and utilizes a flexible sleeve for gas volume control. One feature of this valve was its concentric feature that allows artificial lift in slim hole completions and multiple completions.

Retrievable Equipment

The first retrievable gas lift equipment was a patent issued to H. C. Otis, who developed the side door choke in 1932. This was actually a gas lift patent as related to a side door choke, and some 3000 early wells in Oklahoma were gas lifted by this method. In 1935, Bryan then developed the "drop valve" which was normally the bottom operating valve. This was a center set valve and could be retrieved by wire line tools.

Eventually a method of retrieving was developed whereby a valve could be selectively pulled. This was the patent issued to Howard, McGowan, and Moore and is the so-called "offset mandrel."

Jan. 18, 1944. W. R. KING 2,339,487

TIME AND VOLUME CONTROL FOR GAS INTERMITTERS

Filed May 23, 1940 3 Sheets-Sheet 1

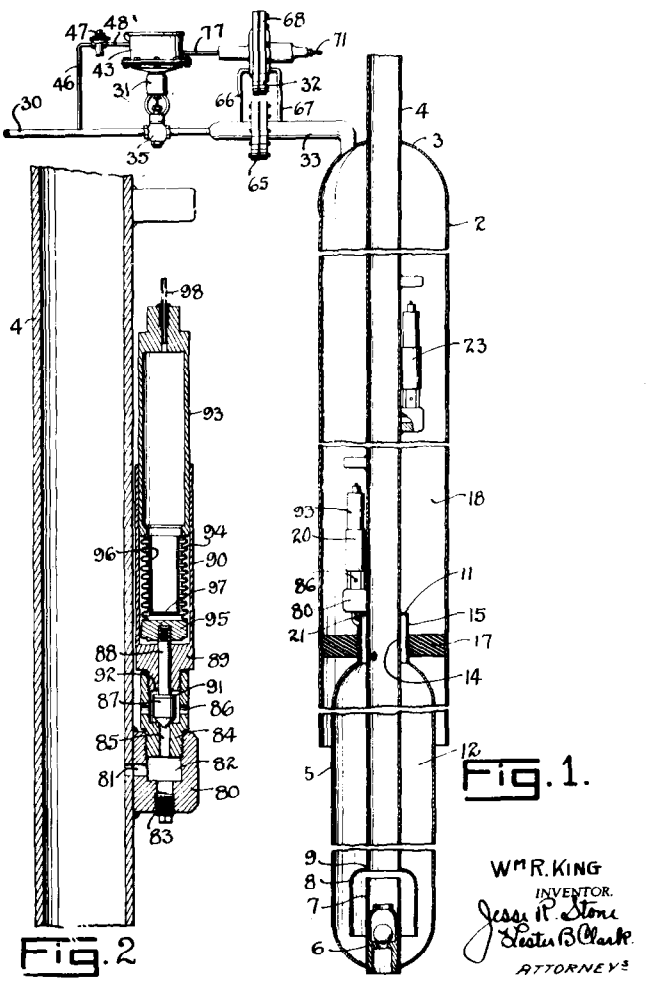


Fig. 1.

Fig. 2.

Wm R. King
INVENTOR.
Jesse P. Stone
Lester B. Clark
ATTORNEYS

FIG. 24.

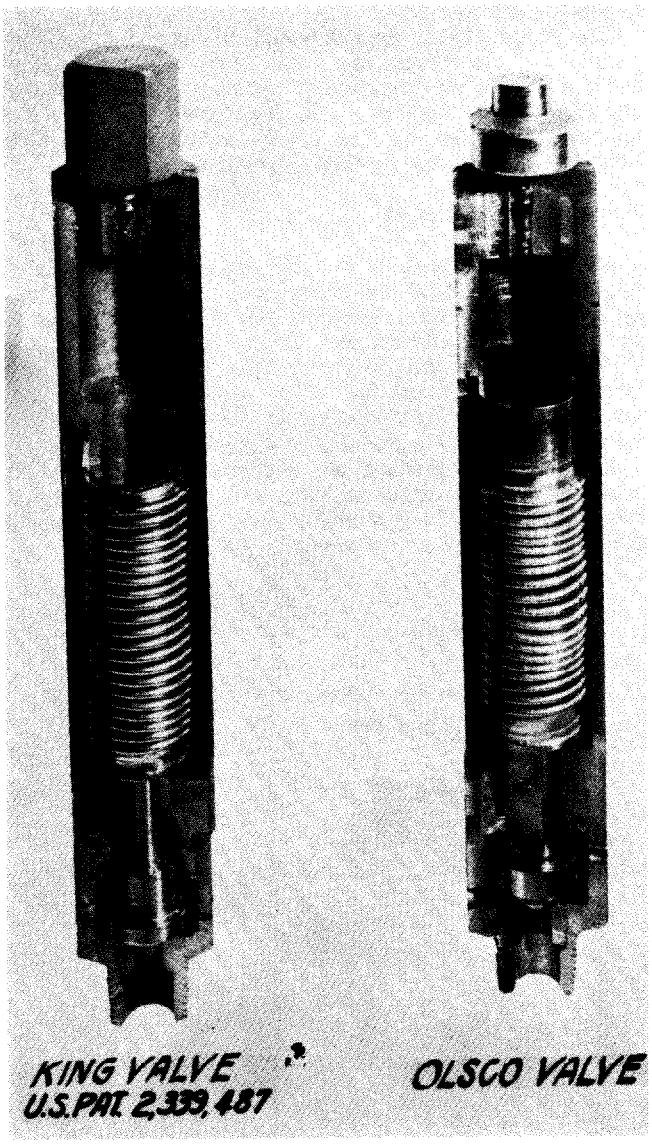


Fig. 25

CONCLUSIONS

In conclusion it should be noted that, since the first experiments in 1797, tremendous strides have been taken to improve gas lift. However, it is the opinion of the authors that the ultimate in gas lift equipment has not yet been reached.

The so-called "oil patch" offers that competitive spirit that calls for better and better equipment. Thus, the competition among manufacturers to place the best valve on the market is good for the industry as a whole.

In conclusion it is known that many patents, events, and pieces of equipment have been omitted, for space would not permit including all the history involved. However, to make the history of gas lift more complete, the authors would appreciate any additional comments or additions.

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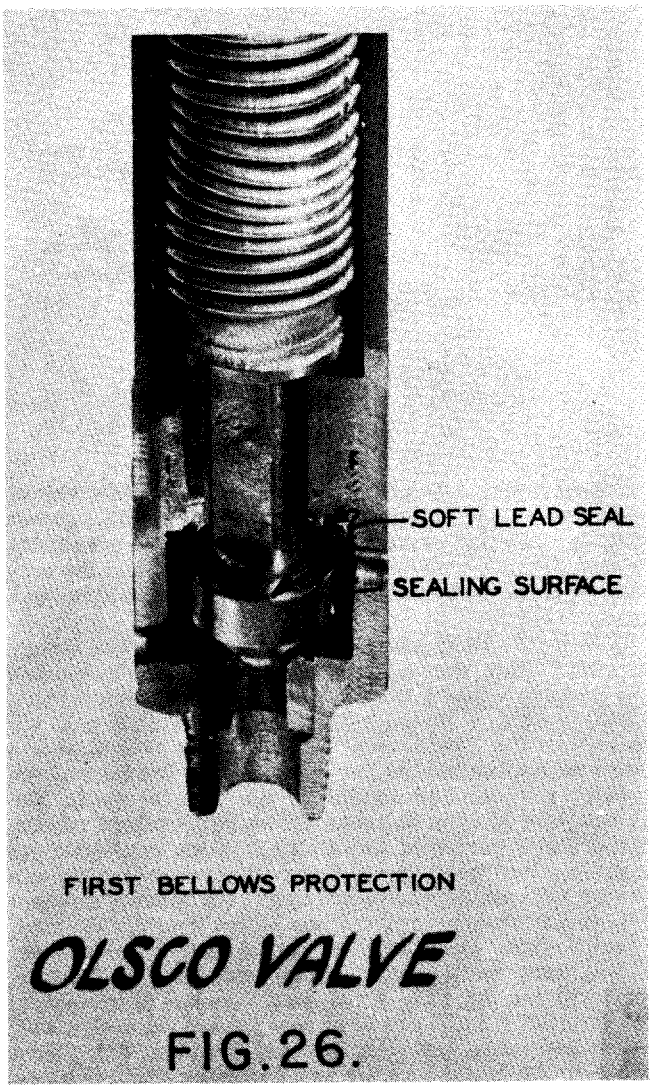

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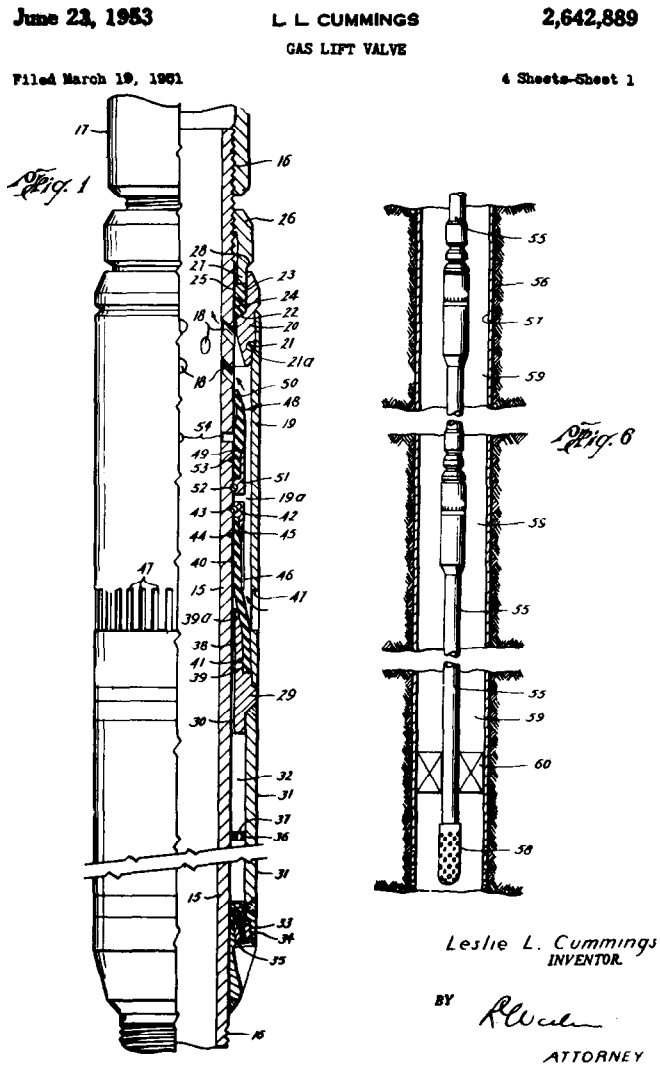

FIG. 27.