June 22, 1943. H. H. KAVELER 2,322,453

APPARATUS FOR CONTROLLING OIL WELLS

Filed Sept. 23, 1940 2 Sheets-Sheet 1

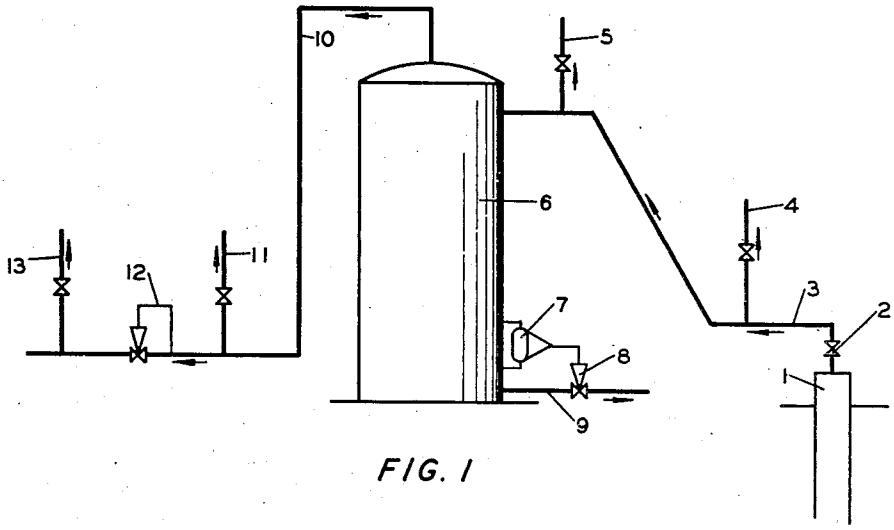


FIG. 1

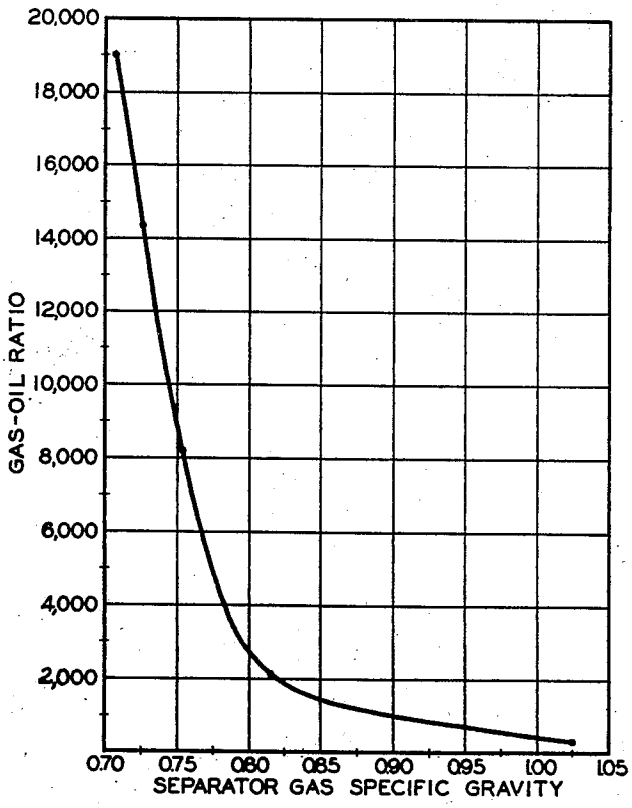


FIG. 2

INVENTOR
H. H. KAVELER

BY
Hudson, Young, Stanley & Yuiger
ATTORNEY

June 22, 1943. H. H. KAVELER 2,322,453

APPARATUS FOR CONTROLLING OIL WELLS

Filed Sept. 23, 1940 2 Sheets-Sheet 2

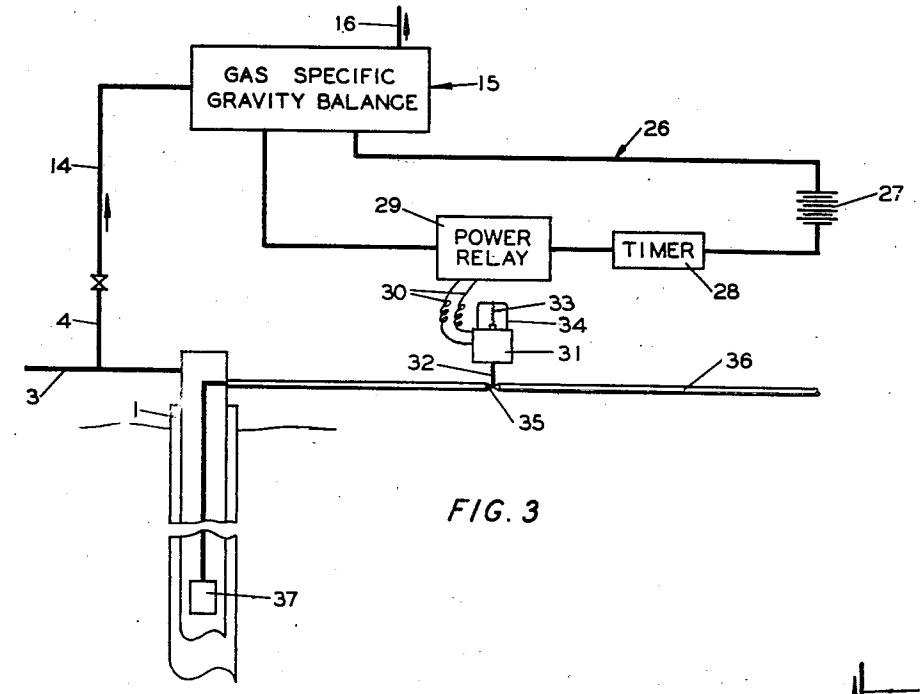


FIG. 3

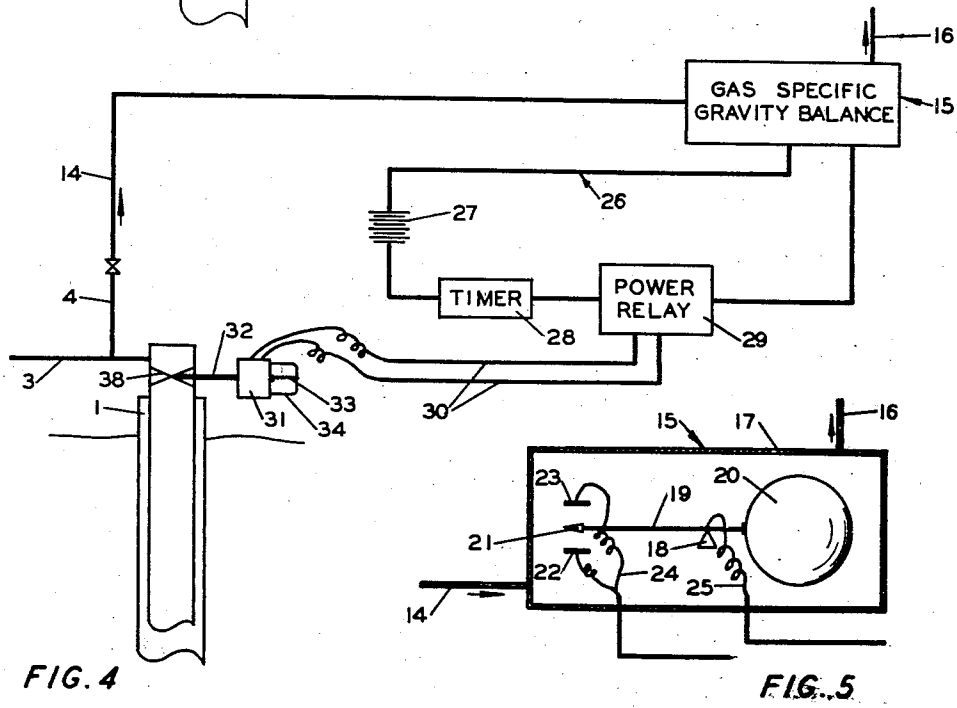


FIG. 4

FIG. 5

INVENTOR
H.H. KAVELER

BY
Hudson, Young, Stanley & Yeager
ATTORNEY

Patented June 22, 1943 2,322,453

UNITED STATES PATENT OFFICE

2,322,453

APPARATUS FOR CONTROLLING OIL WELLS

Herman H. Kaveler, Bartlesville, Okla., assignor to Phillips Petroleum Company, a corporation of Delaware

Application September 23, 1940, Serial No. 357,998

8 Claims. (Cl. 166—2)

This invention relates to apparatus for controlling the withdrawal of fluid through a well bore; and is a continuation in part of my prior filed application, Serial No. 276,108, filed May 27, 1939.

The gas production from an oil well is conveniently expressed in relation to the oil production by the so-called "gas-oil" ratio. The gas-oil ratio is generally defined as the ratio of the number of cubic feet of separator gas measured at 60° F. and some reference pressure (usually 14.4 pounds, absolute) to the number of barrels of oil produced, measured at 60° F. and prevailing atmospheric pressure. The ratio therefore expresses the number of cubic feet of gas produced per barrel of oil during some period of flow.

Heretofore, the only method for accurately determining gas-oil ratios was to measure separately the oil produced in a stock tank and the gas produced through a separator vent-line having an orifice meter or Pitot tube in place. This method of gauging separately the oil and gas produced shall be referred to as the direct method of determining the ratio. This method requires that a separator and storage tank be provided for each well under test during the test period which usually extends from one to twenty-four hours.

The gas-oil ratio of an oil well is dependent on a number of factors such as:

1. Inherent reservoir properties as established by reservoir rock, reservoir temperature and pressure and chemical composition of the reservoir contents,

2. The presence in the reservoir of a free gas phase commonly referred to as a gas-cap,

3. The manner in which wells are completed and the method of producing the well (flow rate, choke size, etc.), and

4. The state of depletion of the reservoir.

Gas is the principal source of natural energy available for the production of oil and every effort is made to conserve reservoir gas by producing oil wells in such a way as to maintain the minimum gas-oil ratio since gas-oil ratios are important in establishing conservative operation of oil reservoirs. Regulatory bodies frequently require extensive periodic gas-oil ratio tests to provide a basis for enforcing the laws established for conservation purposes.

The determination of gas-oil ratios by the direct method described above is time consuming and often expensive whenever individual separators and stock tanks are required for each well under test. This situation led to a search for some other method of accurately determining gas-oil ratios which would permit a saving of time in observation and which would simplify the mechanical equipment required for individual well tests.

In searching for other means of determining gas-oil ratios, a simple relationship between gas-oil ratio and the specific gravity of the gas produced with the oil has been discovered. The employment of this relationship in actual practice provides a means of indirectly determining gas-oil ratios to an accuracy of 10 to 15 per cent.

It is an object of the present invention to effectively control the withdrawal of fluid through a well bore.

Another object of the invention resides in the utilization of the specific gravity of produced gas in the regulation of the gas-oil ratio of fluid withdrawn through a well bore that communicates with an oil-bearing formation.

A further object of my invention is the provision of apparatus for regulating the flow of hydrocarbons through a well bore to maintain the gas-oil ratio thereof within preselected limits. Other objects and advantages of the invention will be apparent during the course of the following description.

In the accompanying drawings, forming a part of this specification, and in which like numerals are employed to designate like parts throughout the same,

Figure 1 shows a schematic diagram of the surface equipment to be used in determining gas gravities, and

Figure 2 is a graph showing the relation between gas-oil ratio and specific gravity of separator gas.

Figure 3 is a schematic diagram of one application of my invention.

Figure 4 is a schematic diagram of another application of my invention.

Figure 5 illustrates a form of gas specific gravity balance, partly in cross section, that may be

advantageously employed in the practice of this invention.

An example of the relationship between gas-oil ratio and the specific gravity of gas produced with the oil is given in the following data which were obtained from field observations in which the gas-oil ratio was determined by direct observation.

Example of the relation between gas-oil ratio and the specific gravity of produced gas

Well No.	Gas-oil ratio	Specific gravity of separator gas
2	1,026	0.921
4	5,700	0.775
4	14,330	0.731
7	1,067	0.835
7	1,575	0.819
14	895	0.933
15	559	0.930
16	19,000	0.705
18	659	0.904
20	652	1.030
22	707	0.972

Separator pressure—30 pounds per square inch gauge

These data are represented in Figure 2 which we shall call a "gravity-ratio" curve. Each and every producing horizon in any field can be represented by a typical "gravity-ratio" curve, such as that cited in the example above. Such representative curves must be established by a field test using the direct method of measuring ratio or the curves may be established by computations if the hydrocarbon analyses of the reservoir liquid and gas and proper equilibrium constants are available. The latter involves operations already known and accepted in petroleum technology.

The gas-oil ratio as defined above depends upon separator pressure since the amount of gas dissolved in the separator liquid and the specific gravity of the produced gas may change sensibly with pressure. The gravity-ratio curve must be determined and interpreted always with respect to a chosen, arbitrary separator pressure. Further, in cases where the separator temperature shows variations in excess of 20° F., a calibration curve to establish the temperature correction would be necessary. In nearly all cases, however, the temperature will not be an important variable. The gravity-ratio curve for a given horizon in a given field will depend upon the pressure in the producing horizon in such a manner that the gravity-ratio curve cited above may have to be redetermined at such intervals as declining reservoir pressures require the adjustment of the curve.

Having the gravity-ratio curve established for a particular field in the manner described above, it is only necessary to observe the specific gravity of the produced gas to obtain the gas-oil ratio. This observation can be made on gas produced from the separator or, to make the greatest use of the discovered relation, the observation may be made directly in the flow line. All that is required is a means of withdrawing samples of the produced gas into a gas specific gravity meter.

Figure 1 shows a current means of doing this through either nipples 4 and 5, which are approximately 2 by 12 inches, attached to the upper side of the flow line 3 through which representative samples of the produced gas could be withdrawn. In the drawings, 1 represents a producing well, and 2, a flow control valve mounted on top of the casing of the well. The flow line 3 connects into the oil-gas separator 6 and delivers the fluid from the well thereto. Valve 7 is a float valve arrangement which controls valve 8 in flow line 9 to allow for discharge of oil from the oil-gas separator. Line 10 running from the top of the oil-gas separator is the vent line conducting the gas from the separator. The nipple 11 represents another point at which samples of the gas may be taken to be run through the specific gravity meter. The valve 12 is a pressure regulator which determines the pressure under which the separator 6 operates. Should the pressure in separator 6 and line 10 exceed a predetermined pressure, for example, 30 pounds gauge, regulator valve 12 will open to vent gas therethrough. As soon as the pressure within separator 6 is reduced to below this predetermined pressure, regulator valve 12 automatically operates again to terminate the venting of gas. An additional nipple 13, through which samples of the gas may be withdrawn, is indicated on the down stream side of pressure regulator 12.

As can be seen from the drawings, the position of the sampling nipples can be: (1) In the separator vent line 10 as at 11 and 13; or (2) In the flow line 3 to the separator as at 4 and 5. The nipples 4 and 5 should be located near the separator in order that the pressure at the nipple may be responsive to separator regulation. The location of the sampling nipples 4 and 5 permits observation of gas-oil ratios without the necessity of individual separator and stock tank installations, and furthermore, this is the only method heretofore proposed which permits gas-oil ratios to be determined in the flow line before the gas and oil phases are separated.

Besides the simplified means of determining gas-oil ratios from observation of the specific gravity of gas produced in either vent or flow lines, the invention also provides a means for controlling the rate of flow of wells; that is, means is provided for constantly checking the producing well in order to maintain the lowest possible gas-oil ratio consistent with allowed daily production. This may be accomplished by several types of installation, using either manually operated or recording specific gravity meters to indicate the instantaneous gas-oil ratio. In one instance when the well is artesian, the operator may manually adjust the control valve on the well to such positions as give the maximum gravity of the produced gas (for a chosen separator pressure) and maintain, therefore, the desirable minimum gas-oil ratio. In the other instance when the well is artesian, the specific gravity meter may be installed with auxiliary equipment which will operate the surface control valves automatically. The invention also provides the means for automatically controlling variable subsurface chokes in artesian wells. Furthermore, my instant invention contemplates operating variable speed pumps of all types in such a manner as to provide automatic adjustments to maintain optimum gas-oil ratios.

My invention may be employed to control the operation of a variable speed pump and an embodiment of such an application of the invention is set forth in Figure 3 of the drawings, wherein a conduit 14, connected to nipple 4, transmits produced gas to a gas specific gravity balance 15, which is provided with a gas vent 16. It is to be understood that conduit 14 may be connected to nipples 5, 11 or 13, if desired, with equally satisfactory results. The gas

specific gravity balance is of a conventional type, the particular construction illustrated in Figure 5 including a case 17 within which is a fulcrum 18 supporting a balance arm 19 having a spherical bulb 20 at one end and an adjustable counterbalance contact member 21 at its opposite end. Above and below contact member 21 is a pair of electrical contacts 22 and 23 which are both connected to a common electric lead 24 while arm 19 is connected to a similar lead 25. The balance may be readily adjusted so that when the specific gravity of the gas passing therethrough is above or below a chosen value of specific gravity, electric contact is made between member 21 and contact 22 or 23 to complete an electric circuit, generally indicated by reference numeral 26 (Figure 3). If desired, the balance may be designed to complete the electric circuit only when the gas specific gravity is less than a predetermined minimum. This may be accomplished by merely eliminating contact 22 from the balance. The electric circuit includes a source of electrical energy, such as the plurality of batteries 27 shown in the drawings, a timing device 28 and a power relay 29, all arranged in series. A pair of electric leads 30 connects the power relay to an electric solenoid having a casing 31. This solenoid actuates a plunger 32 passing therethrough. A coil spring 33 interposed between plunger 32 and a rigid bail 34 normally maintains the plunger in a retracted position when the solenoid is deenergized. Should the specific gravity of the gas passing through balance 15 be above or below the chosen value, electrical contact is made within the balance completing circuit 26, thereby placing power relay 29 into service and energizing solenoid 31. Plunger 32 is urged downwardly into a valve 35 in gas line 36 to partially or completely cut off the flow of gas through this line. This regulation of the amount of gas passing through line 36 will in turn determine the speed at which various types of pumps 37, such as gas lift pumps of the type set forth in U. S. Patent 2,142,482, or 2,142,485, will operate. Pump 37 will be completely closed down, or operate at reduced speed as long as solenoid 31 is energized. The circuit may be interrupted at any desired time by means of timing device 28, which is automatically placed in service when circuit 26 is completed and continues to operate for a predetermined period of time. At the end of such period, timing device 28 is designed to break the electrical circuit, thereby allowing plunger 32 to be retracted by spring 33 and reopen valve 35 to allow unrestricted flow of gas through line 36 and to pump 37.

Figure 4 illustrates a form of my invention which is adaptable to control flowing wells by operating a variable choke that is associated with the well. It will be noted on inspection of the apparatus depicted in Figure 4 that substantially the same equipment is utilized in this embodiment of my invention as that illustrated in Figure 3. In this particular instance, the gas specific gravity balance 15 cooperates with the various items of electrical equipment to control the degree of opening of a variable choke 38.

While I have thus illustrated and described several embodiments covering the application of my invention, it will be obvious that my invention lends itself to a number of other uses of a similar nature.

It is to be understood that the form of my invention, herewith shown and described, is to be taken as the preferred example of the same, and that various changes in the shape, size and arrangement of parts may be resorted to, without departing from the spirit of my invention, or the scope of the subjoined claims.

I claim:

1. Apparatus for controlling the withdrawal of fluid including gas and oil through a well bore comprising means associated with the well and actuable by variations in the specific gravity of said gas, and means responsive to actuations of said means for controlling the flow of well fluid whereby the gas-oil ratio of fluid withdrawn from the well is not permitted to exceed a predetermined maximum.

2. Apparatus for controlling the withdrawal of fluid including gas and oil through a well bore comprising a gas specific gravity balance operating between chosen limits of specific gravity of said gas, and means associated with the balance and cooperating therewith for controlling the flow of well fluid at predetermined gravities of the gas whereby the gas-oil ratio of fluid withdrawn from the well is maintained within a chosen range.

3. Apparatus for controlling the withdrawal of fluid including gas and oil through a well bore comprising means associated with the well and actuable by variations in the specific gravity of said gas, and electrical means responsive to actuations of said means for controlling the flow of well fluid whereby the gas-oil ratio of fluid withdrawn from the well is not permitted to exceed a predetermined maximum.

4. Apparatus for controlling the withdrawal of fluid including gas and oil through a well bore comprising a gas specific gravity balance operating between chosen limits of specific gravity of said gas, and electrical means associated with the balance and cooperating therewith for controlling the flow of well fluid at predetermined gravities of the gas whereby the gas-oil ratio of fluid withdrawn from the well is maintained within a chosen range.

5. In apparatus for controlling the withdrawal of fluid from an oil well, the combination comprising a gas specific gravity balance, means intermediate the well and the balance for transmitting gas from the well to the balance, a variable speed pump in the well, and means cooperating with the balance and the pump to control the speed of the pump to produce the well at predetermined gravities of said gas whereby the gas-oil ratio of fluid withdrawn from the well is not permitted to exceed a predetermined maximum.

6. In apparatus for controlling the withdrawal of fluid from an oil well, the combination comprising a gas specific gravity balance operating between chosen limits of specific gravity of gas admitted thereto, means intermediate the well and the balance for transmitting gas from the well to the balance, a variable speed pump in the well, and means cooperating with the balance and the pump to control the speed of the pump to produce the well at predetermined gravities of said gas whereby the gas-oil ratio of the fluid withdrawn from the well is maintained within a chosen range.

7. In apparatus for controlling the flow of an oil well, the combination comprising a gas specific gravity balance, means intermediate the well and the balance for transmitting gas from the well to the balance, a variable choke associated with the well, and means cooperating with the balance and the choke to actuate the choke to flow the

well at predetermined gravities of said gas whereby the gas-oil ratio of fluid withdrawn from the well is not permitted to exceed a predetermined maximum.

8. In apparatus for controlling the flow of an oil well, the combination comprising a gas specific gravity balance operating between chosen limits of specific gravity of gas admitted thereto, means intermediate the well and the balance for transmitting gas from the well to the balance, a variable choke associated with the well, and means cooperating with the balance and the choke to actuate the choke to flow the well at predetermined gravities of said gas whereby the gas-oil ratio of fluid withdrawn from the well is maintained within a chosen range.

HERMAN H. KAVELER.