United States Patent [19]

Patterson et al.

[11] **3,834,227**

[45] **Sept. 10, 1974**

[54] **METHOD FOR DETERMINING LIQUID PRODUCTION FROM A WELL**

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[22] Filed: **May 2, 1973**

[21] Appl. No.: **356,650**

[52] **U.S. Cl.** .... **73/155,** 73/194 B

[51] **Int. Cl.** **E21b 47/00**

[58] **Field of Search** ... 73/155, 194 E, 194 R, 194 B

[56] **References Cited**

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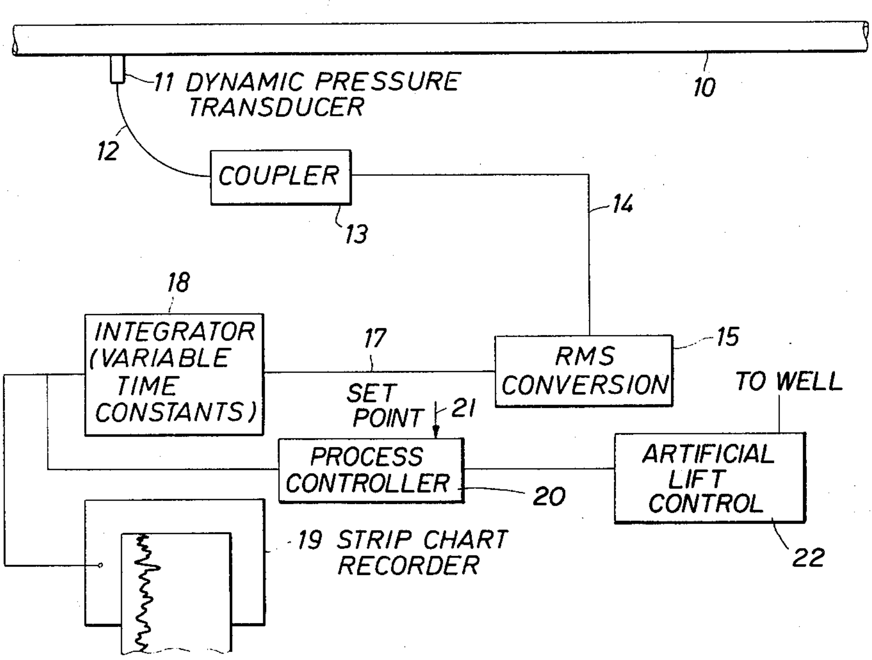
Primary Examiner—Jerry W. Myracle

[57] **ABSTRACT**

A method for determining the liquid flow in a pipe having either slug or two-phase flow wherein the dynamic pressure fluctuations are measured, and converted to a useful signal. The root mean square of the signal is obtained and integrated over a specific time interval to obtain the liquid flow in the pipe.

4 Claims, 8 Drawing Figures



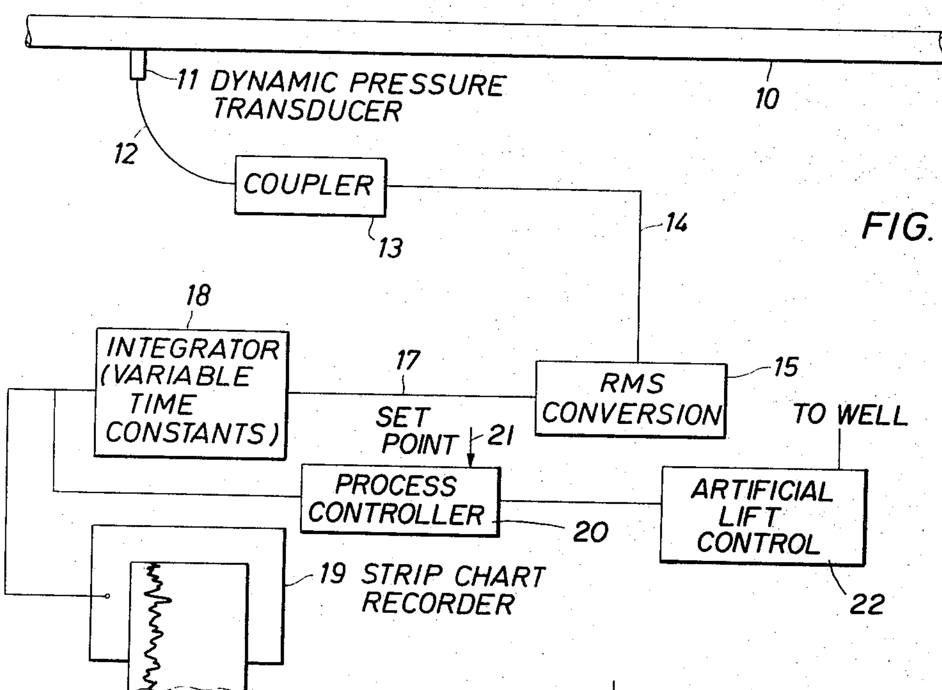


FIG. 1

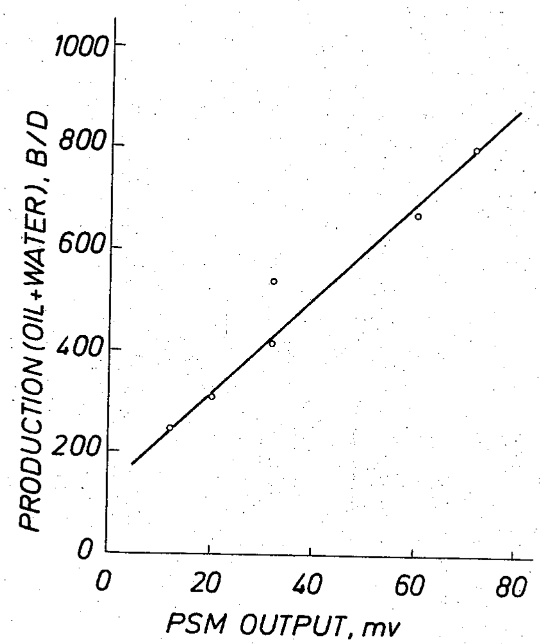


FIG. 7

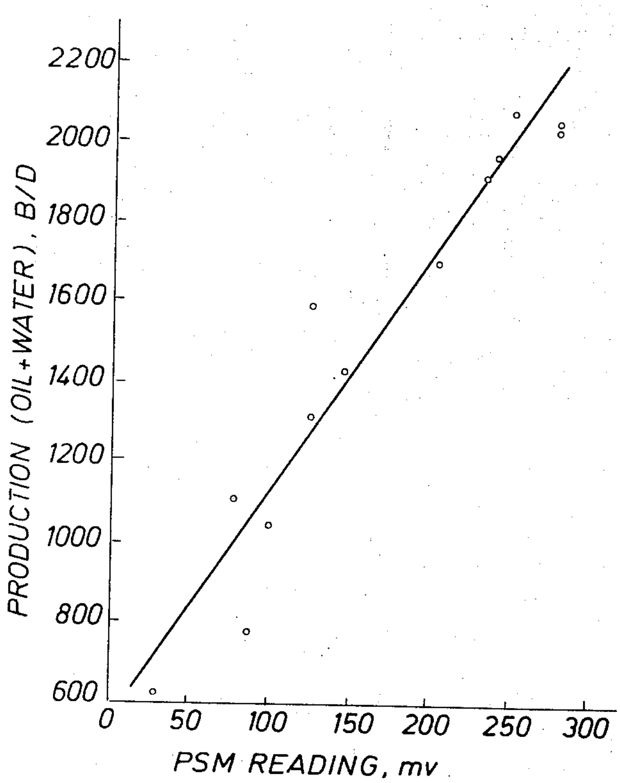


FIG. 8

FIG. 2 TURBULENT ENERGY 1/2" DIA. LINE

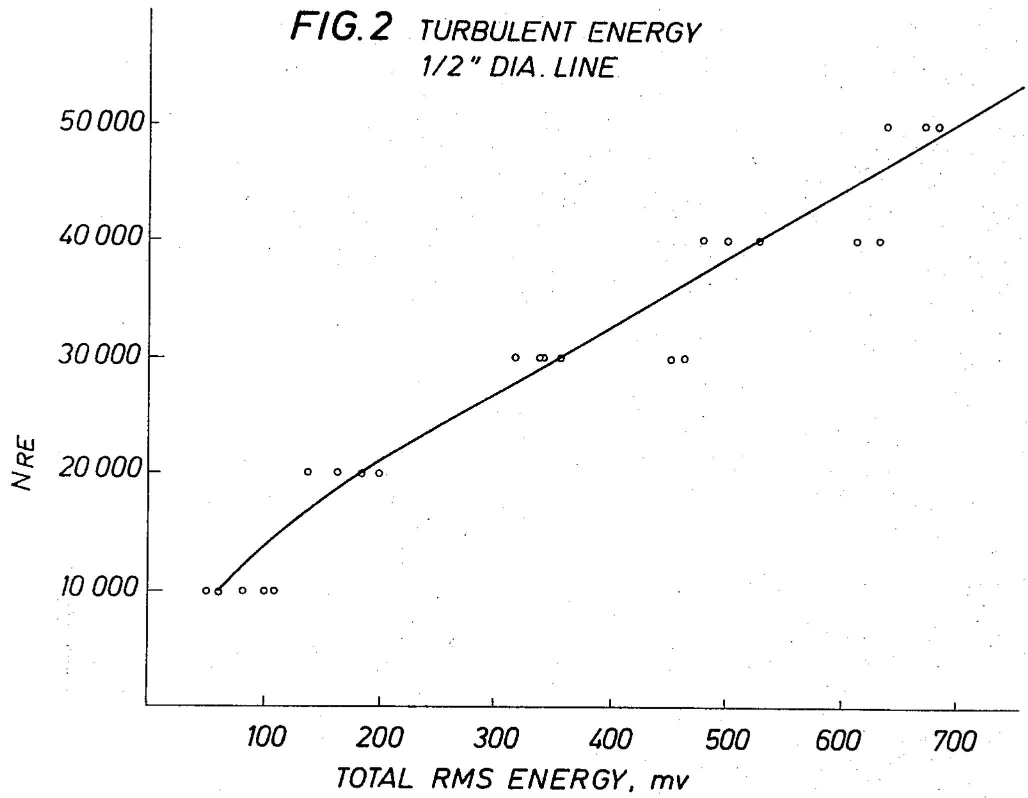
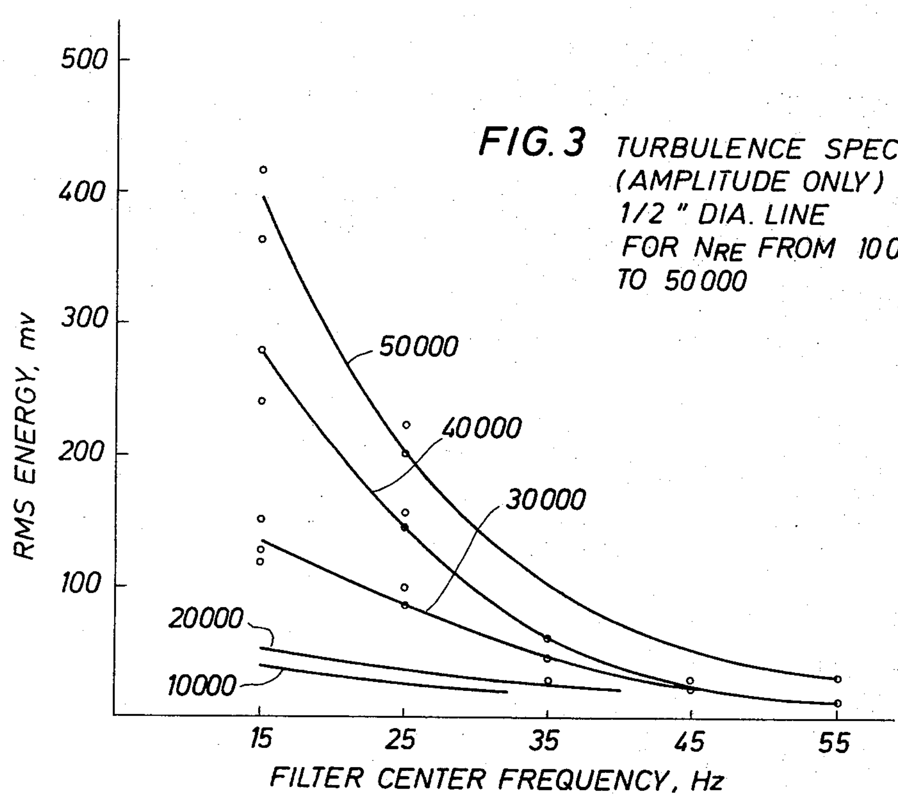


FIG. 3 TURBULENCE SPECTRA (AMPLITUDE ONLY) 1/2 " DIA. LINE FOR N_{RE} FROM 10 000 TO 50 000



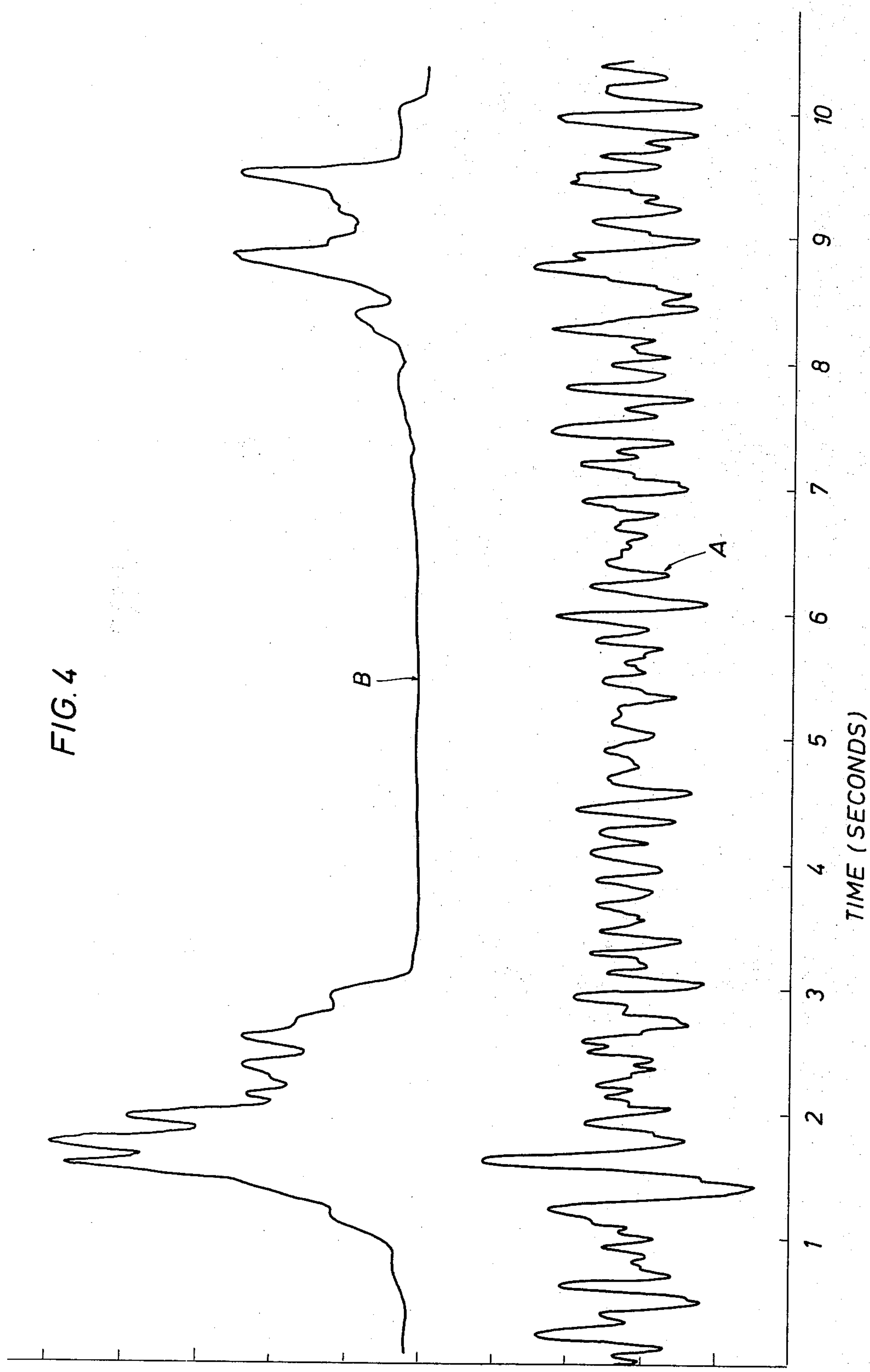


FIG. 4

FIG.5

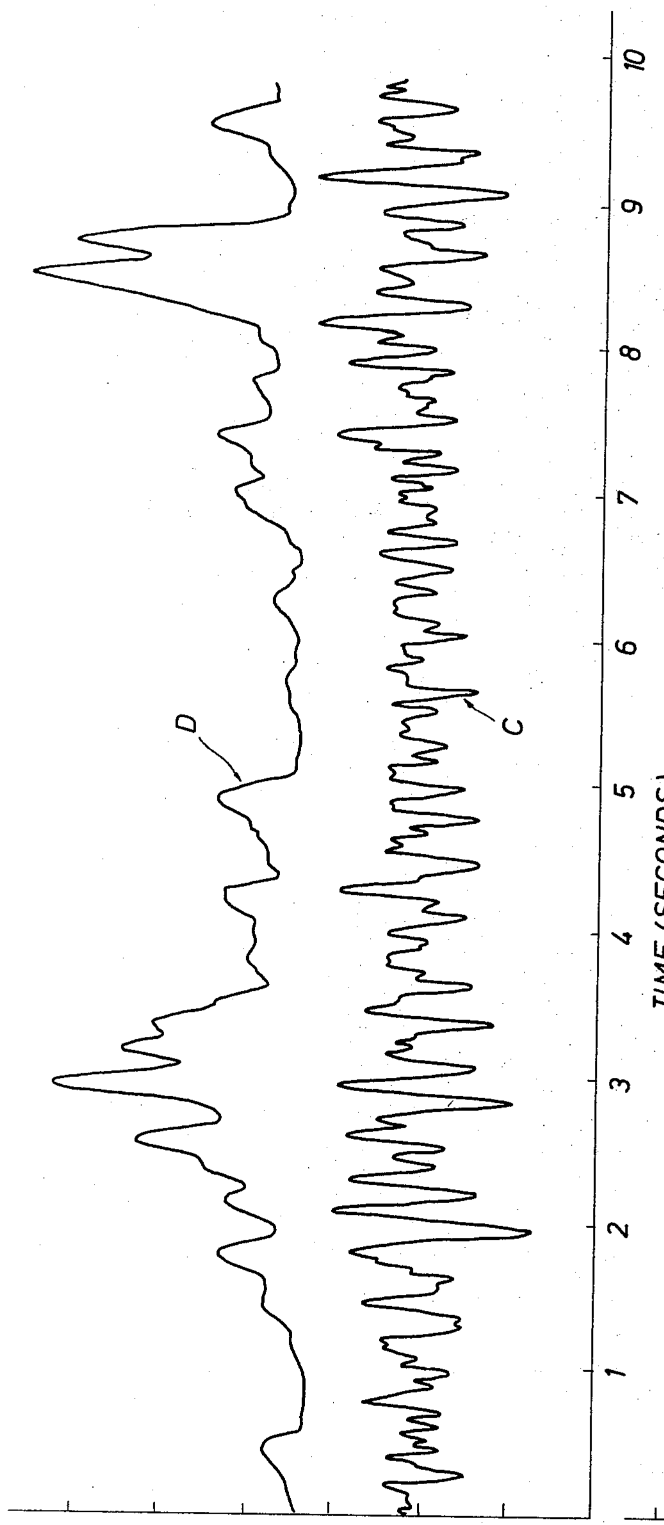
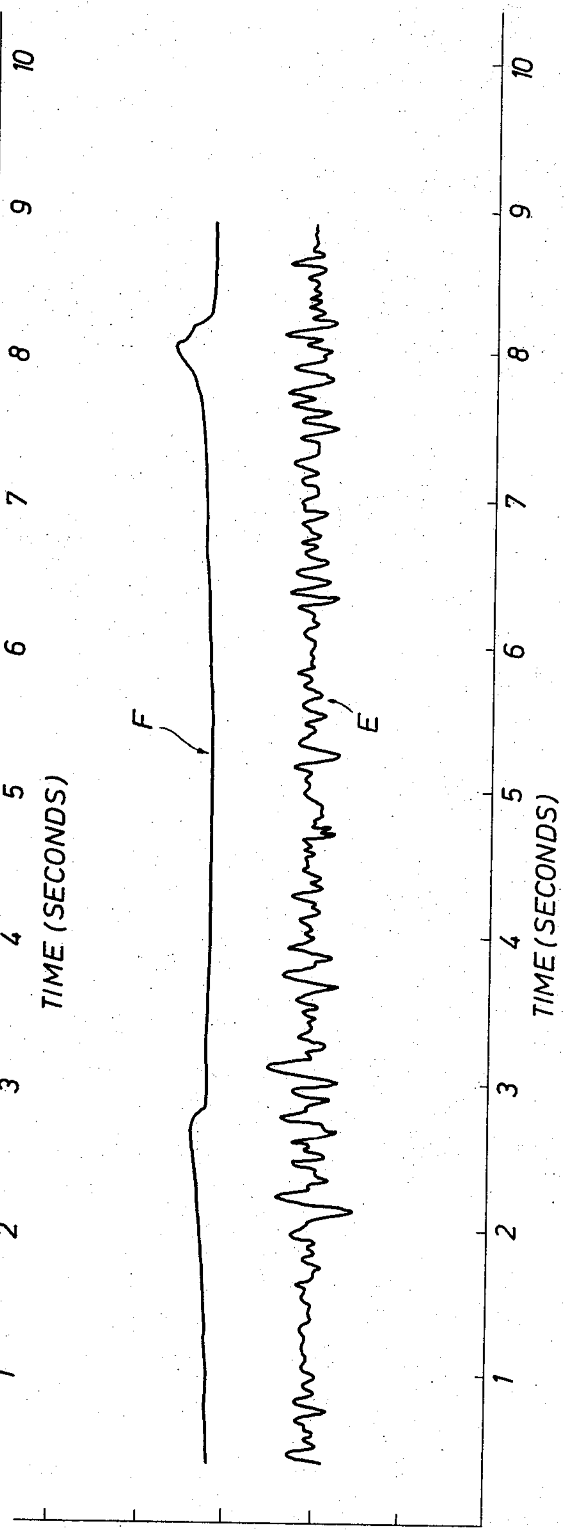


FIG.6



METHOD FOR DETERMINING LIQUID PRODUCTION FROM A WELL

BACKGROUND OF THE INVENTION

The present invention relates to a method for determining the liquid flow from a well and particularly the liquid flow in a well having slug or two-phase flow. In a large portion of the producing oil wells, some means of artificial lifting is used. For example, the well can be pumped by either a rod driven pump or hydraulic pump or a gas lift system can be used. In the case of gas lift, gas is transmitted down the well under high pressure and used to lift the oil to the surface. In a gas lift well the oil flows to the surface in the form of discrete slugs separated by gas. Of course, in the case of a pumped well, the oil is pumped directly to the surface in a solid fluid flow until the well is pumped dry at which point the pump will either pump air or be shut down.

In all of the above-described artificial lifting systems, it is desirable to know the quantity of liquid actually produced at the surface. For example, in the case of a gas lift well, if too much gas is transmitted to the bottom, the gas will tend to disperse into the liquid phase and reduce the quantity of the oil lifted to the surface. Likewise, if too little gas is transmitted to the bottom of the hole, the quantity of oil lifted to the surface will be smaller. Thus, the adjustment of the gas lift system for the optimum flow of gas is highly desirable to obtain the maximum efficiency of the system. Similarly, in the case of pumped wells, it is desirable to know when the well has been pumped dry so that the pump can be secured until the well again fills with liquid. This, of course, conserves the energy required for driving the pumping means and improves the efficiency.

BRIEF DESCRIPTION OF THE INVENTION

The present invention is based on the discovery that the variation in the fluid pressure during turbulent flow can be correlated with the total liquid flow in a slug or two-phase flow system. It has been confirmed that the variation in pressure is linear for turbulent flow and particularly for Reynolds numbers above approximately 20,000. The pressure turbulence of a liquid is 10 to 100 times that of gas flow, thus the device is relatively insensitive to gas flow. While the accuracy of the system is in the neighborhood of plus or minus 10 percent, this is satisfactory for many operations. This is especially the case where the information is used to improve the production efficiency of an oil well and is not relied upon for determining the actual production of the wells for accounting purposes.

The apparatus used in practicing the invention consists of a piezoelectric dynamic pressure transducer, a circuit for converting the electrical signal from the transducer to a RMS signal and an integrating network for integrating the RMS signal. The pressure transducer responds to fluctuations above approximately 1 Hz and does not respond to static pressure or slow changes in line pressure, vibrations, or temperature. Thus, the transducer produces an output signal only when a liquid slug passes the transducer and does not appreciably respond to gas flow. The RMS signal is related to the actual energy in the signal which can be used to determine the total liquid flow and one only needs to integrate the RMS signal over a time period to obtain an indication of the total flow from the well.

The signal from the circuit indicating total flow can be used for adjusting the gas flow in a gas lift well or the length of the pumping periods in a pumped well. Of course, it is also possible to use the system for measuring the flow of water into an injection or disposal well. Normally, injection wells are designed for a certain flow rate and a change in this flow rate indicates either a change in the reservoir into which the water is injected or a breakdown in the injection equipment at the surface.

BRIEF DESCRIPTION OF THE DRAWING

The present invention will be more easily understood from the following detailed description taken into conjunction with the attached drawings in which

FIG. **1** is a blocked diagram of the apparatus used for practicing the method;

FIG. **2** is a plot of the total RMS energy versus Reynolds numbers;

FIG. **3** is a plot of the RMS energy versus various frequencies;

FIG. **4** shows the actual signal produced by the transducer and the corresponding RMS signal;

FIG. **5** is a signal from a second well showing the transducer signal and the RMS signal;

FIG. **6** shows the same well as in FIG. **5** but the well has been pumped off and there is no liquid flow;

FIG. **7** shows the relationship between liquid production and the RMS signal; and

FIG. **8** shows the relationship between liquid production and the RMS signal for a separate set of values.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to FIG. **1**, there is shown a block diagram of a system suitable for practicing the method of this invention. There is shown a fluid production line **10** which can be the production line from an oil well under some manner of artificial lift as, for example, a gas lift, a rod pump well, a hydraulically pumped well, or submersible pumped well. The production line **10** can also be the injection line for an injection well. While the above terms "oil well" is used to simplify the description of the invention, the invention is adaptable to any well having two-phase flow and is not limited to a conventional oil well where the gas to liquid ratio is in the range of 1 to 100.

A pressure transducer **11** is mounted on the production line **10** to sense changes in the pressure of the liquid flowing in the line. Of course, pressure changes will only occur when there is turbulent flow in the line. Turbulent flow occurs in the range of Reynolds numbers 2,000–3,000 although more linear results are obtained at Reynolds numbers above 20,000. Likewise, in case of gas flow where pressure changes are very small, the pressure transducer will not sense the change. Any dynamic type of pressure transducer that supplies an electric signal related to the instantaneous changes in the pressure can be used. For example, a transducer sold under the name Kistler Model 205 H–1 manufactured by the Kistler Instrument Company of Redmond, Washington, can be used. Similar piezoelectric transducer magnetostritive transducers, or magneto electric transducers could also be used. The electrical signal from the transducer is supplied to a coupling device **13** which may be a part of the transducer itself with the coupling device being connected by a coaxial cable **14** to a RMS conversion circuit **15**. The coupling device **13** matches the high impedience signal from the transducer to the imput circuit of the RMS conversion circuit **15**. The RMS circuit may be a traditional volt meter which converts a fluctuating voltage to an RMS signal. The RMS circuit is connected by a lead **17** to an integrator **18** whose output signal is recorded on a strip chart recorder **19**.

The above system can be fabricated from commercially available parts or a specially designed system can be used. The data collected on the strip chart recorder **19** can either be analyzed in the field visually or can be transmitted in the form of digital or analog data to a central location where it can be analyzed in more detail or by sophisticated analysis. Likewise, the signal from the intergrator **18** can be supplied to a simple computer which in turn controls the lift mechanism for the well. For example, the computer may consist of a conventional process controller **20** whose set points **21** is adjusted for the optimum liquid production from the well and whose output controls the lift mechanism. Of course, in the case of a mechanically pumped well, the set point could be adjusted for a minimum liquid flow and when the actual liquid flow from the well falls below the set point, the process controller would secure the pumping unit for a predetermined time interval to allow the well to fill. The output signal from the process controller **20** is used to control the operation of the artificial left control **22**. The artificial lift control may be the power switch for a pump unit on the flow control for the gas supply in a gas lift well.

Referring to FIG. **2**, there is shown a plot of the value of the RMS signal vs. various Reynolds numbers. As can be seen in the range of Reynolds numbers of 20,000 and greater, the RMS signal is substantially linear. Thus one can use the RMS signal as a measure of liquid flow. Of course, the actual liquid flow in volumetric measurement will be equal to the RMS signal times constant wherein the constant is related to the density of the liquid and the size of the pipeline.

FIG. **3** illustrates the relationship between the RMS energy in the signal and the various frequencies of the signal. As can be seen at approximately 15 Hz there is a large difference between the flow rates corresponding to Reynolds numbers of 20,000 to 50,000. Thus it is possible to accurately determine the fluid flow in the flowline from the variations in the energy level of the RMS signal.

Referring now to FIG. **4**, there is shown a portion of a signal from a gas lift well wherein the signal A represents the signal produced by the transducer while the signal B shows the RMS signal. In addition, there is shown the time interval of 1 second. If one intergates the RMS signal, one will obtain the total flow from the well. Also, one can count the times that the RMS signal has values above the base line which indicate the number of slugs of liquid passing through the production flowline. From this information one can determine whether the gas flow should be increased or decreased.

FIG. **5** illustrates signals similar to those shown in FIG. **4** but for a well having a high flow rate. As can be seen in signal B of FIG. **4**, the pressure pulsations are almost continuous and the intervals between the slugs of liquid and the gas slugs are considerably shorter. Still it is possible to count the slugs of liquid and take appropriate action.

FIG. **6** illustrates the same well as shown in FIG. **5** but the condition where substantially all the liquid has been removed from the reservoir. In this condition, there is substantially no liquid and RMS signal is substantially zero. This would indicate substantially zero production from the well. While the RMS signal does have slight amplitude excursions, the total integrated area of the signals would be well within the plus or minus 10 percent accuracy of the instrument. As explained in the introduction, this accuracy is within the requirements for controlling the production of the average oil well.

FIGS. **7** and **8** illustrate the relationship between the RMS signal output in millivolts and the production of liquids, i.e., oil plus water in barrels per day. From these figures one can correlate the data recorded on the strip chart recorder of FIG. **1** to obtain an actual reading in barrels of liquid per day.

We claim as our invention:

1. A method for differentiating between liquid and gas flow in a well producing hydrocarbons and having two-phase flow; said method comprising:

measuring at the surface fluctuations in the pressure of turbulent fluid flow from said well and measuring the RMS value of the fluctuations in the pressure; and

integrating said RMS signal occurring in a predetermined time period to obtain the liquid flow from the well.

2. The method of claim **1** wherein the pressure fluctuation signal is an electrical signal and the energy is measured by taking the root mean square of the signal.

3. The method of claim **2** wherein the well is a gas lift well and pressure fluctuations below two cycles per second are not measured.

4. A method for determining total liquid flow in a well having turbulent flow comprising:

measuring at the surface fluctuations in the pressure of liquid flow in said well and measuring the RMS value of the fluctuations in the pressure; and

integrating said RMS signal occurring in a predetermined time period to obtain the liquid flow in the well.

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