A Portable System for Acquiring and Analyzing Dynamometer Data

James W. Jennings, Texas A & M University
James N. McCoy, Echometer Company
Bill Drake, Echometer Company

Abstract

A new portable system has been developed for both the acquisition of dynamometer data and the subsequent analysis of that data. This equipment may also be used to determine acoustic fluid levels and obtain surface acoustic pressure-transient data. This paper contains a brief description of the hardware system, how the data is analyzed, and how the data is interpreted to obtain the diagnostic bottom hole dynamometer cards and surface torque analysis. Two features of the system include a new load cell concept and a displacement transducer.

The loads are taken with a normal strain gauge which can be of the cable transducer type that is fastened to one of the bridle cables or of the conventional horseshoe type transducer that is placed on the polished rod below the polished rod clamp. The displacements are obtained by recording acceleration from an accelerometer contained in the selected transducer, which is later integrated twice to obtain displacement at the surface. An appropriate method is included in the software to evaluate the constants of integration which result from this integration. Motor current is also recorded when the determination of counter balance is desired. Conventional methods are used to calculate the bottom hole card. The operation of the equipment will not be described here, that may be learned from the operators manual associated with the equipment, rather this paper will deal with how the equipment works and how it may be effectively used.

Description of Equipment

The equipment discussed in this paper is composed of an integrated system of transducers and data acquisition and processing components. Figure 1 shows a diagram of these components. The transducers used to measure polished rod load contain strain gauges and accelerometers. Another transducer is used to measure motor current. The data acquisition equipment is a fast analog/digital convertor which converts the measured voltages to digital data. The data processing component is a lap-top PC type computer. The data is filed by the computer and made available for analysis.

Two types of transducers are available at this time, one is a cable transducer which is fastened temporarily to one of the bridle cables and a horseshoe type transducer which is placed on the polished rod between the permanent polished rod clamp and the carrier bar. These are shown in Figures 2 and 3. These transducers are used to measure load and vertical acceleration at the polished rod. The load is measured with strain gauges and the acceleration is measured with a small accelerometer. The cable transducer, Figure 2, measures load by measuring the bending of the bar of the transducer similar to the way the weight indicator works on a drilling rig. The horseshoe transducer, Figure 3, measures load by measuring the shortening of three internal rods due to the compressive load. In both cases strain gauges are the measuring elements for loads.

The electrical signals from the transducer elements, strain gauges and accelerometers, are conditioned and fed to the input of the A/D converter. The A/D converter acquires data at 20 samples/second, 12 bit, auto-ranging mode for this application. This implies an accuracy of about 10 pounds in load. In addition to the strain gauge and accelerometer data, motor current may also be recorded. All three pieces of data are taken in less than 5 milliseconds, and therefore are assumed to be taken simultaneously. The time between samples being fixed at 1/20 of a second provides the accompanying time information needed for the analysis.

Acquisition of Data

Once the transducers are properly attached to the pumping unit and the equipment connected and checked, the acquisition of data may begin. However, the data available for acquisition is normally displayed before the decision is made to save the data. In the display mode, the screen of the computer works much like an oscilloscope in that the data is plotted as a function of time. Figure 4 shows an example of load data as it is being obtained in real time. The operator can verify that the proper data is being obtained by observing the associated plots on the screen. Plots of load, acceleration, or motor current may be obtained in real time. Figure 5 shows acceleration as a function of time. All pertinent identification information as well as the current time of day is shown on the screen. In addition, the scale of the data is displayed. The operator indicates his desire to capture data by pressing a key on the computer; one minute of contiguous data will be collected. Even though only load information is being displayed on the screen, acceleration and motor current data are also obtained. After the one minute of data is obtained, the operator may proceed to dynamometer analysis, or optionally repeat the data acquisition process. One minute of data will normally result in five or more complete cycles.

Calculation of Polished Rod Position

The operator initiates the calculation of the polished rod position as a function of time by pressing the appropriate key on the computer. The algorithm which performs this operation is the result of careful study. It is fairly obvious that if one integrates acceleration data twice, the position information will be obtained. As it turns out, it is not quite that simple. There are technical considerations such as sampling rate, filter frequency, and determination of the constants of integration.

As mentioned above, the sampling rate used in this system is 20 samples/second. The resulting data is filtered with a digital filter at about 8 hz, the theoretical maximum being 10 hz for the sample rate of 20 hz. The filtered data is then integrated once, which yields the velocity function. This integration is a straightforward digital integration. The constant of integration for this step is determined so as to force the average velocity over an integral number of cycles to be zero.

A second integration is performed, resulting in polished rod position as a function of time. The constant of integration for this step is determined by requiring that the polished rod minimum value is the same for each cycle. That is the bottom of the stroke on each cycle is the same value, arbitrarily set to zero in this case. During this process, the pumping rate (strokes/second) is calculated. Thus the polished rod position throughout the stroke is obtained from twice integration of acceleration data and use of an acceleration sensitivity constant. The operator normally enters the polished rod stroke into a permanent well data file. The calculated polished rod position is fitted to the stroke length entered in the well data file. If the calculated and measured polished rod strokes vary by more than 10%, the software alerts the operator to check the measured polished rod stroke, and if the measured polished rod stroke length is correct, the software prompts the operator to enter a computer calculated accelerometer coefficient which will result in recalibration of the accelerometer. The bottom of each stroke is then shown by a vertical line on all succeeding plots of time varying data. Plots of velocity and position as functions of time which result from these integration steps are shown in Figures 6 and 7. The integration process does not require any operator intervention, other than a single keystroke on the computer.

Display of Dynamometer Data

Once the velocity and position information is calculated, the operator has two display options. An overlay plot of the several surface dynamometer cards, polished rod load vs. polished rod position, may be made as shown in Figure 8. In addition, the operator may also select the display of detailed information on any single stroke. This is shown in Figure 9.

The single stroke display shown in Figure 9 contains much of the information needed to analyze the operation of the pumping system. Of particular note is the fourth plot on that screen, the calculated or downhole dynamometer card. This pump card is usually much more easily analyzed to determine malfunctions than the surface card. This particular display shows a well that is pounding liquid near the top of the stroke. Other diagnostic information such as peak load and motor current balance may readily be obtained from this figure. The peak load shown on Figure 9 is 16,310 pounds. Examination of the motor current plot shows that the unit is overbalanced. This is indicated by the higher motor current on the downstroke. Ideally the peak motor current on the downstroke should be the same as the peak motor current on the upstroke.

Exporting Data to Other Programs

The dynamometer data of load and position on a single stroke shown in figure 9 can be saved to a data file for exporting to other programs. The file is called WELLNAME.FIL. Data includes load and position at 50 ms intervals during one complete stroke plus other relevant data. This data format is completely compatible with Theta Enterprises programs, (714) 879-8951.

Special Tests

The operator may select to run traveling valve, standing valve, and counterbalance tests if desired. The suggested directions for conducting these tests are included in help screens available when running the tests. For example, the following are the suggested instructions for conducting the traveling valve test:

**** INSTRUCTION FOR A TRAVELING VALVE TEST ****

Pump unit. Stop the unit smoothly and slowly when the polished rod is on the upstroke and is in the upper half of the upstroke. The polished rod is supporting the buoyant rod weight plus the fluid load. When fluid leaks past the traveling valve or the plunger, a decrease in polished rod load occurs. A rapid decrease in the polished rod load indicates a leaking traveling valve or plunger.

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Use the arrow keys to move the indicator along the curve. Note the load is displayed at the bottom of the graph along with the difference between the buoyant rod weight plus the fluid load and the measured load. The buoyant rod weight and fluid load were calculated from information provided in the Well File.

At the start of the traveling valve test, there is a display of load data versus time. Data is not being acquired, only displayed until the operator hits a key on the computer. The purpose of this data display is so that the operator can be sure that the unit is operating in a stabilized condition. With a keystroke, data acquisition begins and the operator has one minute to complete the traveling valve test. A plot of this activity is shown in Figure 10. Notice on Figure 10 that the computer displays the buoyed rod weight plus the fluid load on the pump.

The load during the traveling valve test should be approximately equal to this value if the pump intake pressure is low. Also displayed is the buoyed rod weight. The operator may move a vertical line indicator on the screen back and forth to mark the position in which he wants the traveling valve load to be determined. All pertinent values are displayed numerically below the plot. In the example shown, the traveling valve load was decreasing after about 38 seconds, an indication that the traveling valve and/or plunger are leaking slightly.

The standing valve test is performed in a similar fashion with the following instructions:

**** INSTRUCTIONS FOR A STANDING VALVE TEST ****

Pump the unit. Stop the unit smoothly and slowly when the polished rod is on the downstroke and is in the lower half of the downstroke. If the downhole card indicates low pump fillage, the polished rod must be stopped near the very bottom on the downstroke. The fluid load is supported by the standing valve. If the standing valve leaks and will not support the fluid load, the fluid load is transferred to the traveling valve and an increase in the polished rod load occurs.

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Use the arrow keys to move the indicator along the curve. Note the load is displayed at the bottom of the graph along with the difference between the measured load and the buoyant rod weight. The buoyant rod weight was calculated from the rod string information provided in the Well File.

As the unit is running, the operator is shown a display for the load information versus time. Upon pressing a key he has one minute in which to complete the standing valve test. Once the data is acquired and displayed as shown in Figure 11, the operator may move the indicator mark back and forth to mark the appropriate time for the standing valve load. In the example given, the indicator is at 23 seconds.

The counter balance measurement may also be made at this time. This is done with a procedure very similar to the traveling and standing valve tests. If the unit is reasonably in balance the following method is adequate to obtain counter balance effect. Specifically, the method will work if the counterbalance effect is not off more than 1/2 the fluid load.

**** INSTRUCTIONS FOR A COUNTER BALANCE EFFECT TEST ****

Pump unit. Start data acquisition by hitting F2 at 0 time on your watch. Stop the unit on the upstroke when the cranks are horizontal. Hold this position with the brake. Release the brake momentarily. If the cranks move upwards, reset the brake immediately. Continue to momentarily release the brake. As the liquid leaks past the plunger, the polished rod load will decrease and the cranks will remain stationary in a horizontal position. The cranks will probably be at rest for only a few seconds. Note the PRECISE TIME that the cranks are stationary with the brake released. Redo this test if necessary. Position the indicator on the screen at the time of stationary horizontal cranks (without brake) and hit [ENTER] to record the measured counter balance effect load at that time. Generally, this technique will permit counter balance effect load determination without auxiliary equipment. This test will not work if the weights are too far from the proper setting or if the pump is in bad condition.

Figure 12 shows the counter balance effect test. The cranks remained stationary with the brake off at 73 seconds into the test. Figure 13 shows the surface card with the CBE displayed.

Discussion of Load Transducers

As described earlier, two different transducers are available for obtaining the load information. They are shown in Figures 2 and 3. Of the two, the horseshoe transducer is the most accurate. However, the operator must place this device between the carrier bar and polished rod clamp before running the test. This is fairly easy to do, but does require supporting the rod load on the well head while the carrier bar is lowered (by lowering the horsehead) to create approximately 3 inches of space in which to install the transducer. This step requires an additional polished rod clamp be placed on the well for this purpose. So even though the horseshoe transducer is more accurate, it does require additional time and effort to install.

The cable clamp is very easy to install on one of the bridle cables, however it has been found to be less accurate than the horseshoe clamp. Experience has shown that the accuracy is quite adequate for most diagnostic purposes however. The inaccuracies come from several factors:

1. The load in the two bridle cables may differ by as much as 15%.
2. Different size and age of cable gives slightly different loads.
3. To a small degree, the readings from the cable transducer depend on the technique in installing the device.

Development is continuing on the cable transducer concept to further improve what is already a very useful device.

Printing Analysis Screens

Software prompts the operator to save analysis screens for later printing. Figures 8, 9, 10, 11, 12 and 13 can be saved to files which can either be printed from the well analyzer computer using an attached printer or the files can be exported by floppy disk to another computer for analysis and printing.

Findings

1. The cable transducer is a useful device that offers the ability to easily acquire loads for a surface and downhole pump card.

2. Position can be obtained by twice integration of acceleration data. The compact and inexpensive accelerometer is convenient to use and less expensive than conventional string position indicators.

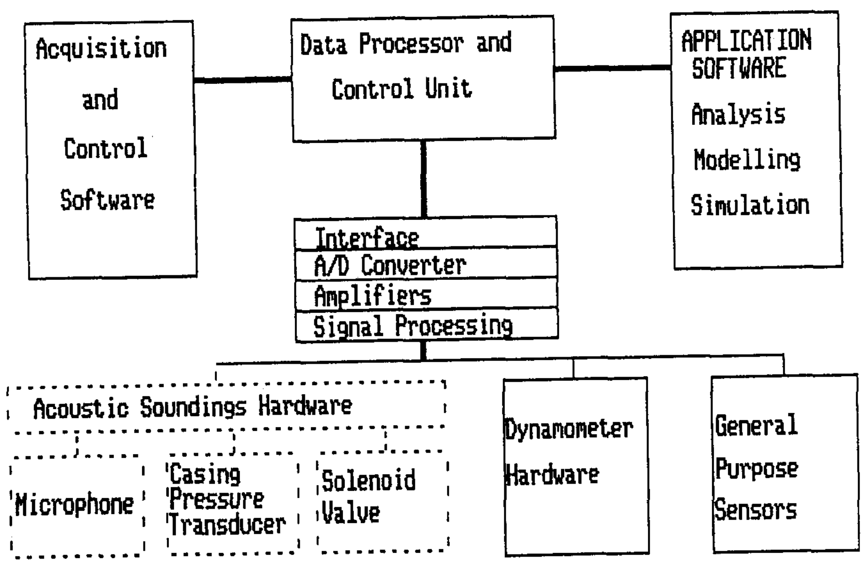

Figure 1

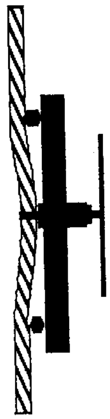

Figure 2 - Cable transducer

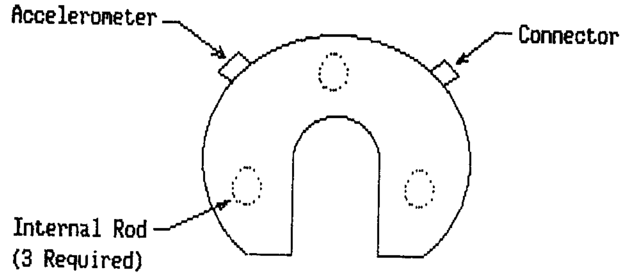

Figure 3 - Horseshoe transducer

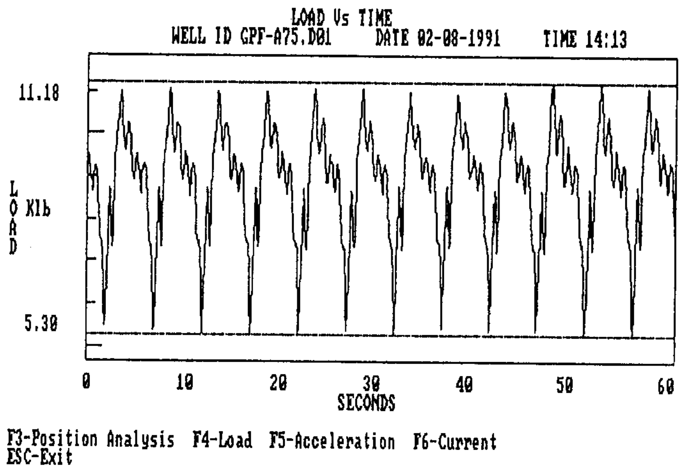

Figure 4

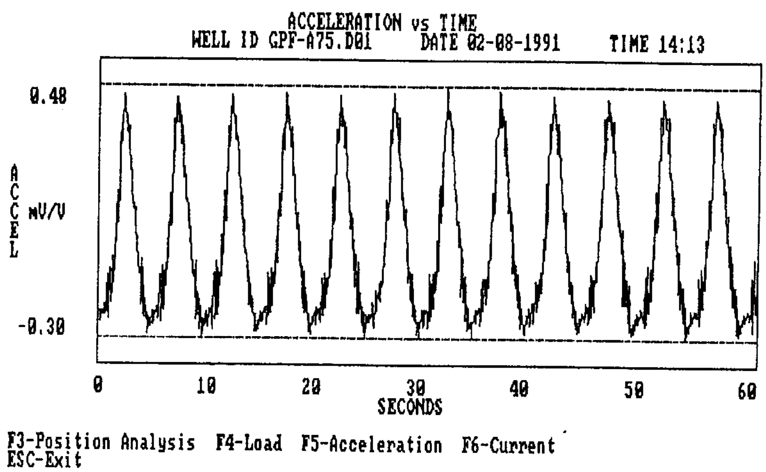

Figure 5

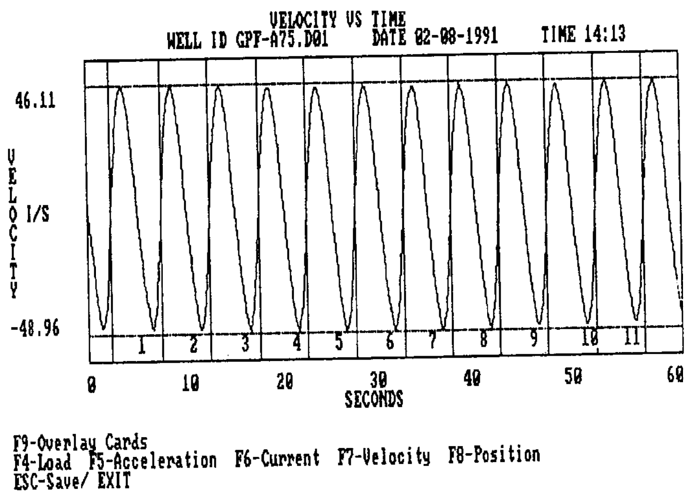

Figure 6

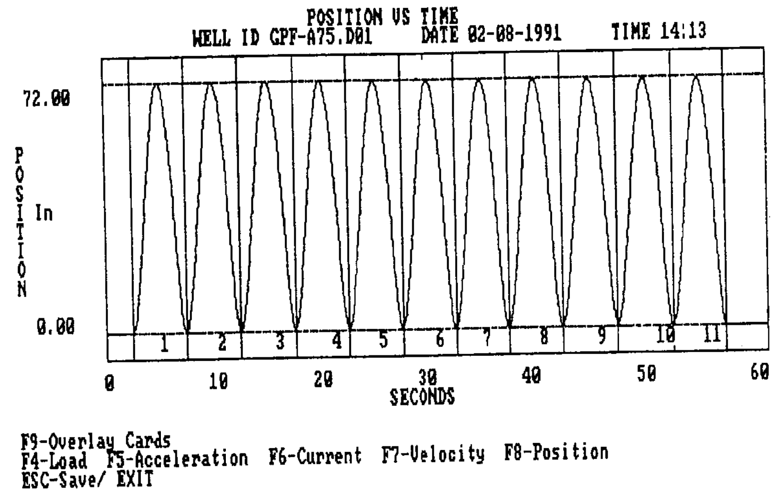

Figure 7

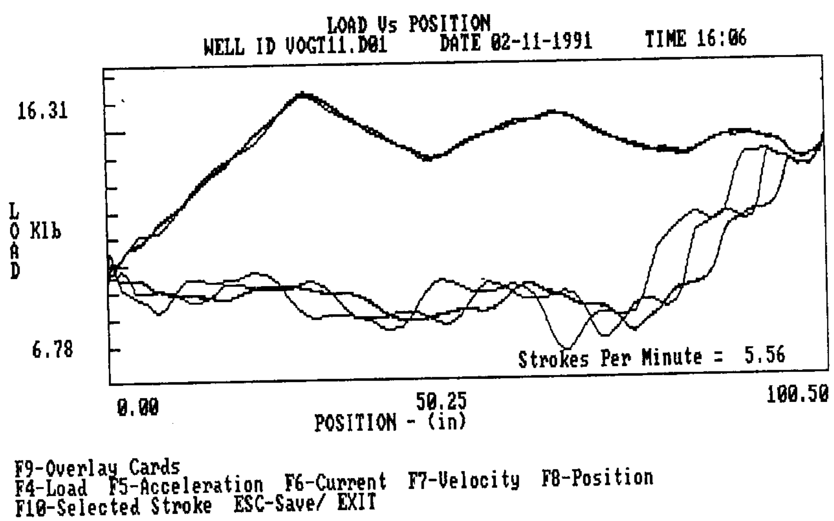

Figure 8

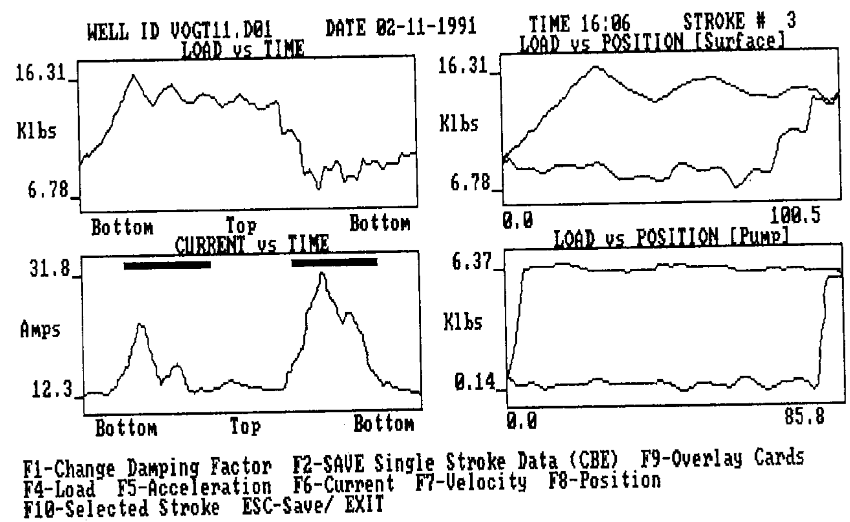

Figure 9

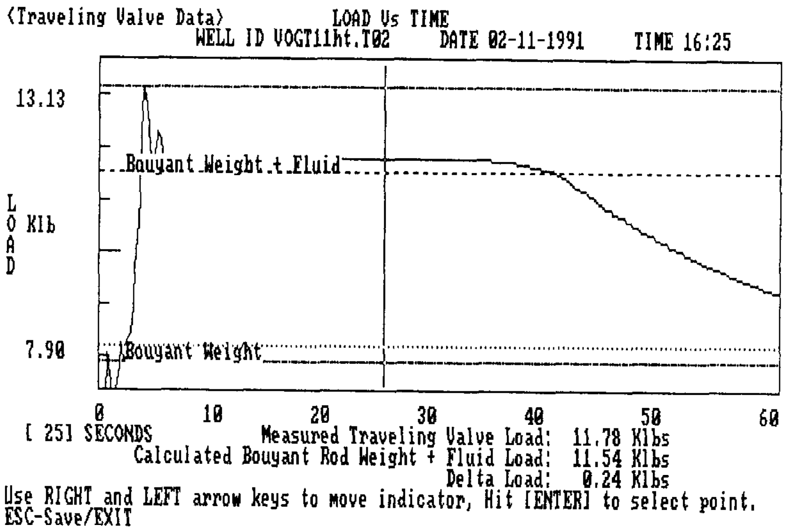

Figure 10

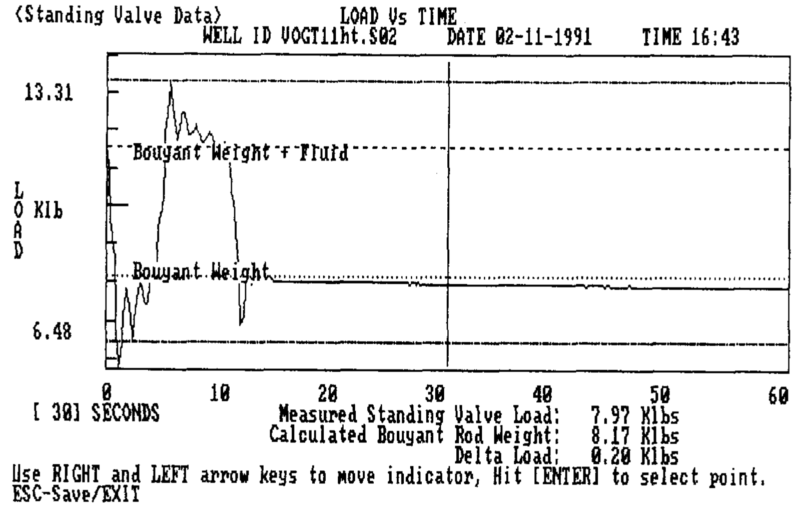

Figure 11

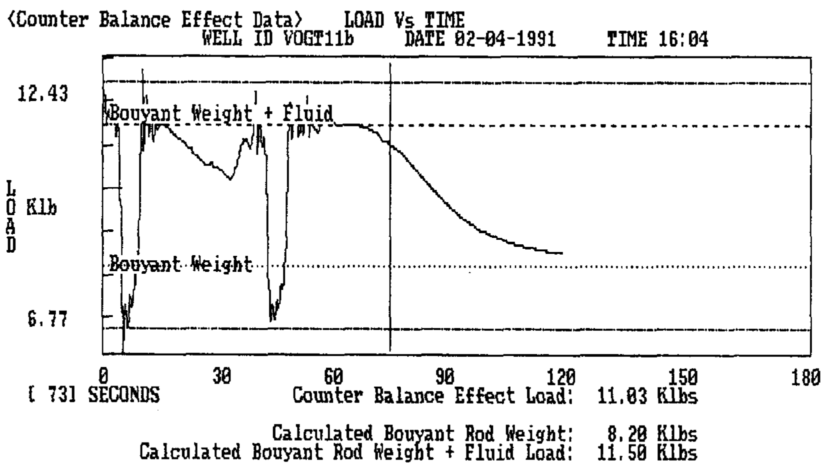

Figure 12

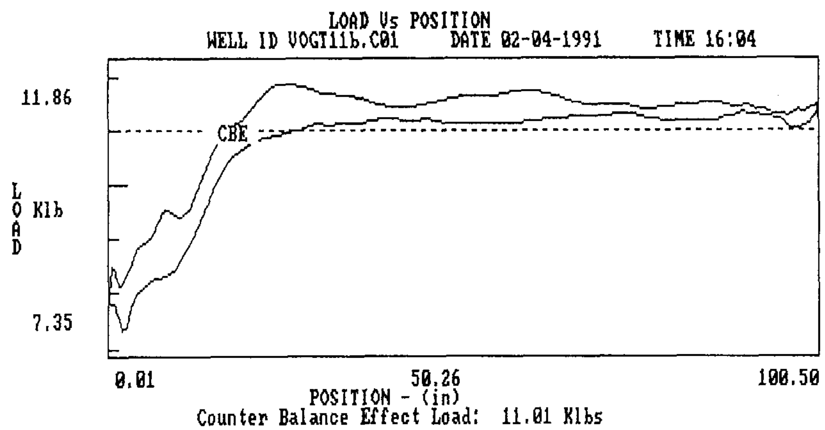

Figure 13