DOWNHOLE DYNAMOMETER UPDATE

Glenn D. Albert
ALBERT Engineering

The Downhole Dynamometer is a tool designed for making dynagraph measurements at any point in the rod string. The tool is completely sealed, battery-operated, and microprocessor-controlled to sample axial load, position, lateral acceleration, fluid pressure, and temperature at preprogrammed times and sampling rates and to store the data digitally in a non-volatile memory (Figure 1). Load is measured at three points spaced radially equidistant around the body of the tool enabling the derivation of bending and buckling loads. Rod velocity and acceleration are also measured.

The tool is used in the industry as a diagnostic device and to validate predictive and diagnostic codes. Any number of tools can be used simultaneously at different points in the string. 1994 was a maturing year for the tool. This presentation one year ago was devoted to the evolution of the downhole device. The focus this year is on the present state of the tool, calibration, accuracy and how to use it.

Calibration and Accuracy

The following figures illustrate the accuracy of measurements as determined by laboratory calibrations. In each case the data measured by the tool under test is plotted versus that measured from independent calibration transducers collected simultaneously by a set of electronics developed just for calibrating.

Figures 2, 3, and 4 illustrate the linearity of each of three load channels on a single tool. The calibration transducer (X axis) is a precision load cell placed in series with the tool under test, and the stimulus is provided by a hydraulic cylinder. Figure 5 shows a similar relationship for the pressure transducer versus applied pressure.

Figures 6, and 7 show the accuracy of the tool-derived position, at two different pumping rates, by plotting it on a time scale along with the actual position. The stimulus for this calibration is a laboratory apparatus designed to simulate pump motion with a 100" vertical stroke, and the actual position is measured on a string pot. Figure 8 includes the velocity and acceleration data which are also available on any downhole test. Also, the derived position signal is not adjusted for the filter phase delay which is adjusted in the two other figures. The sampling rate for each of these three graphs is 50 samples/second.

User Application

To run a downhole test, the user's needs are first listed in terms of which combinations of signals are to be sampled, how often, specifically which days and times, and at what sampling rates (more detail is provided in the next section). This is generally an iterative process and is extremely flexible. Once the schedule is defined, the tools are programmed, prepared and shipped to the user. The user then installs the tools in the rod string, much like any other section, and leaves them in the operating well the prescribed period of time. Surface measurements are usually made and can be easily coordinated with those being made dowhhole by the schedule.

At the end of the test the tools are returned for data recovery and generation of graphs. The data is also available in disk file format. Since the graphs and any other information that come out of a test are the sole property of the user, no graphs are presented here. At least one other paper presented at this conference will contain graphs generated using the tools, and will reflect the standard data quality and graph format.

Data Storage Capacity

The amount of data collected is limited by the total capacity of the digital memory. Tradeoffs can be made between the sampling rate, number of signals sampled, and total time of sampling to arrive at the best solution for a given application.

The total size of the data storage space is around 500,000 bytes. Each channel sampled requires two bytes of data storage space per sample. There are eight possible channels to sample; three load channels, one position channel, one pressure channel, one temperature channel, and two lateral acceleration channels. For a given sampling period any number of these channels can be selected.

Sampling rates are selectable from 5 samples/second to 75 samples/second and there are two fixed sampling rates which are one sample/second and one sample/minute. If multiple channels are selected the sampling rate applies to all channels simultaneously.

As an example, if six channels were sampled at 50 samples/second there would be storage space for about 14 minutes of data sampling. If the sampling rate were reduced to 20 samples/second the sampling time could be increased to 35 minutes. The total sampling time can be divided up as desired over a period of several days. Nearly any sequence can be defined with combinations of sampling rate, duration, and time of day to sample. A standard option is to maintain a once-per-minute account of the six main channels (all but the lateral accelerations) throughout the test. For a four-day test this amounts to about 70,000 bytes.

Physical Specs

The body of each tool is a Harbison-Fischer, 12" pump extension and the ends are standard 3/4", male HF connectors (see Figure 1). Dynamic load capabilities are in excess of 20,000 pounds. The unit is sealed and the pressure is ported to the pressure sensor through a small hole in one of the flats of the bottom connector. Each tool is 23.25" long by 1.75" in diameter and weighs around 12 pounds. The electronics package has an industrial grade operating temperature limit of 85 C, and the battery capacity provides a maximum test duration of around 10 days.

Summary

Like most tools, this one was developed to meet a need. Most features of the tool are designed to meet the express needs of industry and the improvements that have occurred over the past three years reflect this. An example is the concept of using multiple tools, distributed in the same string to gather synchronous data at many points, as suggested by Russ Ott and Greg Mendenhall.

The electrical and mechanical hardware for this particular design is now very mature and extremely effective for its purposes. To take it a step further, I would like to challenge all those in the industry who are so inclined to think of other problems that might be solved with the aid of a small data acquisition device with the capabilities described in this paper. The maturity of this electronics set can be leveraged into other package designs of nearly any size or shape.

Acknowledgements

I would like to thank the following companies; Mobil E & P, U.S., the Exxon Co., and Amoco, for their suggestions and regular use of the tools over the past few years that have made the Downhole Dynamometer possible. Also Sandia National Labs' Sucker Rod Working Group for sponsoring certain refinements and the construction of five tools that are available for use by industry partners for the purposes of developing an industry-wide data base.

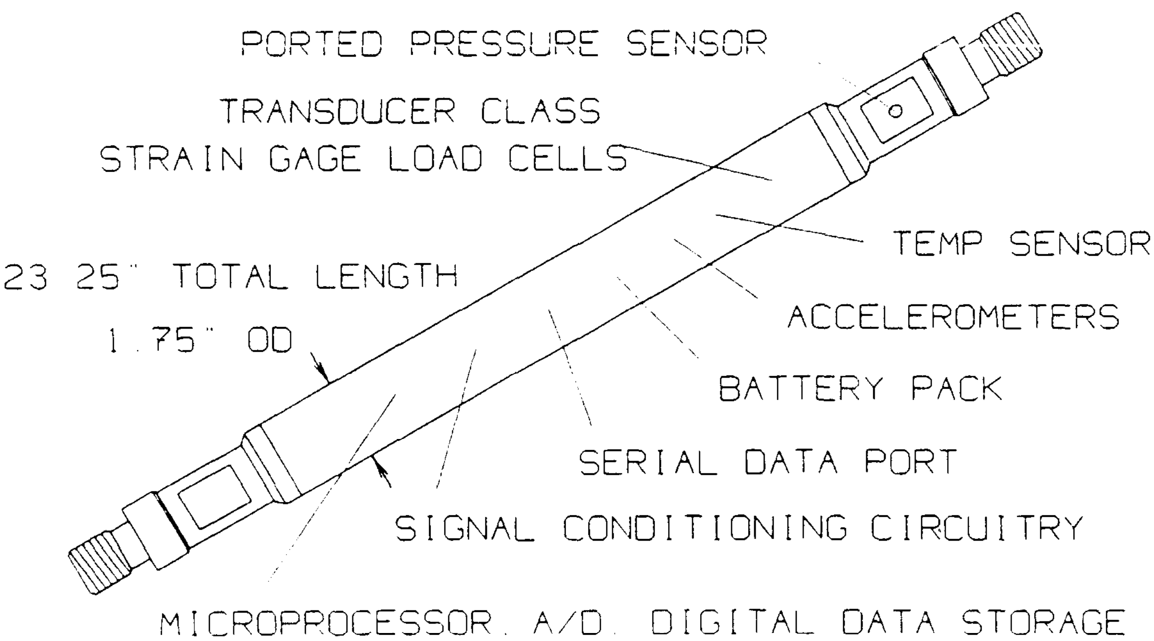

Figure 1 - Downhole Dynamometer

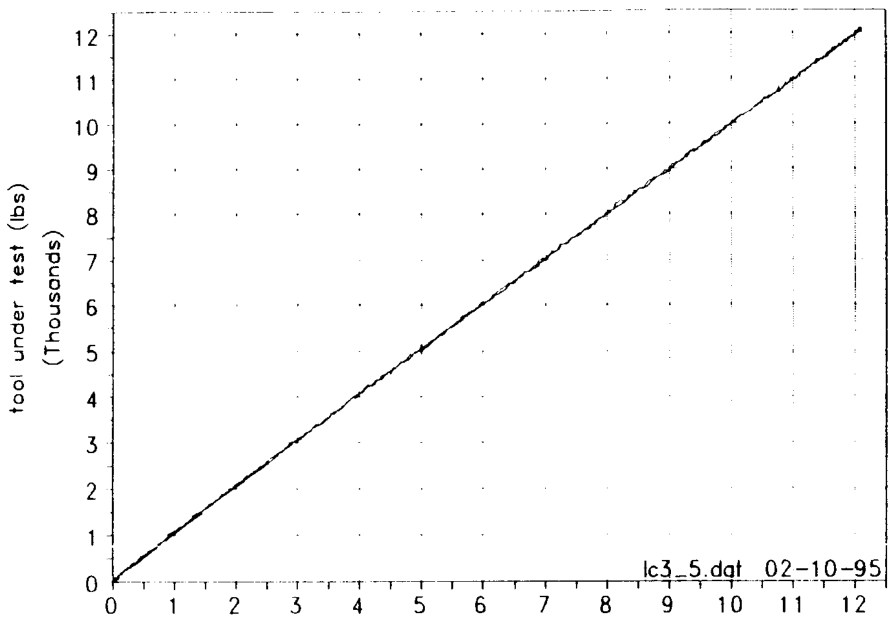

Figure 2 - Load Calibration Channel 1

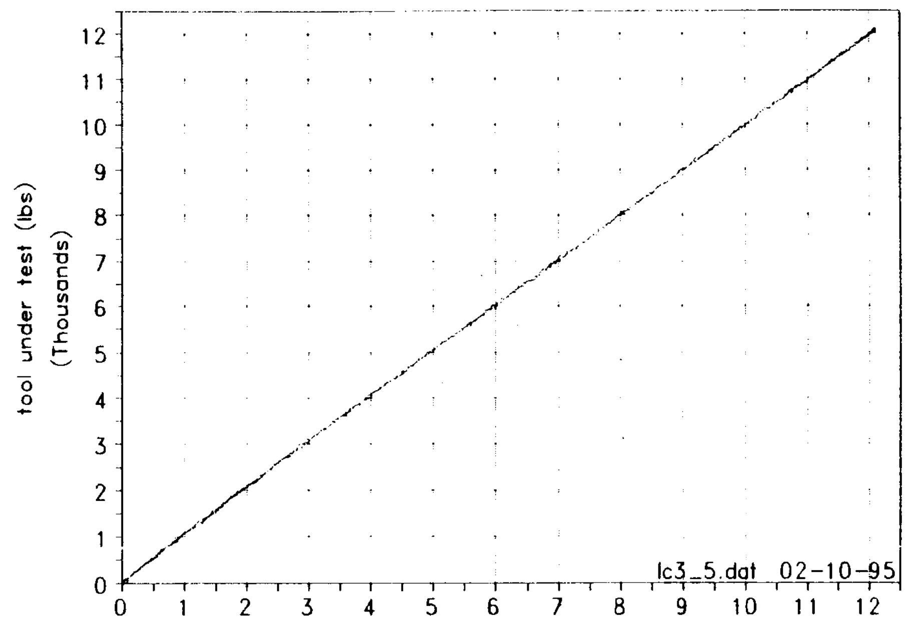

Figure 3 - Load Calibration, Channel 2

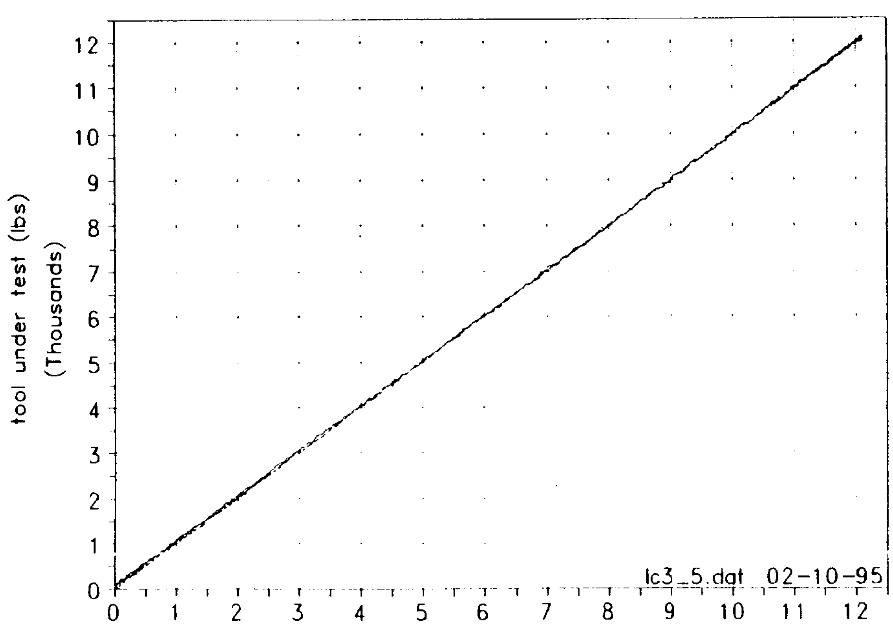

Figure 4 - Load Calibration, Channel 3

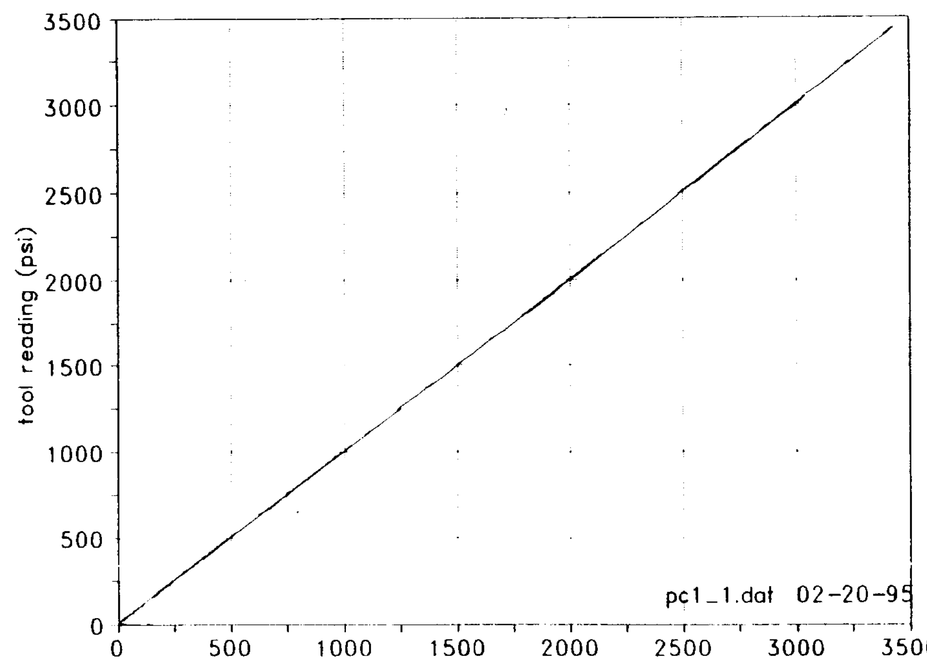

Figure 5 - Pressure Calibration

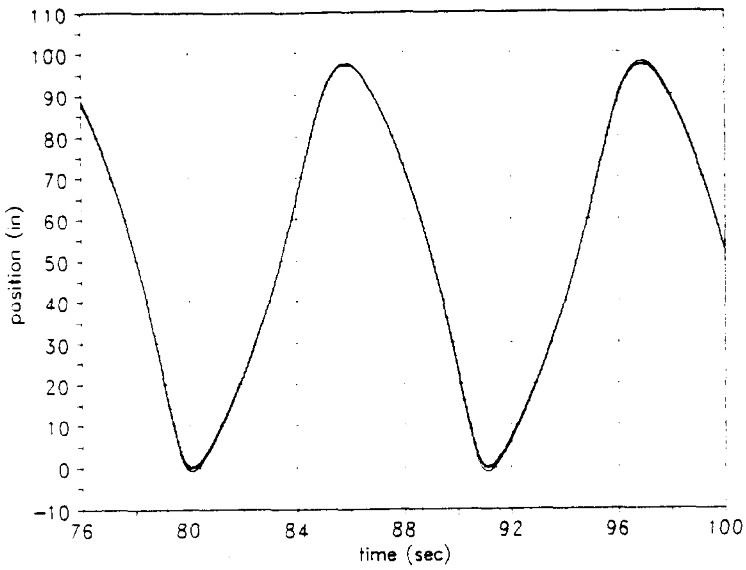

Figure 6 - Derived Position Accuracy at 5.5 spm

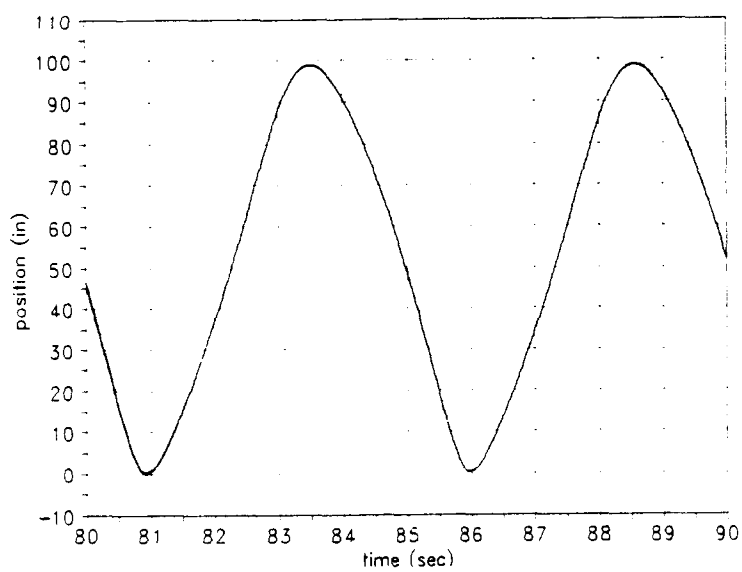

Figure 7 - Derived Position Accuracy at 12 spm

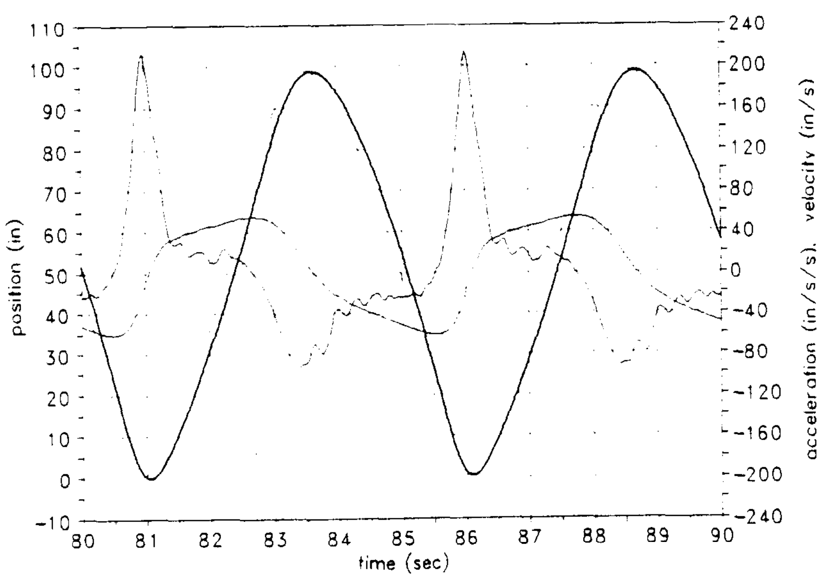

Figure 8 - All Available Acceleration Data