North American Society for Trenchless Technology (NASTT)
NO-DIG 2004

New Orleans, Louisiana
March 22-24, 2004

TensiTrak™ – A tension load and drilling fluid pressure-monitoring device for Horizontal Directional Drilling installations.

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ABSTRACT: Horizontal Directional Drilling tracking systems have seen significant advances in recent years with continually more improvements being brought to the market. Most, if not all, of these developments have focused on the pilot bore process. It is however the installation of the product (conduit) which is the purpose for the whole exercise. Manufacturers of locating equipment have not paid as much attention to this important aspect.

In 1999 Digital Control Incorporated (DCI) was awarded a patent for a tension or load monitoring device which was intended to give a real time indication of the loads being applied to the product during the reaming and pull back process. TensiTrak, which is currently under development, is a product that works with the Eclipse locating equipment. It provides real time information of both the tension load and down hole drilling fluid pressure during the pullback operation.

With the TensiTrak, the rig operator can therefore monitor real time the loads on the product as well as the mud pressure. Having this information decreases the likelihood of damaging the product as well as the possibility of inadvertent returns (frac-outs). Primary benefits of this system are the maintenance of the integrity of the product (it is not being over stressed) and the monitoring of drilling fluid pressure which can be used to minimize damage to road ways or other above or below ground structures that hydraulic pressure can disort.

1. INTRODUCTION

In the fall of 2001, the Belgian National Gas Association (KVBG) mandated the use of a load and pressure monitoring device for all HDD installaltions under their jurisdiction. Their requirements called for the monitoring and recording of tension loads as well as down hole drilling fluid pressure. KVBG's intent was to documentat load and pressure data available for each of their installations. Originally the plan was to implement the regulation by July 1st, 2002.

Allthough KVBG has at this time not yet started enforcing their mandate, DCI embarked on the development of a product to fulfill the KVBG's requirements. This product is the TensiTrak load and pressure monitoring device. This paper will describe the product, its testing and some of the initial field trial results.

2. TENSITRAK CONCEPT

The concept includes a strain gauge and a pressure-measuring device which are connected to a transmitter. The transmitter transmits the load and pressure readings in real time on the frequency used by the Eclipse locating system. The information transmitted includes the pull force, drilling fluid pressure, transmitter temperature and a magnetic signal, which can be used to locate the depth and direction of the monitor.

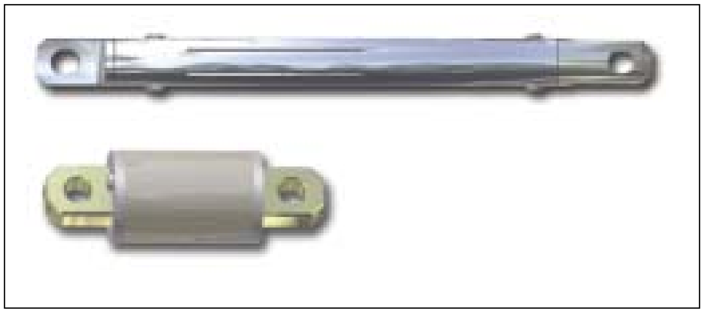

Figure 1. The two current versions of the TensiTrak load and pressure monitor.

The exterior construction of the monitor is similar to conventional HDD transmitter housings with slots that are cut into the body to allow the magnetic signal to be emitted through the housing. The TensiTrak monitor is connected to a sviwel between the reamer and the product. In this configuration, only the load on the product is measured.

3. PRODUCT DEVELOPMENT

The Eclipse locating system is the most flexible design of the various locating systems manufactured by DCI. Because of this, it was the logical candidate to serve as the platform upon which to develop the TensiTrak system. The Eclipse receiver can store large amounts of data which means that not only is the data visible in real time but it is stored until it can be downloaded to a PC for subsequent documentation.

The primary consideration was the real time aspect, giving the operator the ability to monitor the product tension and drilling fluid pressure during product installation. This will give the machine operator the ability to monitor and control the installation and potentially avoid damage to the product or other adjacent structures.

The standard Eclipse transmitter was used as the base for the design of the TensiTrak monitor. The Eclipse transmitter sends out the following data:

Orientation (Roll)
Inclination (Pitch)
Temperature
Battery Status
Magnetic Signal for depth and direction

The transmitter is powered by 2 D-Cell Alkaline batteries which provide approximately 30 hours of continous operation. The transmitter is designed to transmit continously while the batteries are inserted. The range of the transmission is approximately is 60 feet (18.3 m).

Since the first two parameters, roll and pitch, are not required, the pitch and roll data is replaced with tension and pressure information.

On the Eclipse receiver side, the TensiTrak software allows the receiver to recognize this "new" data. Once the operator commences taking data, readings are automatically recorded twice per second and stored in memory. Data will be collected until the operator ends the data collection session. This session can be started again at any point which means that the pullback process can be stopped and started as needed untill the installation is complete.

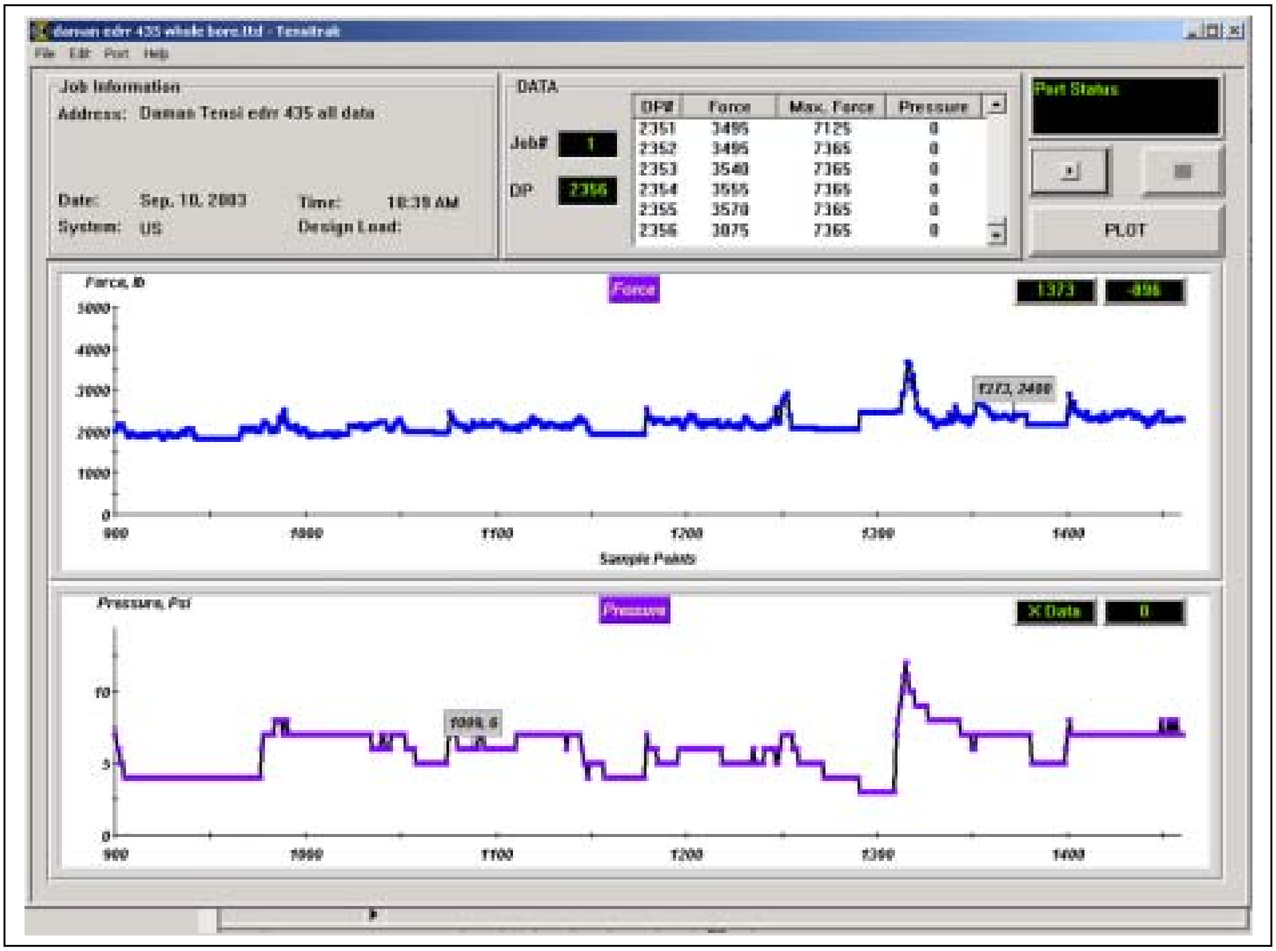

Figure 2. View of downloaded tension and pressure data.

The Eclipse receivers have enough memory to store 25 separate runs before data needs to be downloaded. Each of the runs is numbered sequentially from 1 to 25 and can be selected for downloading individually. The Eclipse loactor has an infrared communications port which is used for downloading data into a computer using an Infrared Wireless Adapter. The data is downloaded using software created by DCI which accompanies the TensiTrak system.

The data is displayed and recorded in the units of measure that the Eclipse receiver is set to. The receiver can be set to either the English or Metric systems of measurement. This means that load and pressure readings are in lbs and psi respectively or in Newtons and Pascals in the metric system.

4. PROTOTYPE FIELD TESTING

The first prototype design allows for a maximum pull force of 40,000 pounds (178,000 N) and a maximum pressure reading of 100 psi (689,500 Pa). The TensiTrak device measures 32.75” (832 mm) in length and 3” (76 mm) in diameter. The force is recorded in 15-pound increments while the pressure is measured in 1 psi increments. The Eclipse receiver continuously displays the real time load and pressure data as well the maximum load recorded (Max Force). When this value is exceeded, the new maximum

Figure 3. Typical Eclipse receiver display while in TensiTrak mode.

load value is displayed and stored until it changes.

The first field test where data was recorded was in Kircheim/Nabern in Germany. This involved the installation of 262-ft (80 m) of a 6.3 inch (160 mm) PE gaspipe, at a maximum depth of 4-ft (1.2 m). The tension graph looks about how one would expect. There is a gradual increase in load, but there are peaks and valleys denoting rod changes. Maximum recorded load was about 11,200 lbs (50,000 N). It

Figure 4. TensiTrak load monitor attached to the reel ready to start logging data.

should be pointed out that the units on the x – axis are data points and cannot be correlated to distance. The x-axis is essentially a time scale since the readings are taken at fixed time intervals as can bee seen on the graph on the following page.

This particular system did not have the pressure sensor installed and there were some rather large pressure spikes recorded. According to the DCI employee who was running the test it appeared that these spikes coincided with trucks driving past the area where the Eclipse receiver was being used. The receiver was incorrectly recording pressure where there should not have been any. The question at that point became, was the TensiTrak transmitter sending out incorrect data, that is including pressure values where there were none or was the receiver incorrectly reading these pressure values. Based on the high "pressure values" that were recorded it looked more likely to be a digital processing error in the Eclipse receiver. The final answer to that question lay in a separate field trial performed in New York State in early September 2003.

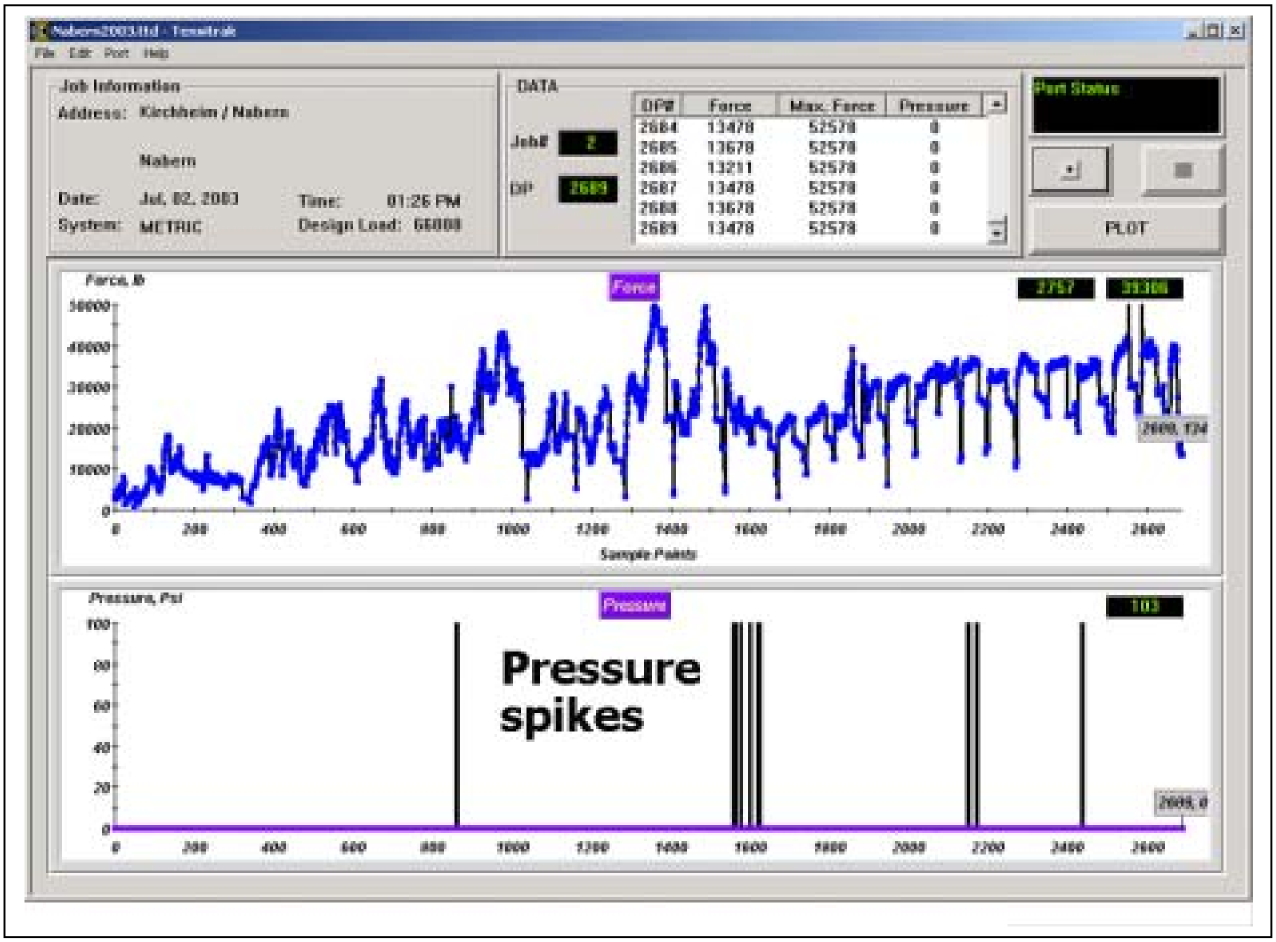

Figure 5. Tension monitor test in Kircheim/Nabern, Germany

The New York field trial was aimed at answering the above question as well as testing the drilling fluid pressure capabilities of the TensiTrak monitor. Mr. Frank Canon of Baroid Industrial Drilling Products participated specifically to be in charge of the drilling fluid operation and to monitor the test.

The ground conditions ranged from fine sand to silty sand. The length of the bore was 460-ft (140 m) and the maximum depth reached was 14-ft (4.3m). The product was a 6 inch (150 mm) HDPE pipe.

The proposed drilling fluid properties test was as follows : Start with a typical drilling fluid mixture (75 second mud) for about half of the installation. At about mid point a much thicker mud (153 seconds) was mixed. Towards the end of the installaion, a Baroid product called AQUA-CLEAR™ PFD was added. This is a Phosphate-Free Dispersant which primarily affects the drilling fluid viscosity. In other words, it acts as a thinning agent. The results of this test can be seen on the graph in figure 6 below . On the load scale there is a period of no load (from about data point 1500 – 1600. This occurred when the driller pushed a rod back a little bit thereby relaxing all the load on the TensiTrak monitor.

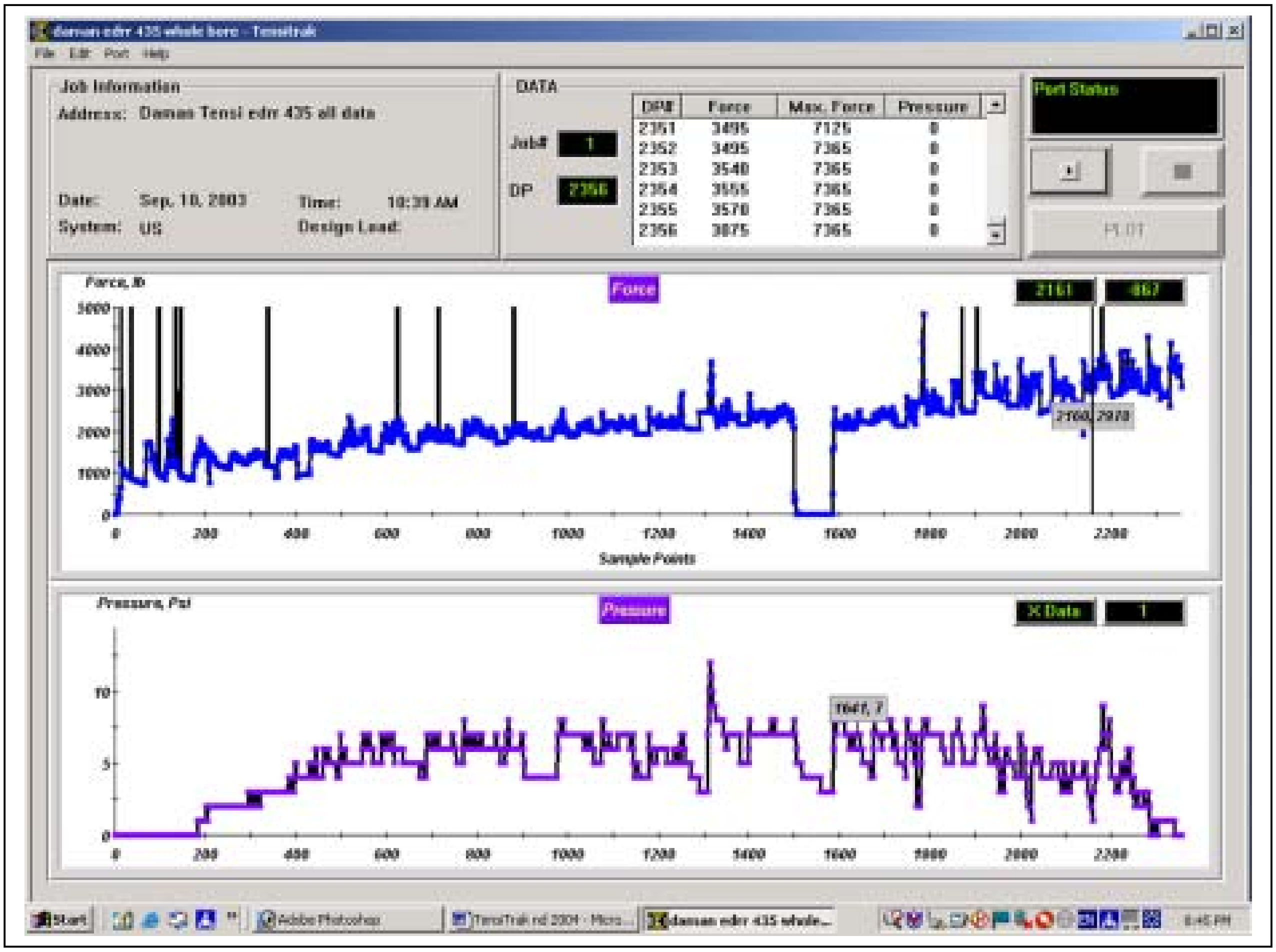

Figure 6. Tension and drilling fluid pressure test in September 2003, Rome NY.

Secondly, similar data spikes are seen, however this time in the load readings. By using two separate receivers and comparing the readings the answer to the data spikes was found. Both units recorded some of these spikes but not at the same time. In other words, the data spikes were not coming from the transmitter but rather from each of the receivers. At the time of this writing, more sophisticated signal processing and data transfer methods have been incorporated which have alleviated this issue.

The first pressure readings occurred about 10 minutes into the pullback and the pressure gradually increased to a level of 6- 8 psi (41,400 – 55,200 Pa) and fluctuated between these values for the most part. It should be noted that about 15 minutes into the pullback we lost flow on the exit side, that is the side where the pipe was entering into the ground. At or about data point 1300, a 45-minute break was taken to mix the second batch of drilling fluid. Data collection continued for a few minutes after the machine pump was shut off to gauge the “stationary” fluid pressure. This turned out to be 3 psi (20,700 Pa). Almost as soon as the pump started circulating the much thicker fluid, the pressure rose to the highest recorded value of 12 psi (83,000 Pa). At the same time, an increase in the load readings was seen. After the drilling fluid had circulated for a few minutes the pressure values seemed to settle at a slightly higher rate than before albeit over a greater range than before. As the reamer started to approach the entry pit, the pressure decreased. This can be explained by the fact that the pressure was being relieved into the entry pit. This was expected as no flow was seen on the opposite side.

The PFD additive was added at data point 2242. At that point, the pressure readings maintained at 5 psi (34,500 Pa). Two minutes after the addition of the PFD, the pressure readings dropped to 2 psi (13,800 Pa) and after 5 minutes they stabilized at 1 psi (6,900 Pa). As the reamer came within 20-ft (6 m) of exiting at the drill side, drilling fluid pressure readings fell to 0 and stayed there.

Figure 7. View of Eclipse remote display at drill rig operator station.

The results of this test showed nothing unexpected which in this case was a good thing. The load applied to the pipe being pulled increased linearly with respect to the length of pipe in the ground. Also exhibited were load peaks and valleys, which corresponded with the drill rod changes on the machine. As a function of distance, the load for this particular bore could be described as

$$F = 1,035 + 5.36 \times L \qquad [1]$$

where F is the load in lbs and L is the horizontal bore distance measured in feet. In the metric system the equation would be

$$F = 4605 + 78.35 \times L \qquad [2]$$

where F is the load in Newtons and the distance is measured in meters.

One of the future research topics might include the comparison of the traditionally calculated pipe loads as compared to the results of this or other similar tests.

5. CURRENT EFFORTS

At this point in time the developmental efforts are focused in three areas; a second generation larger TensiTrak monitor, capable of measuring loads up to 60,000 lbs (267,000 N), further development of the PC based software and enhancing of Digital Signal Processing (DSP) methods currently being used.

The larger TensiTrak model will be much shorter or 15” (381 mm) in length but larger in diameter, or 4.75” (121 mm). As the market accepts this technology, the need may arise for units with even larger load capacities than the 40,000 lbs (178,000 N) or 60,000 lbs (267,000 N) models.

The PC based software is being designed to be very user friendly to use with straightforward reporting. The data will be downloaded via an IR link, directly from the Eclipse receiver into the software. The user will be able to determine the number of data points to be printed, thereby controlling the amount of data being reported. In this case, the highest values are the ones selected within the reporting interval. The data from any run can of course be downloaded as many times as required. The reporting will be in the form of a graph as seen in this paper as well as a data list, which shows the load and pressure for each data point. This same data is also available in the data portion of the software, which is in the upper right half of the screen; see Figure 6 as an example.

At the time of the writing, software changes as well as DSP changes in the Eclipse receiver software have been implemented. The graph below depicts the data from the New York field trial that was loaded into the most recent version PC software. All of the data spikes previously seen are now gone. Additionally, based on test data compiled in our laboratory during a 4-hour test with a TensiTrak monitor under a constant load running an Eclipse receiver with new DSP software and loading the data into the most current version of PC software, no data spikes were observed in any of the data.

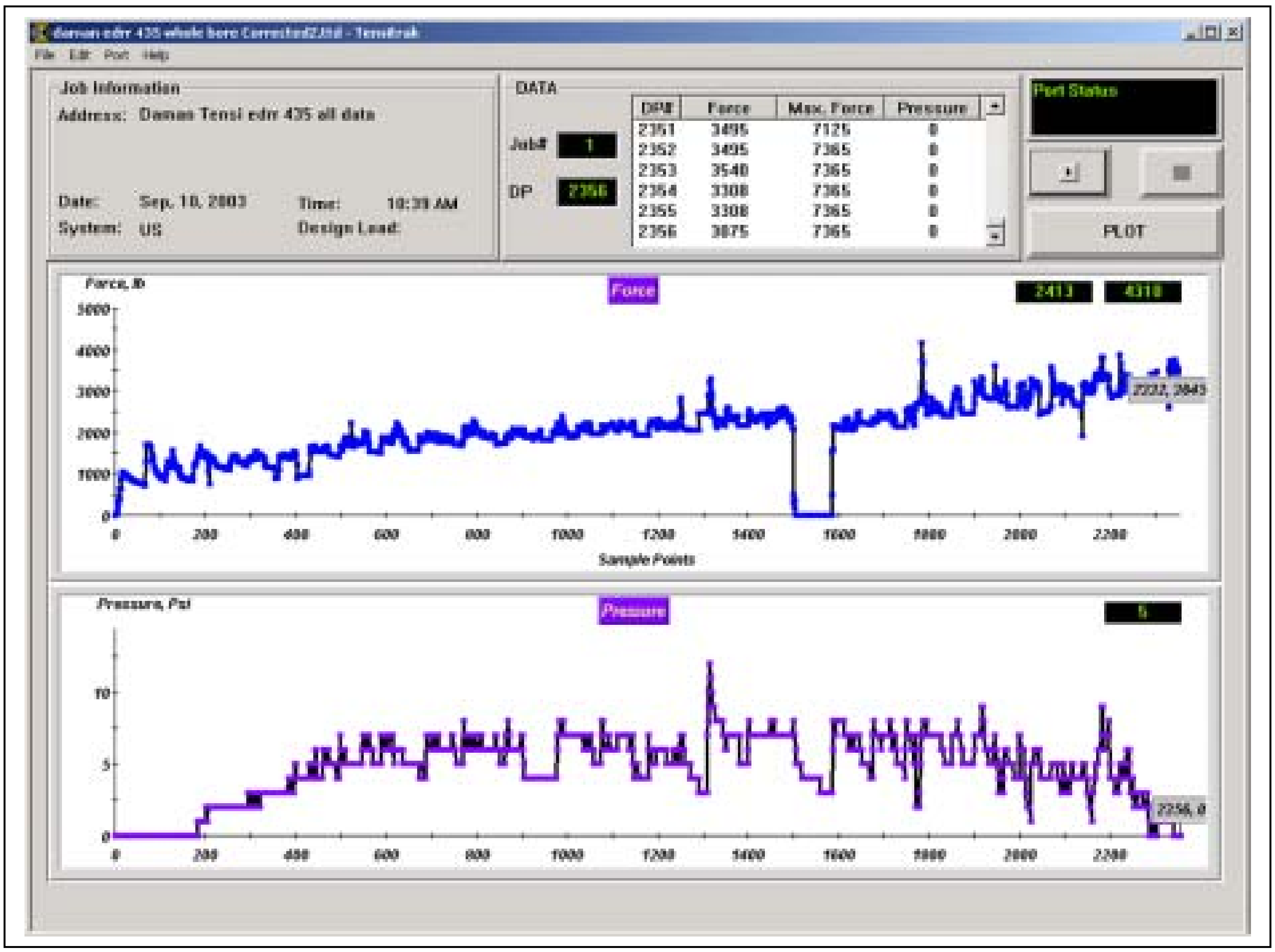

Figure 8. Rome, NY tension and fluid pressure data in current version software

6. SUMMARY

The TensiTrak load and tension monitor is a tool that enables a HDD contractor to monitor the product tension and down hole drilling fluid pressure during installation. The primary benefits of the TensiTrak is that the drill operator can observe in real-time whether corrective actions are necessary to compensate for high drilling fluid pressures or high pull forces. This information may assist with preventing stuck product, compromised product or inadvertent fluid returns, or worse, damage to nearby structures.

Research is currently being conducted with the goal of developing formulas that based on ground conditions, depth, drilling fluid composition and various other factors will give an estimate of expected drilling fluid pressures. It is the intent of the author of this paper to offer the assistance of Digital Control Incorporated to help improve or fine-tune these empirical formulae.