RISER CABLE TENSION MONITOR WITH TON CYCLE INDICATORS

1.0 INTRODUCTION

The methodology currently being used to measure riser cable loads and estimate remaining wire rope life has limited value. The reason is that it's blind to dynamic loads large enough to snap the cable and can't sense small amplitude load cycles that weaken the cable due to fatigue. The consequences can be removal of the cable from service earlier than necessary or cable breakage.

In this proposal, Viten DynaTension, Inc. proposes a different, cost-effective technology that captures all loads and all load cycles. It utilizes *DynaTension®* technology to derive tension and from the tension extract ton-cycles, an indirect measure of rope wear. This approach was implemented in the oil patch by Rucker Controls in the 1970's and proved to be a dependable way to predict remaining wire rope life. *DynaTension* technology is an improved version, incorporating state-of-the-art microprocessor hardware and software.

We propose to provide a system that continuously monitors tension in ten riser cables and derives the ton-cycles. (The number of cables monitored can be easily adjusted to match the need). It maintains a time and date stamped data log of all the tensions, the ton-cycles experienced in each line, peak tension values and low tension values. Any tension anomalies are flagged. Abnormally high or low tensions generate aural and visual alarm warnings. On demand data recall provides the ability to correlate tension amplitude and frequencies with other factors that influence them, such as sea state and dynamic loads experienced in different modes of operation. In addition, the system provides a continuous readout of the total sum of all the cable loads on the riser, as well as peak loads and minimum loads on the riser. If ever desired, the vertical and horizontal components of the riser loads can be obtained by adding angle sensors to each of the cables.

Through *DynaTension* load measurement technology, cable breakage may be prevented by immediate detection of excessively high loads. In that case, action to reduce loading can prevent breakage. Through our Ton Cycle Indicator (TCI) technology, it may be possible to safely get more use life out of the cables.

2.0 TECHNICAL DISCUSSION

Most offshore drilling companies derive riser cable tension measurements from pressure in the riser tensioner cylinder. That method is largely blind to dynamic loads placed on the cables by environmental forces. If the compensator were perfect, no dynamic loads would be sensed at all. However, dynamic loads may often exceed the average loads by 100% or more. Also, loads less than the compensator friction force do not result in a change in pressure, so they go un-detected by the pressure measurement system.

Combined friction of the compensator piston seals and sheaves is on the order of +/- 20 % of the cable tension, so substantial cable fatigue factors go un-noticed.

This proposal offers an alternative method of measuring the cable tensions that provides readouts of dynamic loads as well as average loads. In addition, it senses and counts all cyclic loads, regardless of their amplitude. Through knowledge of the cumulative cyclic loads, the remaining wire rope life may be estimated. This will help insure that the wire ropes are not removed from service before its necessary, and warn if dangerously high loads are being experienced.

The proposed method of tension measurement is called *DynaTension®*. *DynaTension* infers tension from the frequency of vibration of a span of the cable. There are several advantages that accrue from this technology.

- No in-line installation
- Non-contact sensing
- Zero wear on sensor or cable
- Never requires recalibration
- Encapsulated exciter and sensor
- Excellent repeatability
- Excellent accuracy
- No drift with time or temperature

3.0 DESCRIPTION OF DYNATENSION TECHNOLOGY

The *DynaTension®* technology exploits the "vibrating string equation" shown below to achieve high accuracy, high repeatability, high reliability and low maintenance at a very reasonable cost.

Vibrating String Equation:

$$\Omega n = \left[\left(\frac{N\pi}{L} \right)^2 \frac{T}{M} + \left(\frac{N\pi}{L} \right)^4 \frac{EI}{M} \right]^{\frac{1}{2}}$$

Ω = Radian frequency - Radian frequency is $2\pi f$, where f is the frequency in Hertz, or cycles per second.

Ωn = the nth harmonic, i.e., 1, 2, 3.... n of the radian frequency

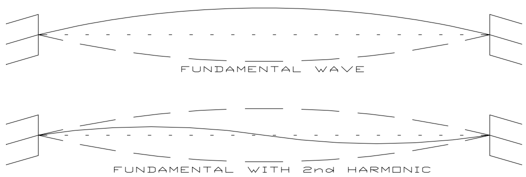
$\frac{N\pi}{L}$ = Any integral multiple of pi, or 3.1416, divided by span length in feet

$\frac{T}{M}$ = Tension divided by mass per unit length, i.e., slugs per foot or kilograms per meter

$\frac{EI}{M}$ = (*E*) modulus of elasticity multiplied by (*I*) area moment of inertia, divided by (*M*) mass per unit length

Mass per unit length is the same as weight per foot divided by “g”. “G” is gravity constant which is 32.2 ft per sec per sec, or ft per second squared. In the metric system, mass per unit length is in kilograms per meter.

DynaTension® senses the vibration frequency of a length of the cable (L) between two bridge points and calculates the tension (T) using the **fundamental wave** in the equation on the previous page. See the waveforms below.



Referring to terms in the equation above, circuit filters select the fundamental, n = one. The span L is the distance between two sheaves in each line, M is the cable weight per foot divided by the gravity constant and T is the tension in the line. The error due to cable stiffness is automatically corrected for by deriving E and I from the cable type and diameter and subtracting it from the raw measurement before displaying tension.

An Exciter/Senor/Assembly (ESA) excites and maintains cable vibration by synchronously plucking the cable with a magnetic pulse as often as required to maintain the amplitude above a preset level. By this method, a high signal-to-noise ratio is maintained.

The ESA is positioned with roughly a half inch gap from the cable. It contains an electrical solenoid and a sense coil. A current pulse through the solenoid creates a magnetic pulse across the gap that silently plucks the cable without physical contact. The sense coil is part of a variable inductance circuit that generates an electrical analog of the mechanical vibration. The amplitude of the electrical signal is on the order of several tenths of a volt. That relatively high level ensures a good signal-to-noise ratio even in high ambient noise levels that render load cells useless.

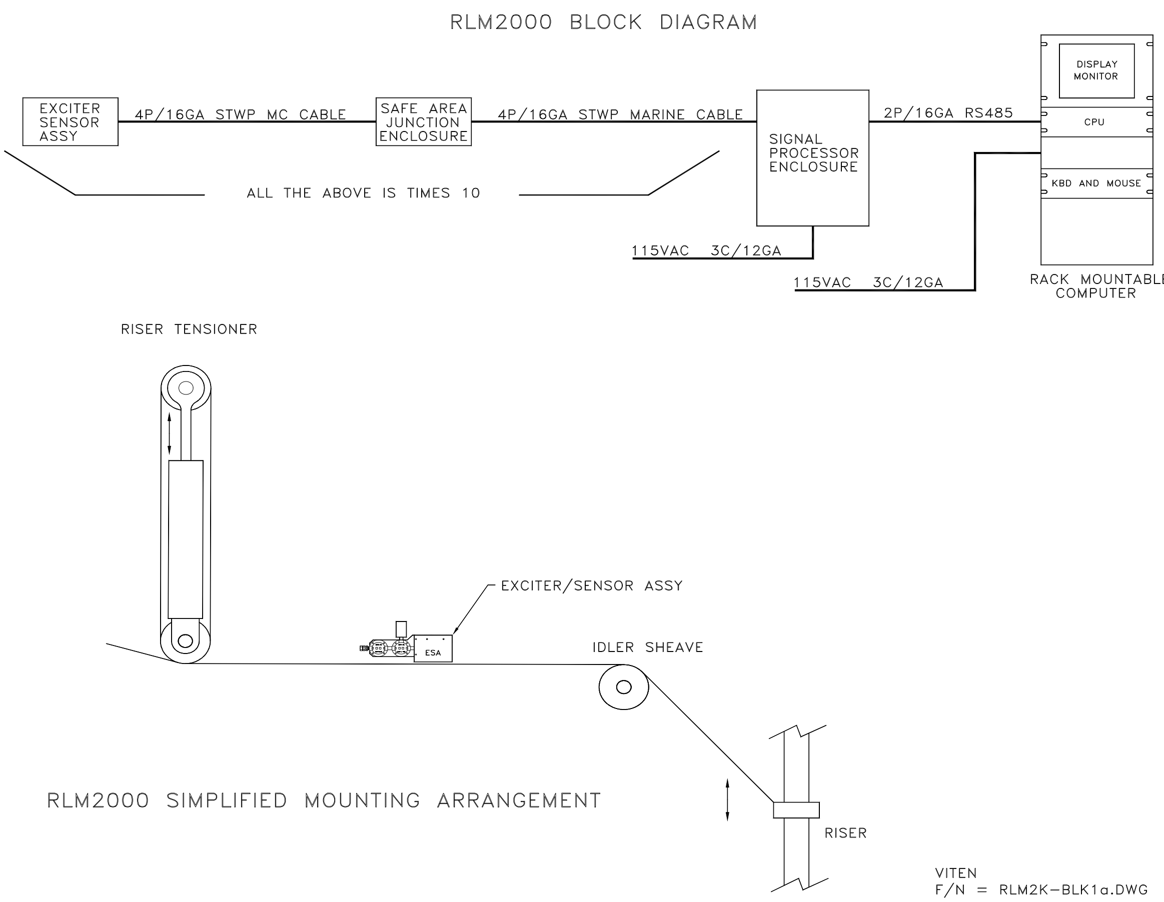
Because *DynaTension* derives tension from frequency as opposed to amplitude, it is inherently immune to electrical noise. The FM versus AM feature, coupled with a relatively high amplitude sensor output renders *DynaTension* highly immune to electromagnetic interference such as thunder storms, navigation aids, SCR spikes and other sources of electrical noise.

Ton Cycles are determined by multiplying the average tension by the number of tension cycles detected. Cycles are detected by sensing successive peak tensions.

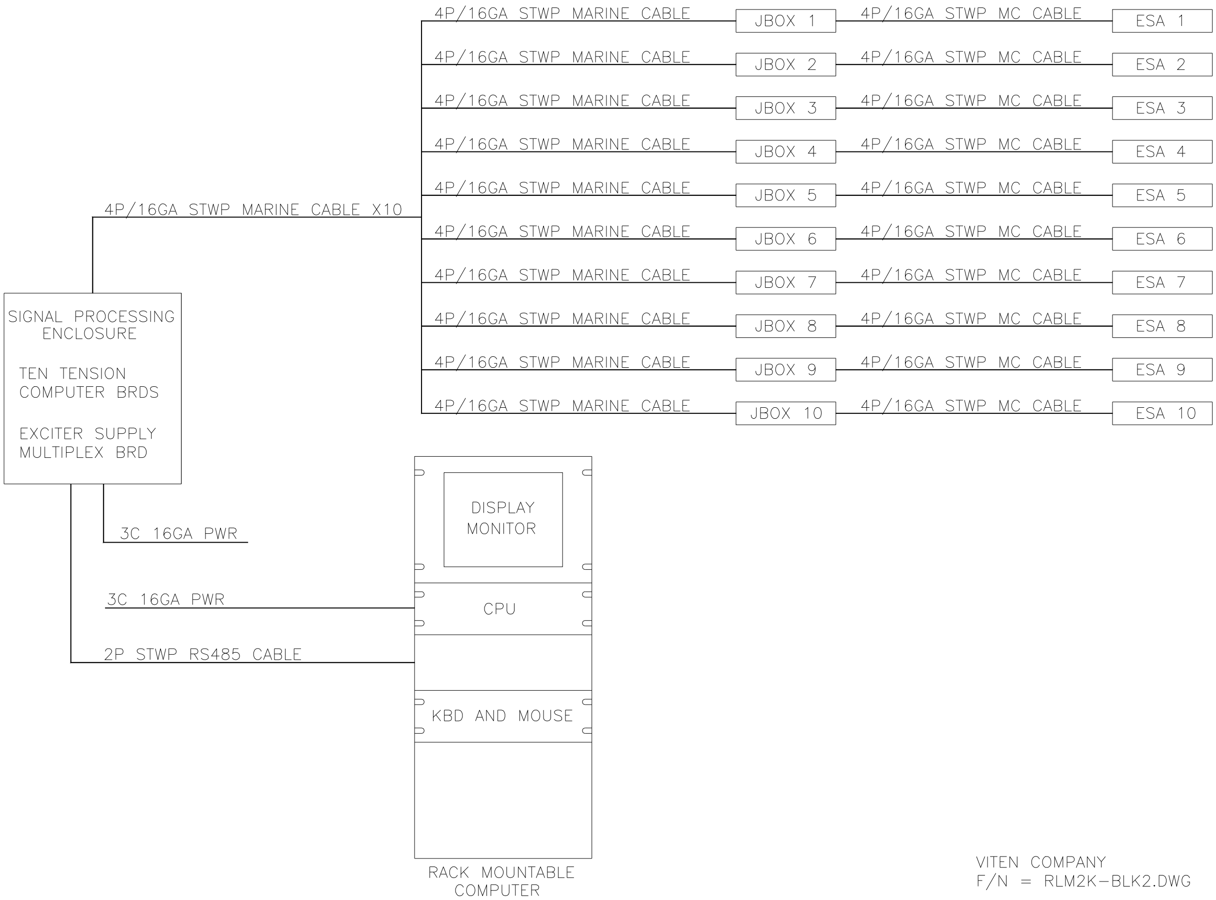
4.0 SYSTEM DESCRIPTION

A representative system layout is shown in drawing number RLM2K-BLK1.DWG below. Each of the Exciter/Sensor/Assemblies is located roughly mid-way along a span of each riser cable. The span is defined by the compensator exit sheave and either the turn-down sheave at the moon pool or an interposed idler sheave.

To optimize signal-to-noise ratio and minimize the power required to maintain appropriate vibration signal amplitudes, the spans should be no less than thirty feet and no more than 50 feet.

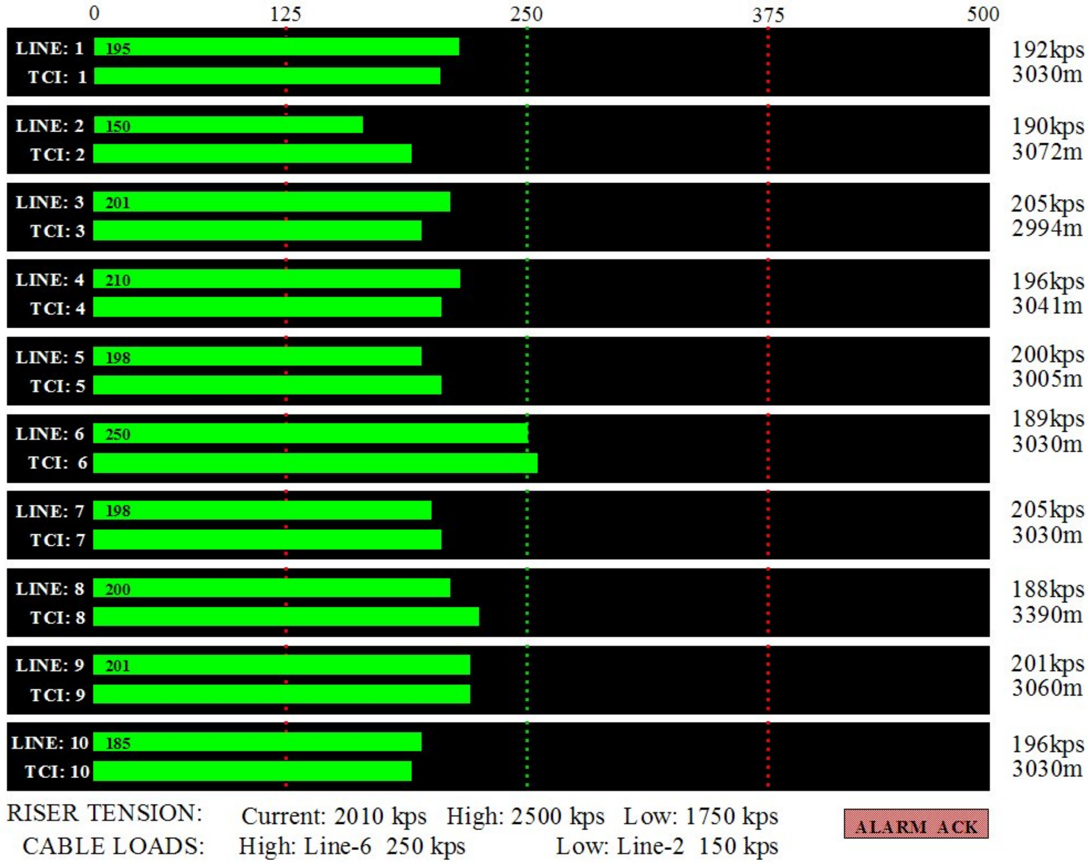


Drawing RLM2K-BLK2.DWG on the following page is a block diagram of the system. An explosion proof cable runs between each ESA and a small, intermediate J-box located outside the zone one area. Less expensive cable runs from the intermediate J-boxes to the Signal Processing Unit (SPU), also located in a safe environment.



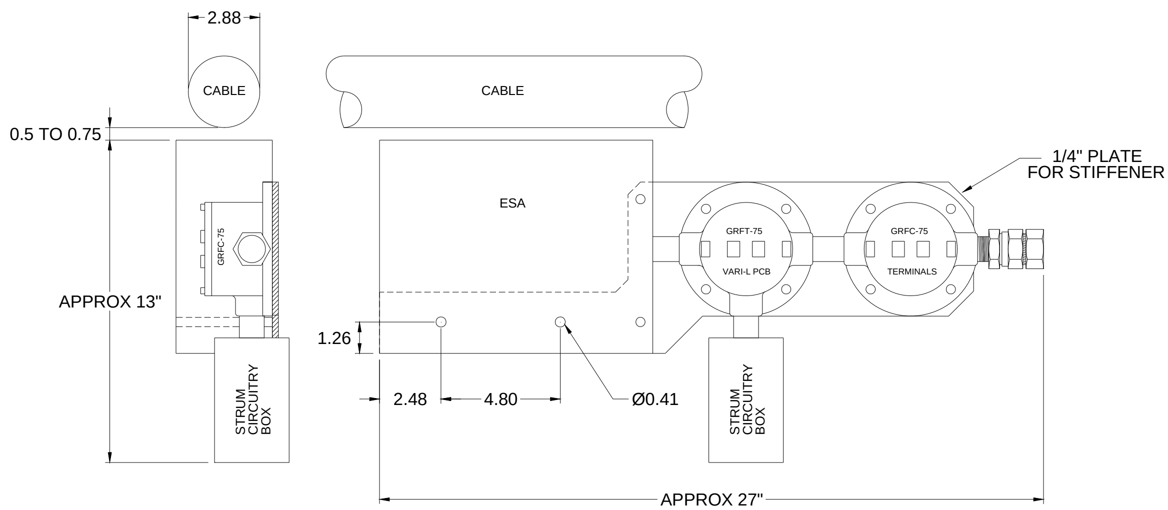
Each of the cable tensions are measured in the SPU, combined into a RS485 data stream and sent to the Display Station (DS) via appropriate cable.

Ton cycles are derived by software in the DS. The DS monitor provides a display of the ton cycles, the current tension, average tension, peak tension and minimum tension experienced by each cable. A representative display is shown on the following page.



5.0 EXCITER/SENSOR/ASSEMBLIES

The ESA's are fully encapsulated with water impregnable, flame retardant epoxy. An explosion proof J-Box attached by a nipple to the ESA housing contains vibration sensor electronics, strum circuit, strum capacitor, transient suppressors and a terminal block for connecting to the explosion proof cable. Drawing RLM2K-ESA1.dwg on the following page shows the ESA properly positioned proximate to the cable.



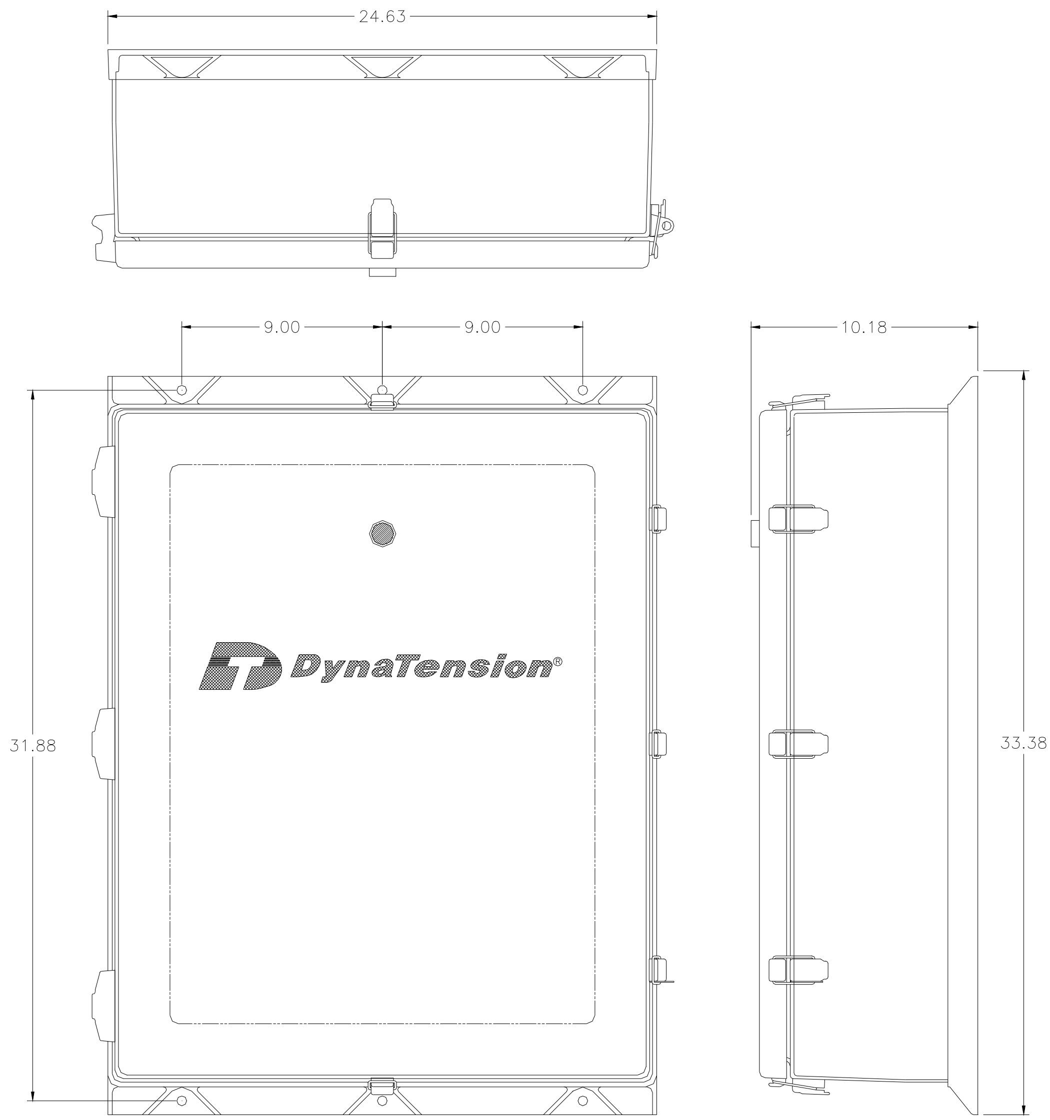
EXCITER/SENSOR GENERAL ARRANGEMENT

VITEN
F/N = RLM2K-ESA1a.DWG

The ESA houses an electrical solenoid that plucks the cable with an electromagnetic pluck force. To strum, the strum voltage is gated on by a field effect transistor located on a circuit board inside the Strum Circuitry Box. The resulting short duration current pulse through the solenoid winding produces a magnetic pull pulse that plucks the cable. Strum pulses are synchronized with the vibration signal. Plucks only occur when the vibration amplitude decays to a preset level.

6.0 SIGNAL PROCESSING UNIT

The Signal Processing Unit houses a 60 VDC power supply for strumming the cables and a +/- 15 VDC power supply for the electronic circuitry and the signal sensing circuitry. It houses ten tension computing boards (TCB) and a tension acquisition board (TAB). A SPU general arrangement is shown below.



J-BOX GENERAL ARRANGEMENT

Each tension computer board generates the strum pulses required to initiate and maintain vibration in a cable. The TCB's condition the vibration signals, control the tracking filters, compute the cable tensions and output the tensions in RS232 format. The tension acquisition board multiplexes the ten tensions into a continuous data stream and outputs the data stream in RS485 format to the Display Station.

High and low pass tracking filters, controlled by the microprocessor on each TCB tune to the fundamental of the cable vibration frequency envelope and continuously track it as the frequency changes with changes in tension. Extraneous signals from external sources as well as harmonics of the vibration frequency are rejected with a high rejection rate.

The low pass rejection rate is -48 dB/octave and the high pass rejection rate is 24 dB/octave.

Strum pulses are generated only as needed to maintain an adequate signal-to-noise ratio. Each time a cable is strummed, the vibration amplitude is restored to some nominal peak value. As the amplitude decays with time, the signal falls below an established threshold. At that point a strum command is generated, causing the vibration amplitude to be restored. This method eliminates the possibility of generating ever increasing vibration amplitude due to positive feedback yet insures that the amplitude is always sufficient to provide a good signal-to-noise ratio.

7.0 DISPLAY STATION

The Display Station is a rack-mountable computer with suitable software. The software disassembles the RS485 tension values and displays them on the PC monitor. The software may be modified as necessary to meet customer preferences. As it is currently configured, it computes and displays the average, peak high and peak low tensions in each cable and displays them on the monitor. It defines each successive pair of tension peaks as a cycle. It accumulates the cycles experienced by each cable and multiplies the cumulative cycles by the average tension in the cable and displays the products as Ton Cycles Indicated (TCI).

High, low and medium alarm limits may be set via the keyboard. If the low limit is exceeded, the corresponding bar turns from green to yellow and the ALARM ACK button will turn yellow. If a high limit is exceeded, the corresponding bar will turn red and the ALARM ACK will turn red and blink. In addition, an aural alarm will sound. The sound and blinking button will continue until it is acknowledged by placing the cursor on the button and clicking the mouse button. Acknowledgement will be complete as soon as an operator has clicked on ALARM ACK and entered his/her name via the keyboard. The acknowledgement will be time and date stamped.

The data will be time and date stamped as it comes into the DS from the SPU. Initial tensions and all changes will be logged onto the hard drive. A time block of the data may be specified and retrieved by keyboard command for event analysis.

An uninterruptible power supply is included in the DS that will retain the data in event of a power failure, long enough to copy it to another storage media such as a DVD or a USB flash ROM.

8.0 CONCLUSION

The proposed riser cable monitoring system will provide a measure of security not currently available to the customer. It will provide a realistic measure of rope wear that may be used to extend useable rope life.

DynaTension technology is well proven by years of demonstrated dependability in other offshore drilling applications. Examples are the Mooring Tension Monitoring System (MTMS) installed on the M.G. Hulme Jr. in 1996, the MTMS installed on the Jim Cunningham in 2002 and M2000 crane load monitors installed on Discoverer Seven Seas and D534 drill ships.

DynaTension technology offers unprecedented accuracy and inherent reliability and maintainability. That technology, applied in this system, offers the user potential to realize significant savings through increased useful rope life and prevention of expensive, possibly catastrophic rope failures. Every offshore drilling rig should have one.