“Slickline Fatigue Tracking Software Delivers Economic Benefits”

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ICoTA Round Table
Calgary, AB

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Today’s Highlights

- **Drivers for New Slickline Technology**
- **New Technology to Monitor SL Fatigue Life**
  - **Slickline fatigue model development**
  - **Corrosion life reduction**
- **Slickline Inspection**
- **Example Results**

Why Focus on Slickline Fatigue Life?

- **Cost, Safety, and Expand Market**

Fatigue Life Monitoring Goals

- **Extend Life / Reduce SL Expenditures**
- **Improved Safety (SL failures @ surface)**
- **Reduce Downtime / Fishing Operations**
- **Increased Customer Confidence in SL Operations**

Causes of Slickline Failures

- **Mechanical Damage**
  - Abrasion, severe bending (kinking)
- **Corrosion**
  - Rust, acid, H_2S, CO_2
- **Fatigue Damage**
  - Sheave wheel, overpull

Failure Causes can be Interrelated

- Example: Cracks caused by corrosion can exacerbate fatigue damage

Technology to Quantify both Corrosion & Fatigue Life

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Slickline Data Acquisition & Fatigue

- **Data Acquisition System**
  - Acquires depth and weight channels
  - Display & record data during field operation
- **Calculates:**
  - Fatigue damage caused by SL movement/tension
- **Displays:**
  - % Fatigue Life Used vs. length of SL
  - Slickline history (cuts, re-spooling events, etc.)

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SL Fatigue Model Development

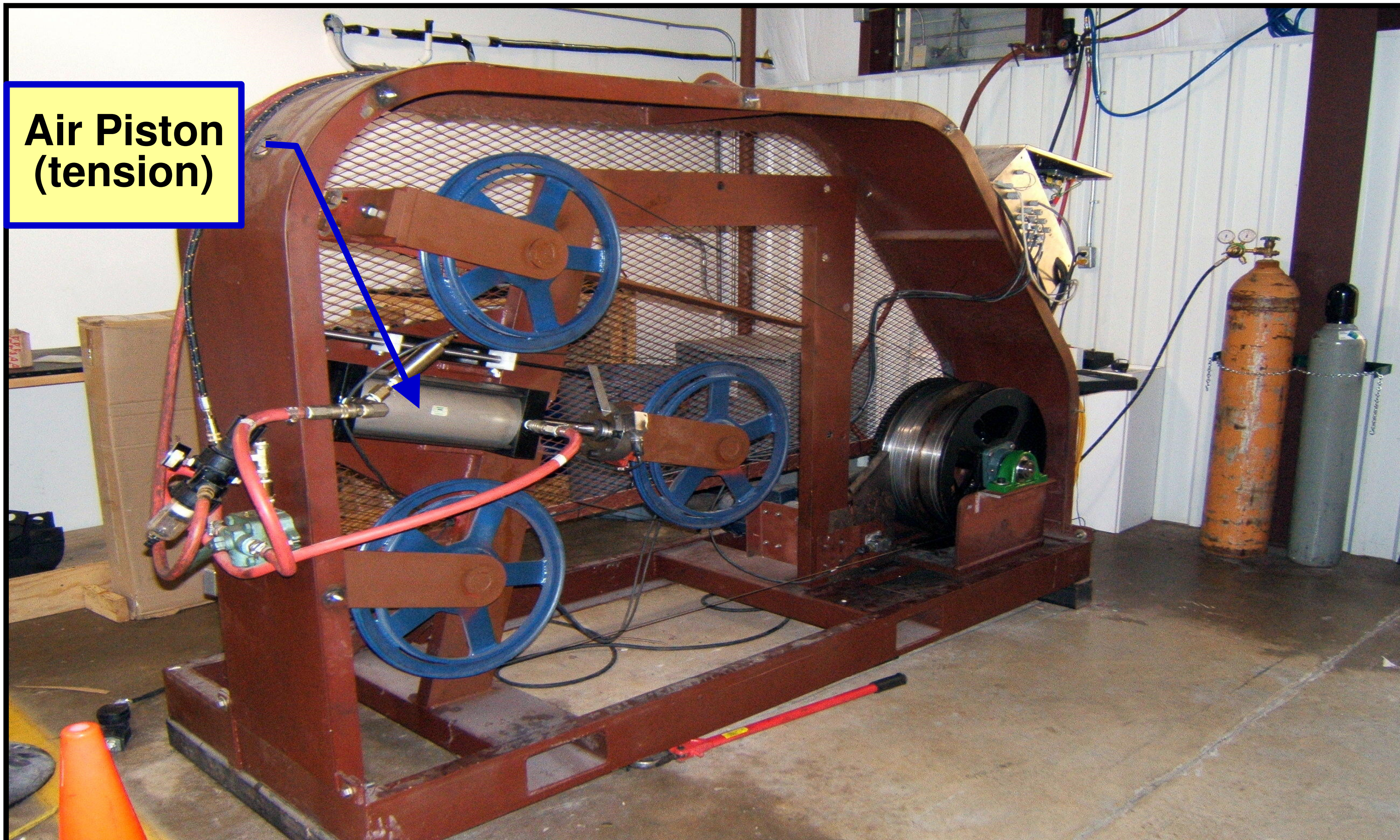
(Fatigue vs. Crack Propagation)

- **Fatigue Damage**
  - **Damage (bending) accumulates until crack initiation**
- **Crack Propagation (following crack initiation)**
  - **Repeated bending causes crack propagation until a failure (fracture) occurs**

- **CT Fatigue – includes only crack initiation**
- **DP Fatigue – usually includes only crack propagation**
- **Slickline Fatigue – includes effects of both**

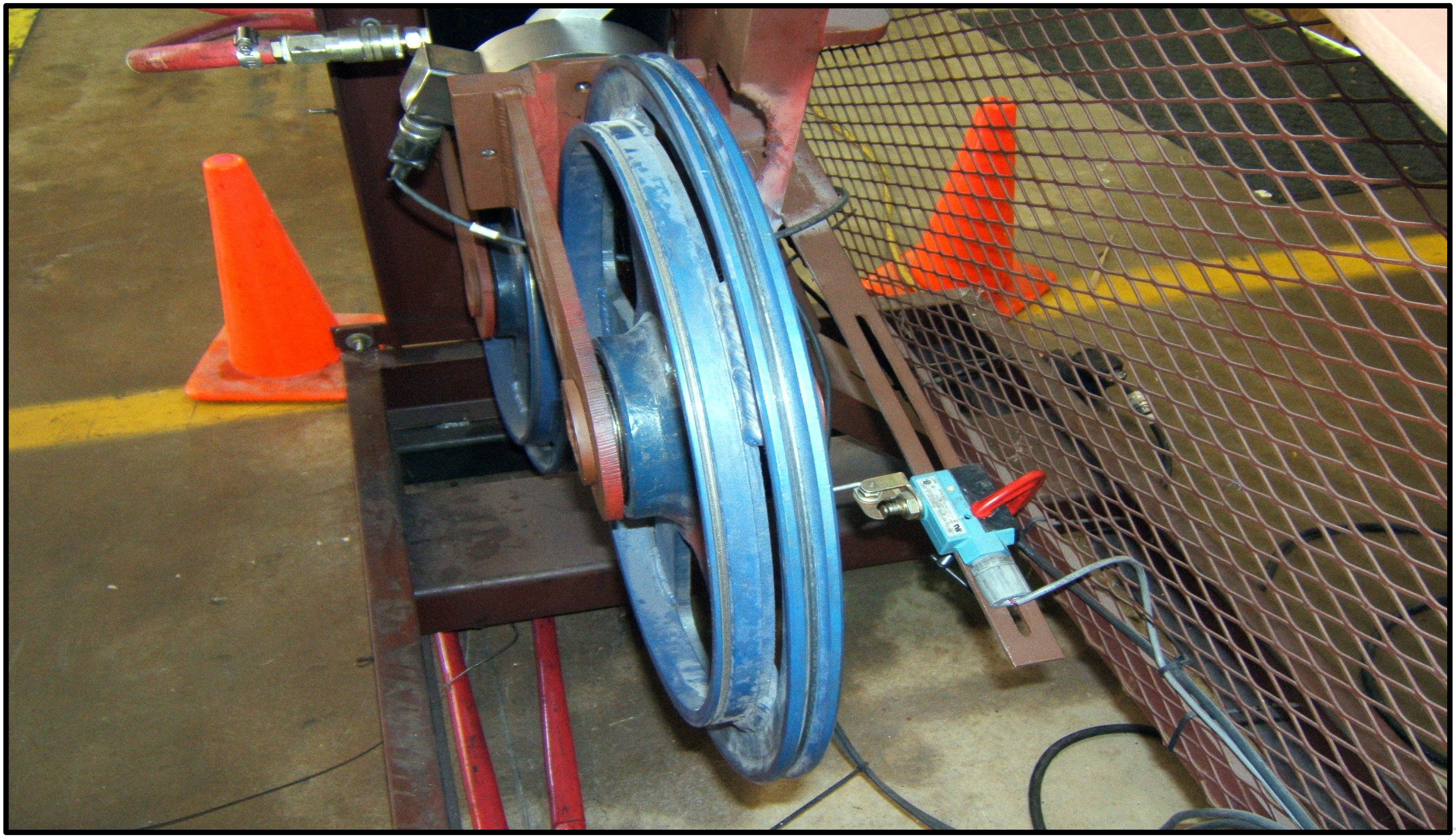
Large Test Machine

(SL Fatigue Model Development)



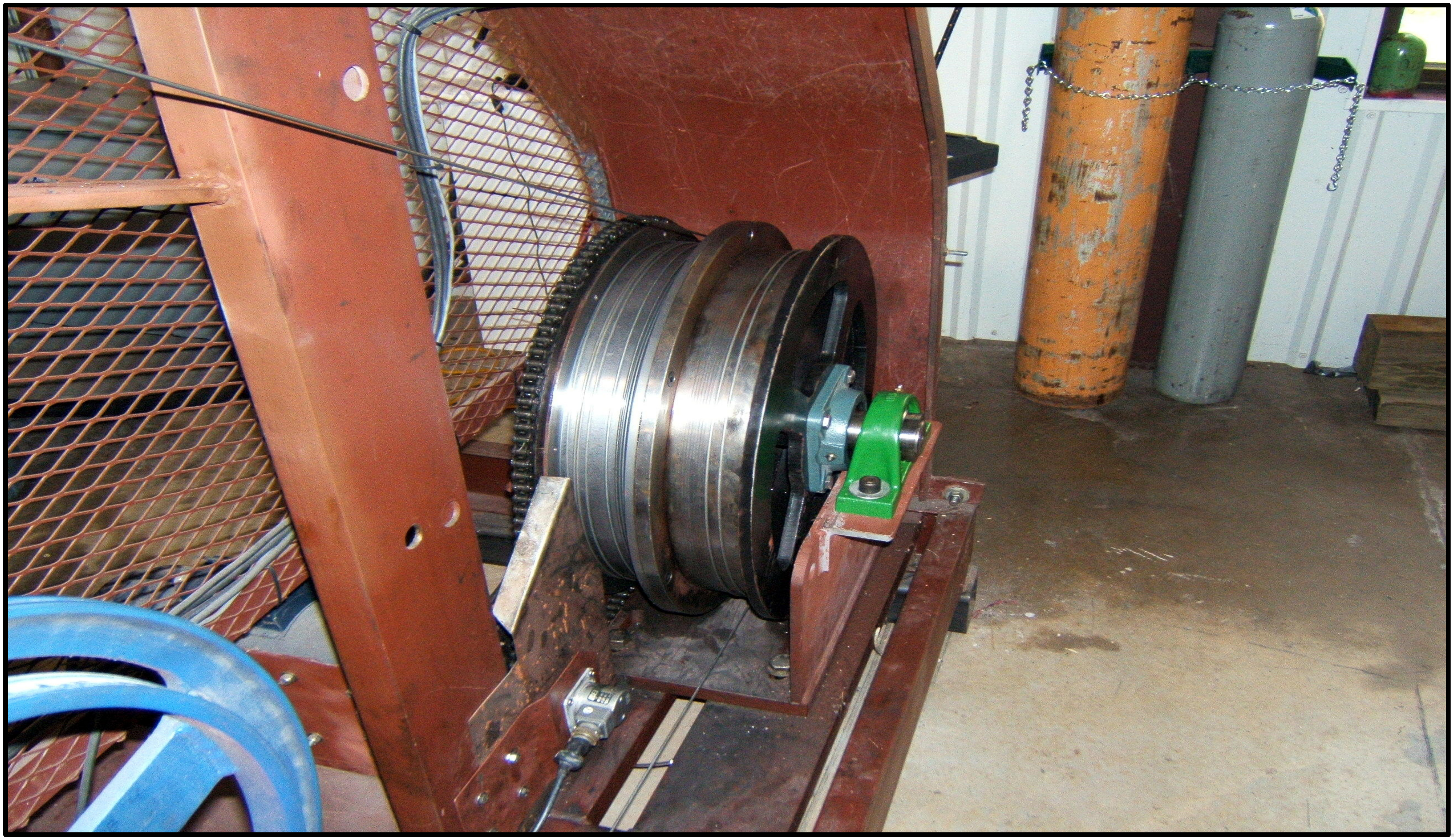
Large Test Machine

(16” and 19” Sheave Diameters)



Large Test Machine

(Spilt-Drum Used for Testing)



Plastic Fatigue from Bending Events

(Bending Strain *Inversely* Proportional to Sheave Size)

d (in.)	Dy (in.)
0.092	19.7
0.108	23.1
0.125	26.8
0.140	30.0

Bending Diameter to Initiate Yielding:

$$D_y = \frac{dE}{\sigma_y}$$

Where:

- D_y = Bending diameter at which yielding begins
- d = Diameter of slickline
- E = Modulus of elasticity (30 x 10^{-6})
- σ_y = cyclic yield stress (~140k PSI typical, varies by material)

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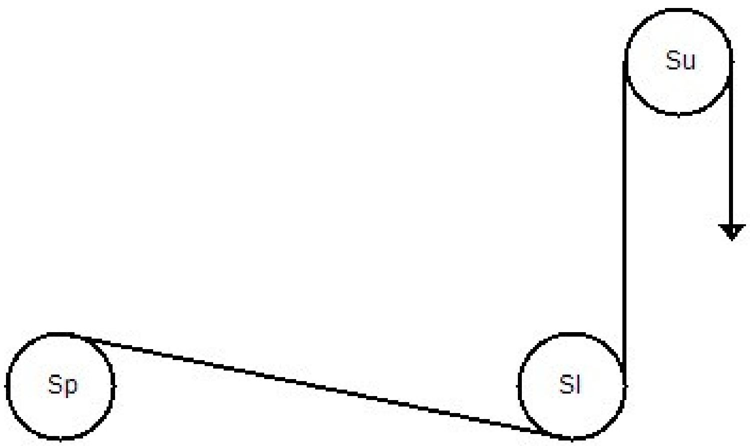
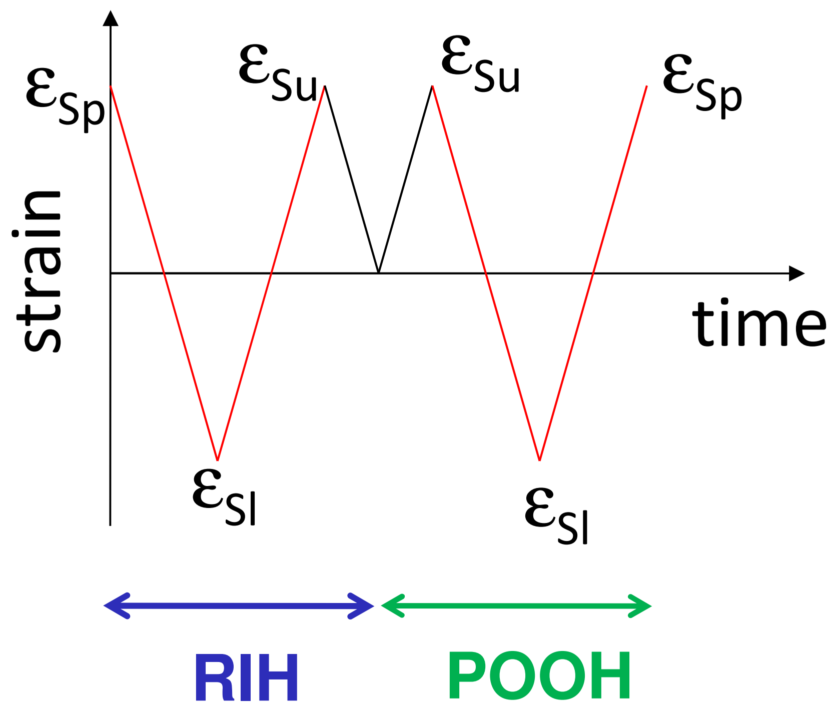
Strains from a Type 1 SL Rigup

(SL Fatigue Model Development)

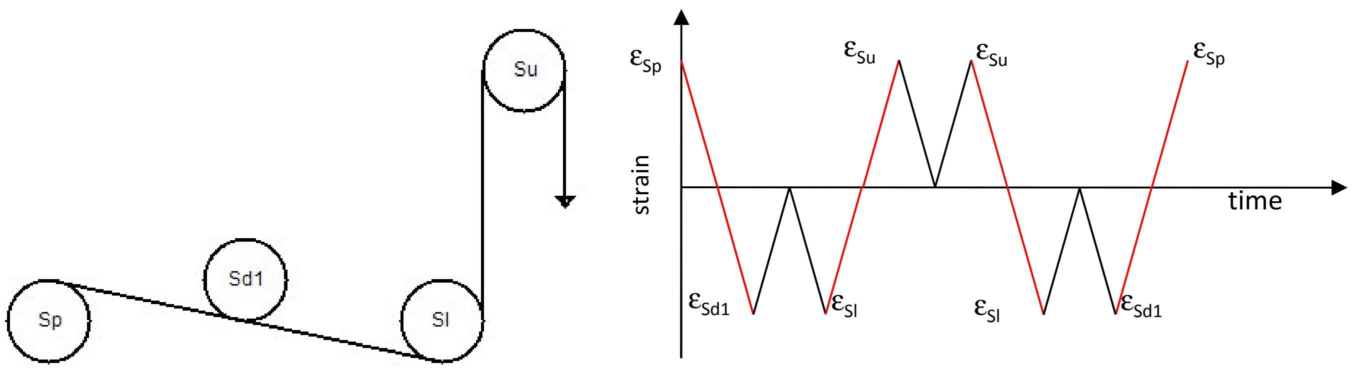




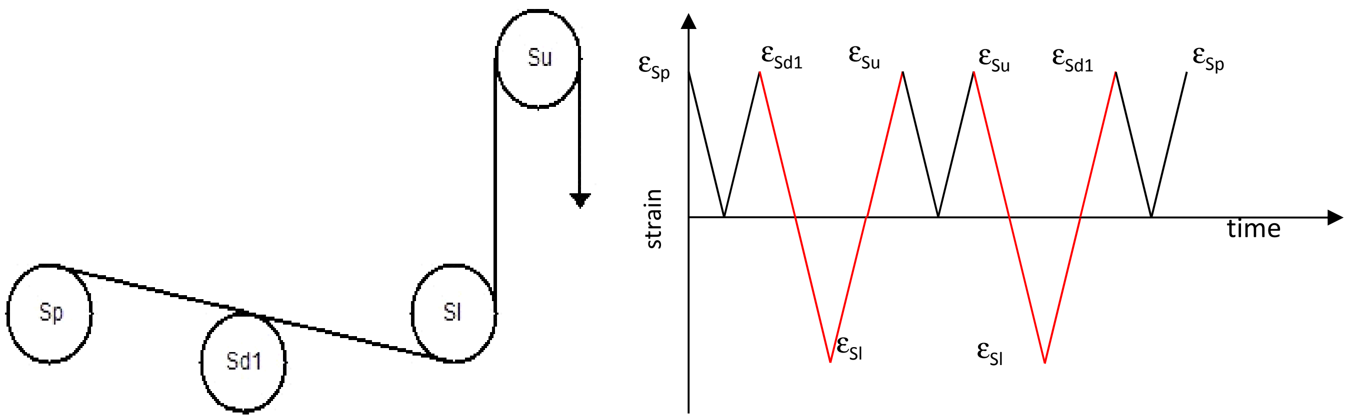
- **Sp = power sheave**
- **Sl = lower sheave**
- **Su = upper sheave**

Strains from a Type 2 SL Rigups

(SL Fatigue Model Development)



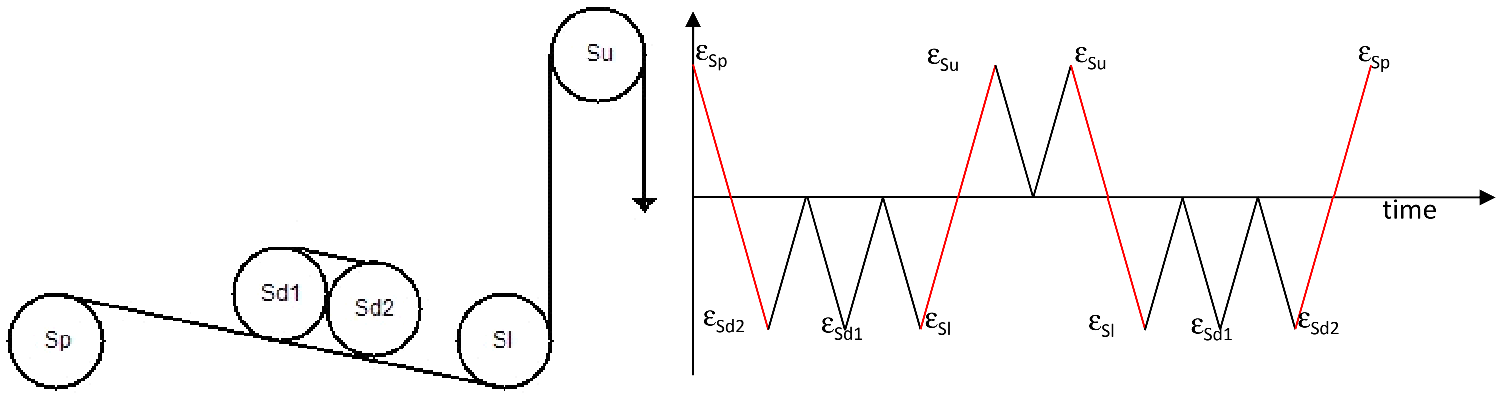
Type 2a



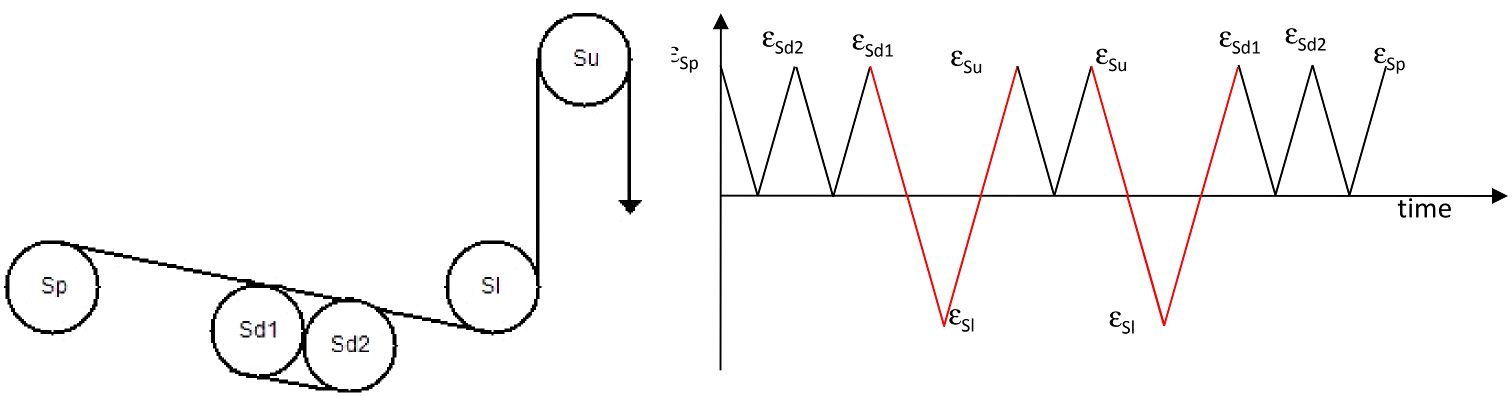
Type 2b

- **Sd1 = depth sheave 1**

Strains from a Type 3 SL Rigups
(SL Fatigue Model Development)



Type 3a



Type 3b

- **Sd2 = depth sheave 2**

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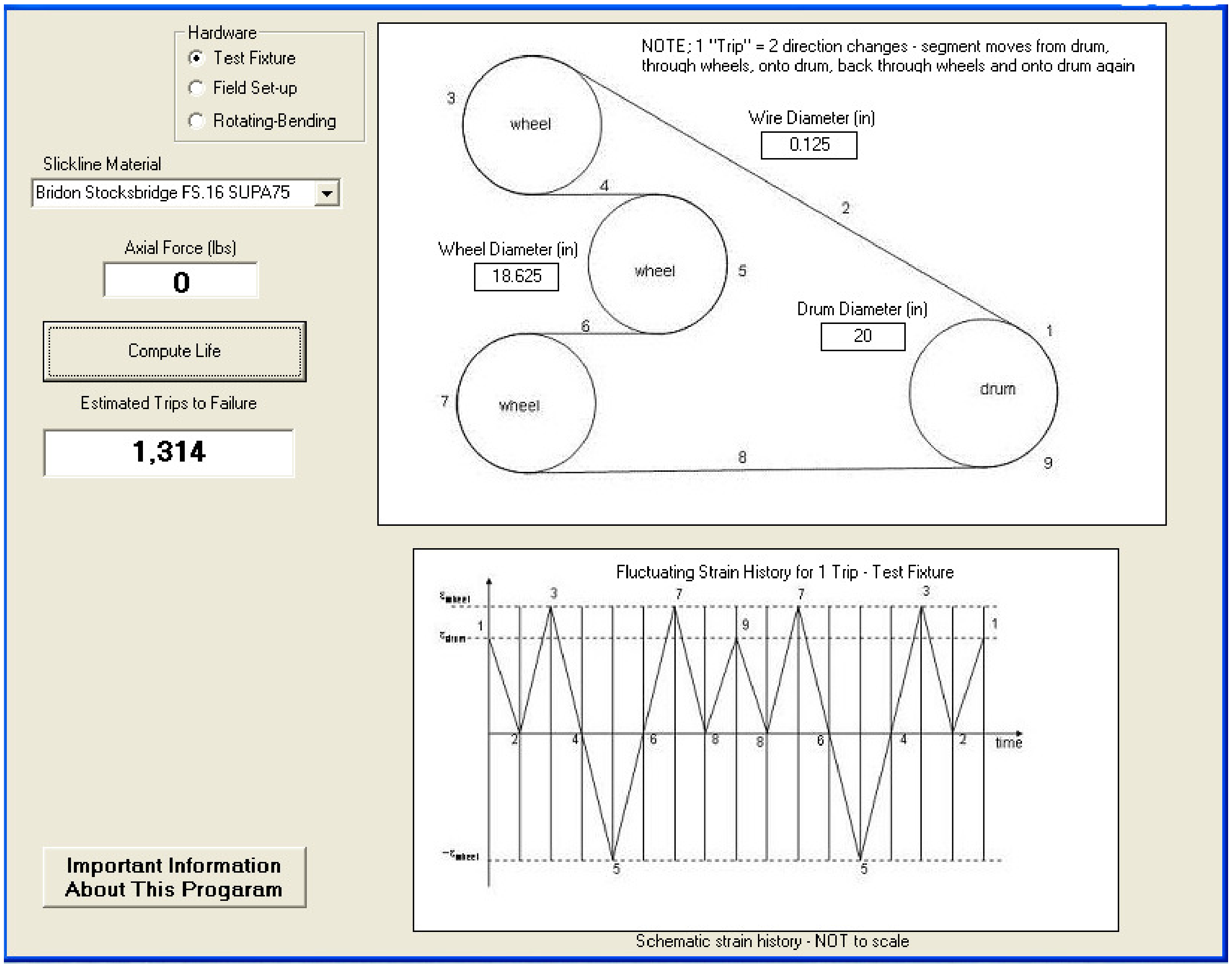
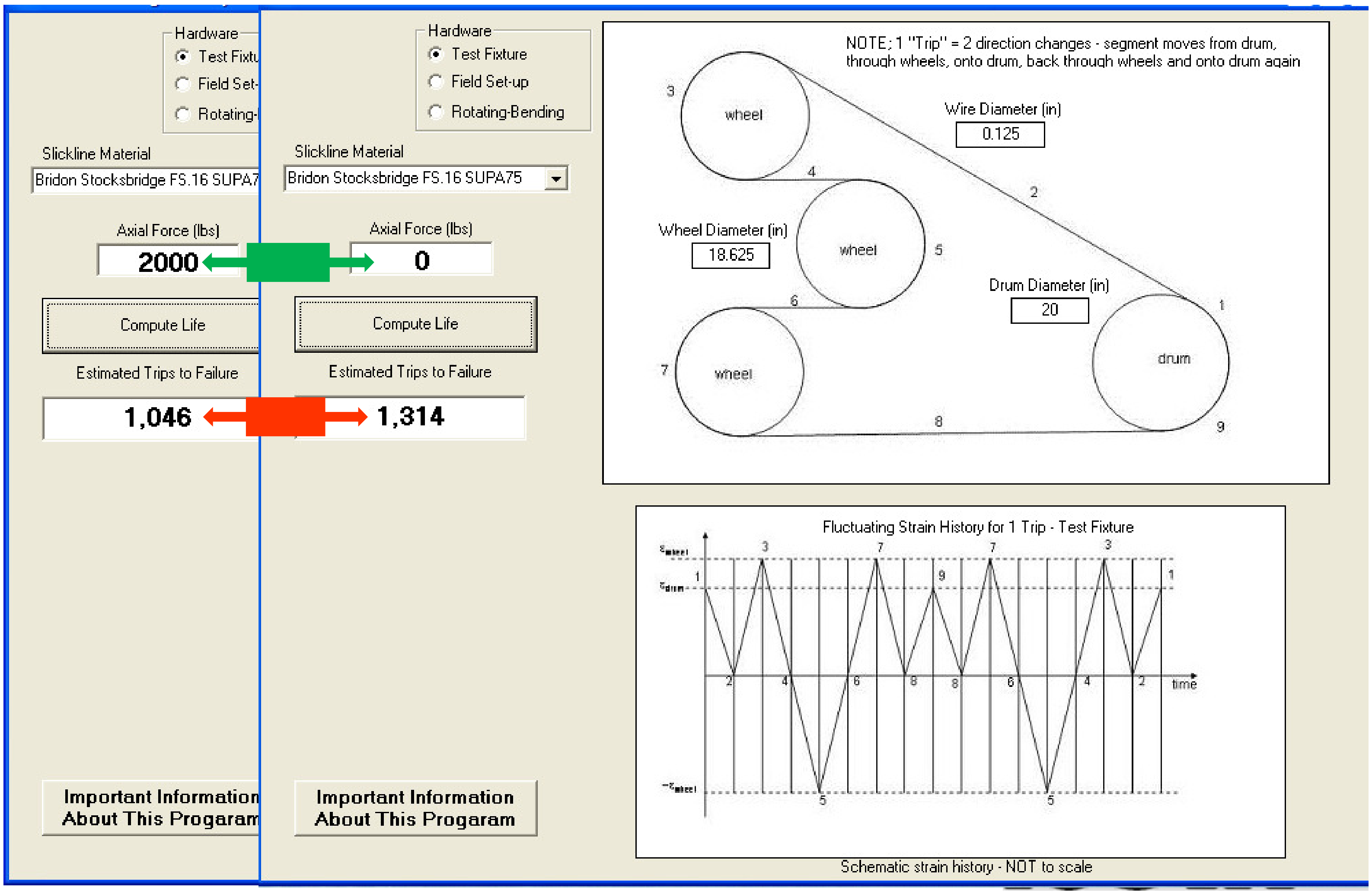
Model Results / Tension = 0

(SL Fatigue Model Development)



Model Results / Tension = 2,000 lbs

(SL Fatigue Model Development)



Corrosion / Tracked Fatigue De-Rating

(Portable Slickline Fatigue Tester)

- Portable SL Fatigue Test Machine
  - Wellsite use
- Rapid Testing of Short SL Samples
  - Rotation of SL sample imparts bending strain
  - Repeatable results
- Determine Life Reduction Due to Corrosion
  - From tests of actual SL being ran in the field

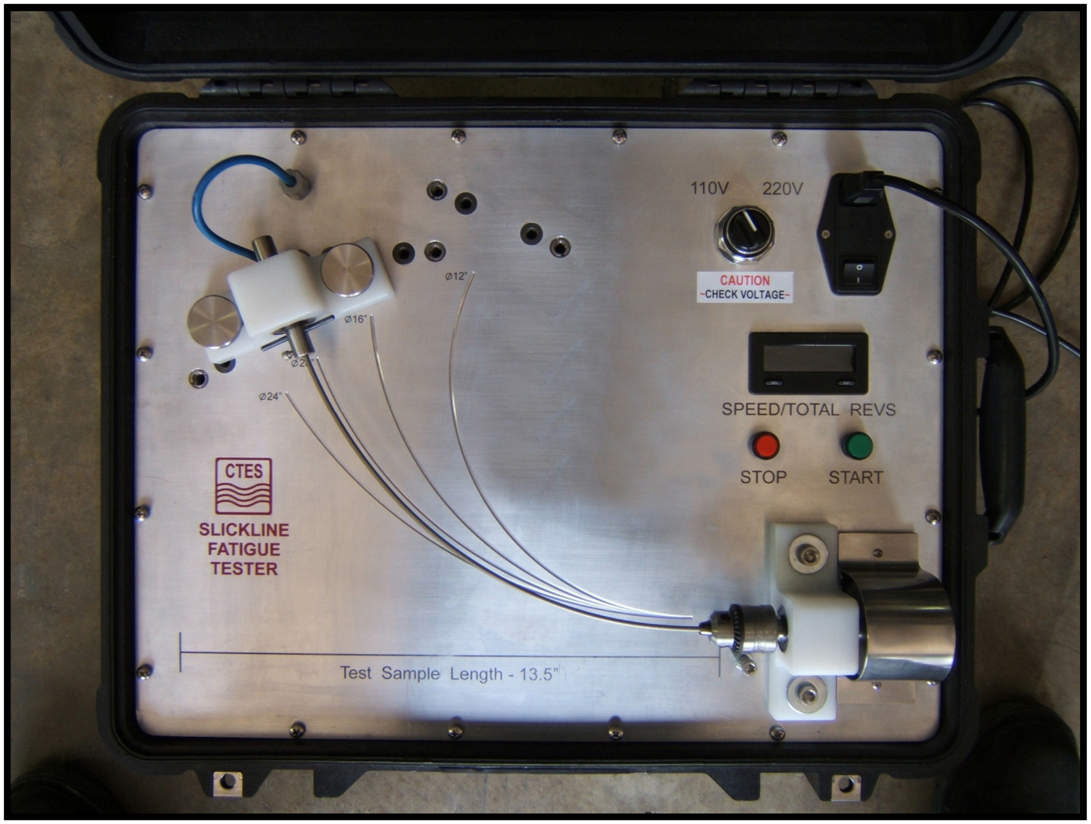
Corrosion Life Reduction

- **Maximum Corrosion @ Downhole End:**
  - Hottest corrosive wellbore fluids
  - Longest period of time in well
  - Exposure to atmosphere when on drum

- **Corrosion Testing**
  - Samples taken from downhole end during life of SL
  - Test samples in portable tester
  - Compare test results to SL fatigue model
  - If worse, add a corrosion factor to fatigue results

Portable Slickline Tester

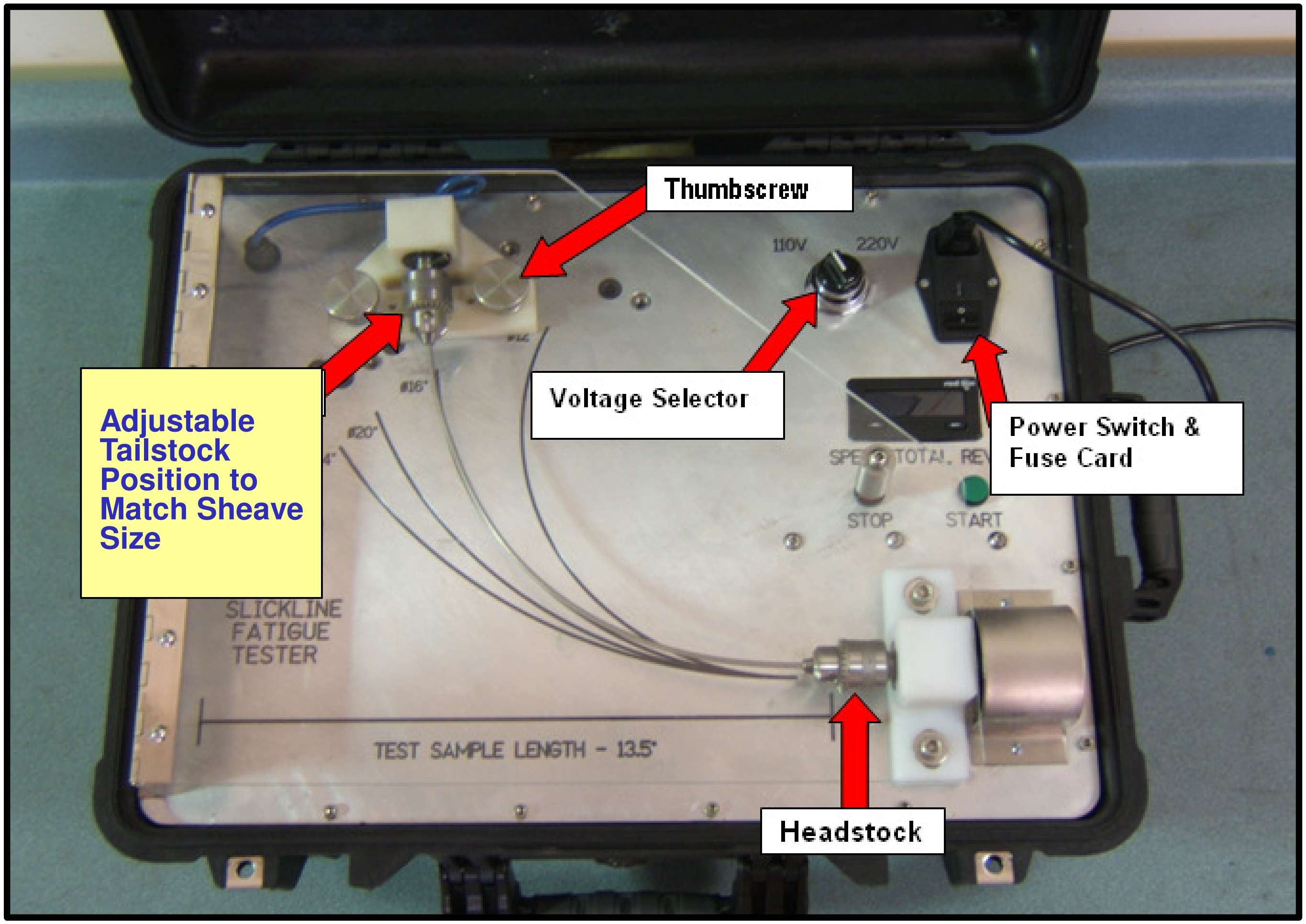
(Corrosion De-rating & Maximum Remaining Fatigue Life)



- Records Revolutions to Failure
  - Rotation of SL imparts bending events
  - Convert revolutions to fatigue life
- Sample length = 34 cm
- Multiple Sheave Sizes
  - 30-61 cm (12-24 in)

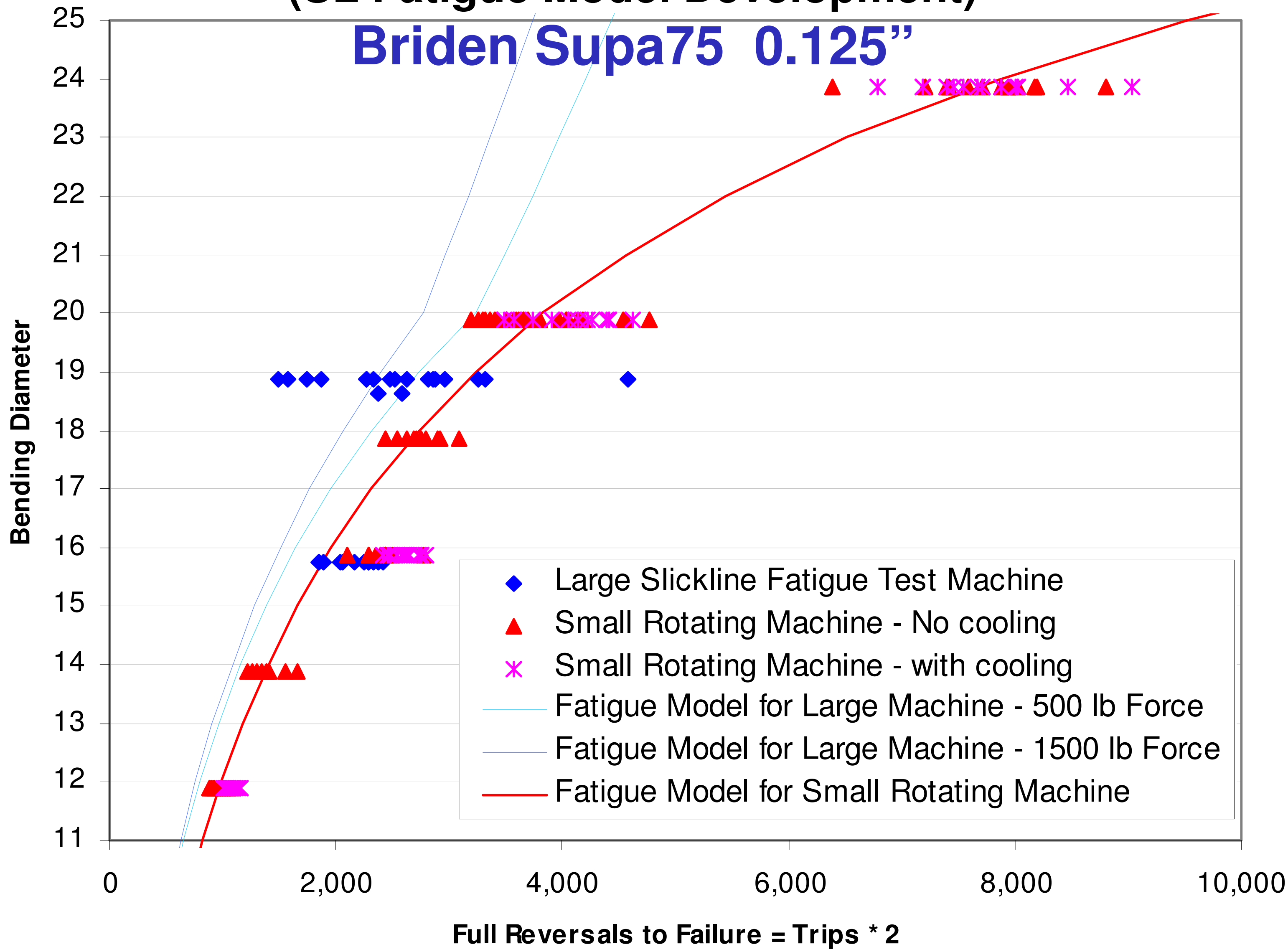
Sheave Size Adjustment

(Portable Slickline Tester)



Fatigue Model vs. Data Comparison

(SL Fatigue Model Development)



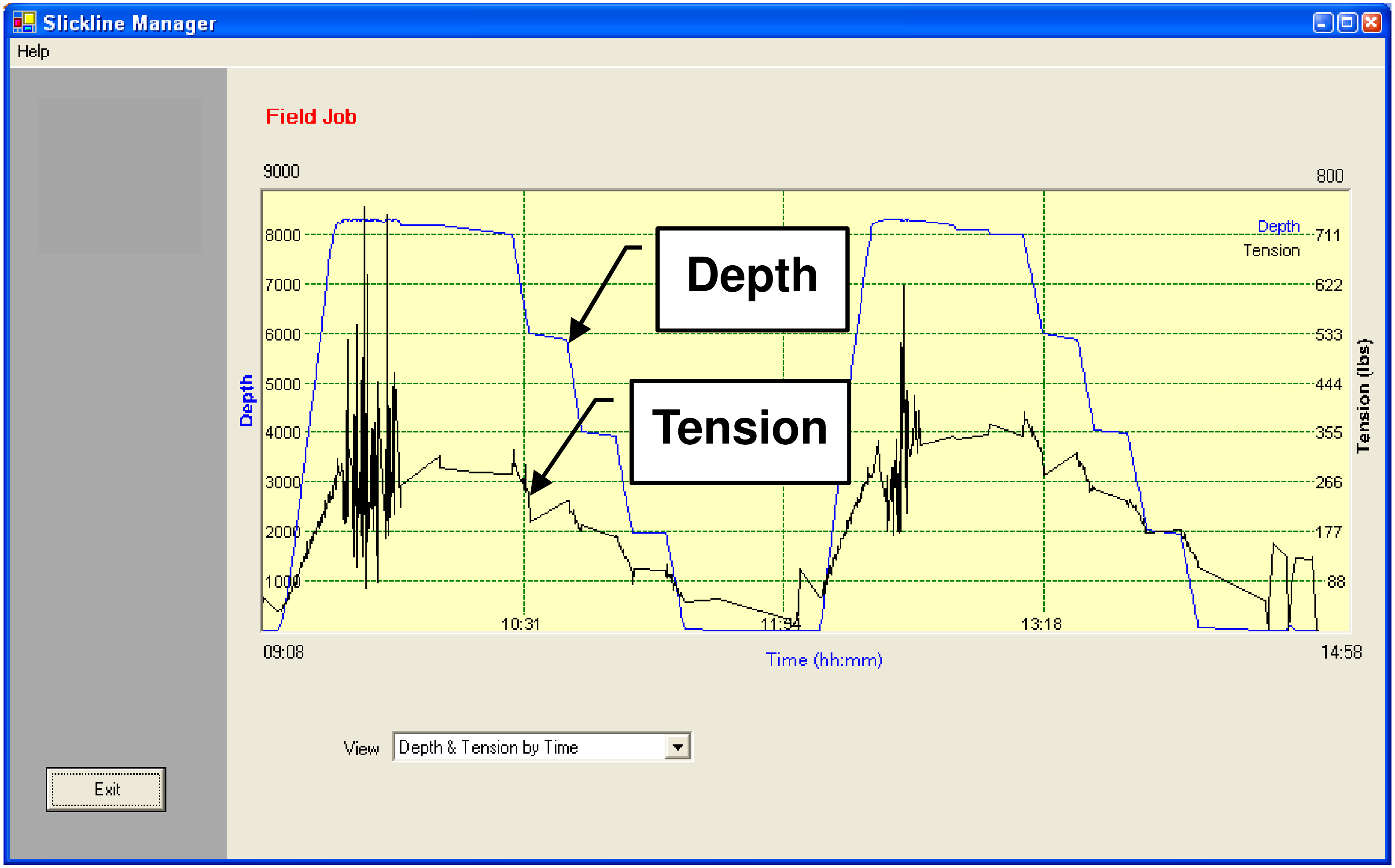
SL Inspection vs. Fatigue Tracking

- **Inspection Systems *Can* Locate:**
  - **Defects**
    - Cracks or pits
  - **Diameter changes**
    - Necking

- **Inspection Systems *Cannot*:**
  - **Measure fatigue damage**
  - **Estimate SL life reduction due to the defects**
  - **Estimate remaining SL fatigue life**

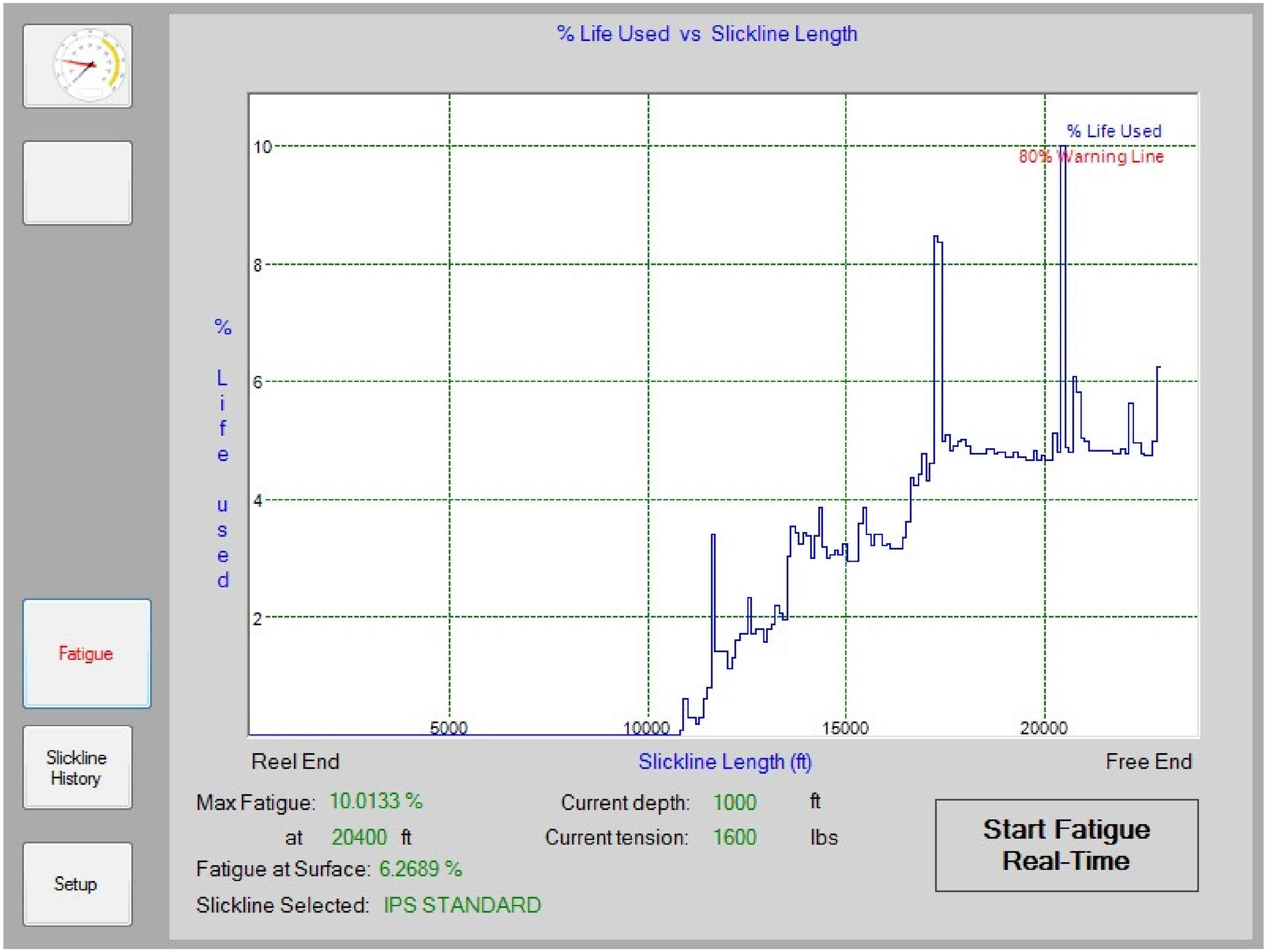
Slickline Job Data

(Example: Tension & Depth vs. Time)



% Fatigue Life Used Output

(Example)



Slickline – Case History 1

Background

- **Sandvik 2RK66 0.108" slickline**

- **Slickline data acquisition system used to record field job data**
  - **Depth, tension, sheave size & configuration**

- **Field Data**
  - **37 Individual job records (i.e. work on a single well)**
  - **Up to 7 downhole trips per well**

- **Slickline History**
  - **Time in service: 90 Days**

Slickline

(Case History 1)

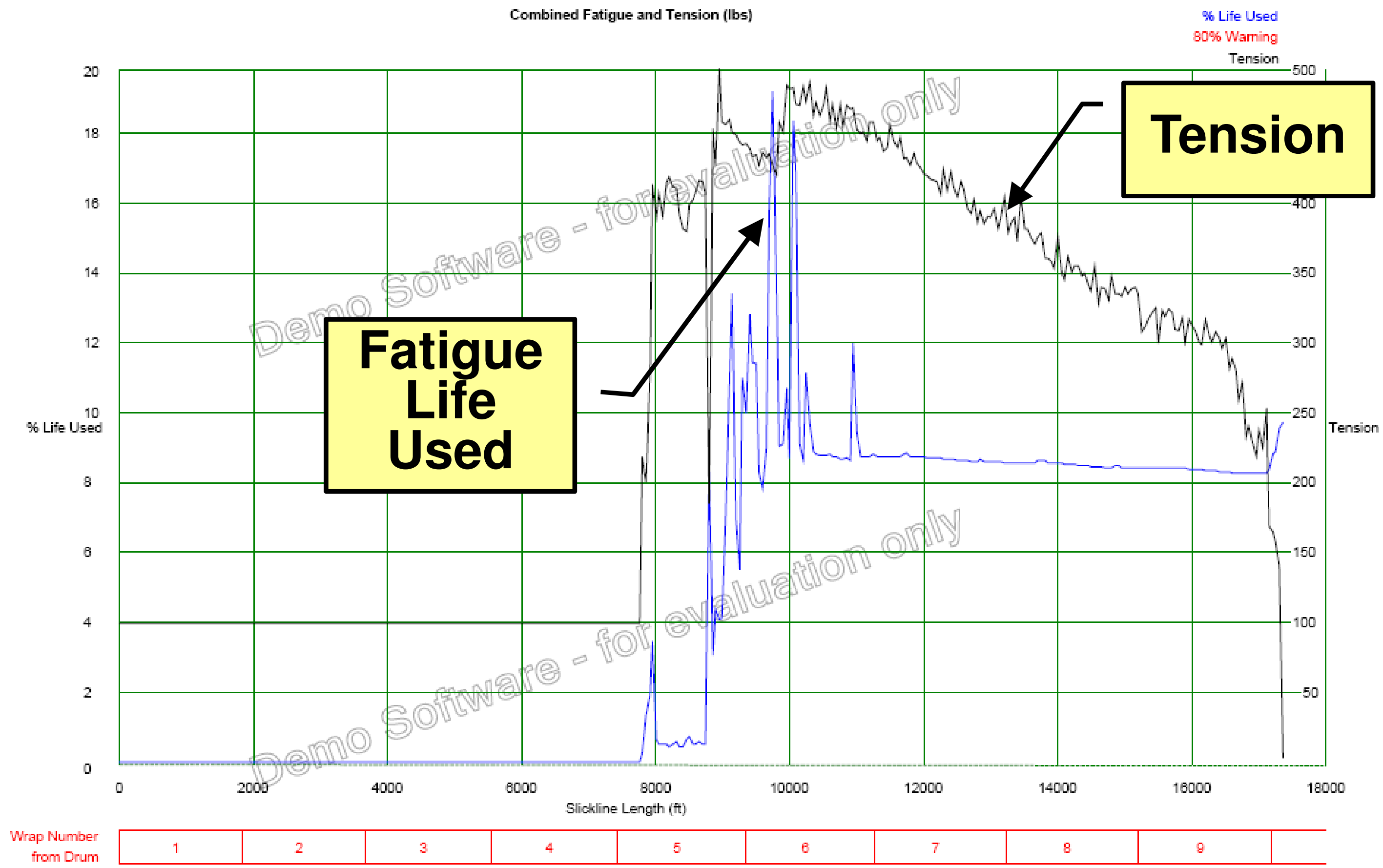
Assumptions

- Fatigue Calculated as GD31MO 0.108” Slickline
- Several Jobs Not Recorded (<10% of total)
- Rig Up: Dual-wheeled Measuring Head
  - Upper & lower sheave wheels (‘Type 3’ rigup)
- 6 m Slickline Cut Off after Each Job (avg.)
- No Exposure to Corrosive Environments

Fatigue Calculation
(Case History 1)

Results

- Slickline Retired with Only 20% Fatigue Life Used !
- Wasted $ for Unnecessary Line Replacement



Conclusion

- **Slickline Fatigue Software**
  - Display/record job data
  - Record line cuts & spooling events
  - Real-time remaining fatigue life
  - Can be utilized with DAS provided by numerous manufacturers
  - Generates post-job customer reports
- **Portable Fatigue Tester**
  - Test for corrosion
  - Fatigue life de-rating
- **Questions?**