Information on Helicopter Hoist Wire Rope, Failure Modes, and Rejection Criteria

Courtesy of:

Then and Now


21st SOS Downed Crew
And Rescuers
Feb. 1969
Holt
Dunn
Col White
Barbin

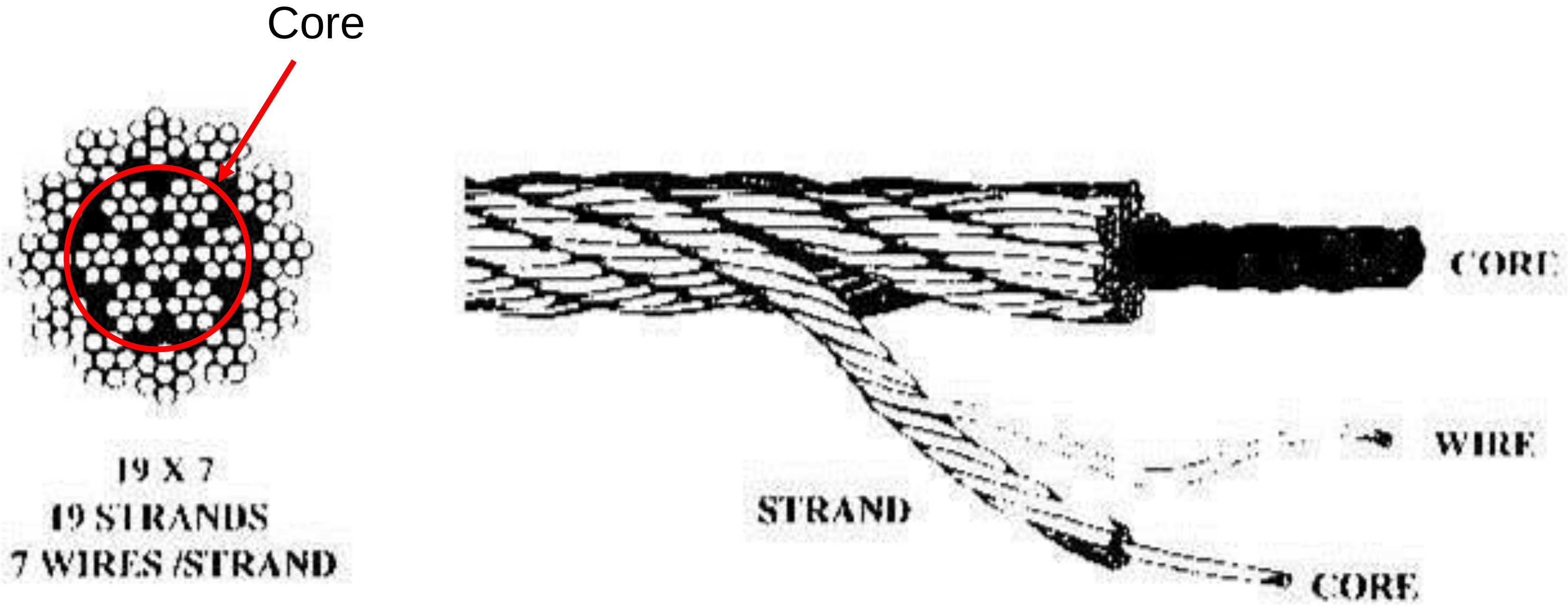
Helicopter, Hoist & Humans “The System”

- The hoist is mounted to a dynamic platform.
- The force reactions in the wire rope are due to the platform performance and mechanical compliance.
- The forces are influenced by the human inputs.
- The system is open loop with a single point failure mode; the wire rope or cable.
- System maintenance is critical to mission success.
- The System is often taken for granted by humans.

Helicopter Hoist Wire rope

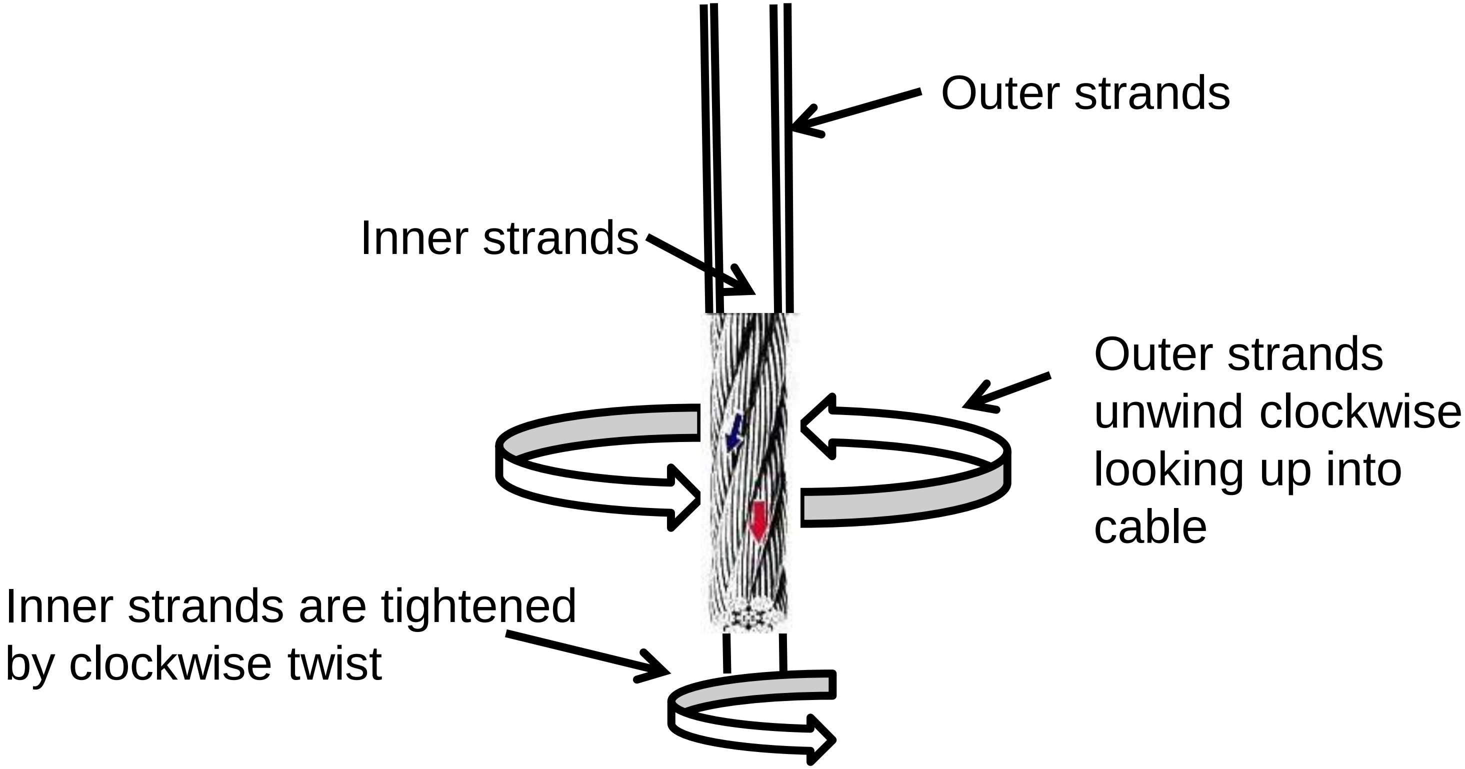
- Basic design and Specification has not changed over the years
- Used in a Dynamic and Corrosive Environment
- 19x 7 construction
- Some hoists use lubricated and some use non-lubricated cables
- Is the essential load carrying element in the rescue hoist system

Rescue Hoist Wire Rope Construction



Class 19x7 ropes are ROTATION RESISTANT but NOT non-rotating

If the end is allowed to swivel the cable unwinds under load



The outer strands elongate as they unwind and the inner strands tighten up. The outer strands take less load and the inner strands stands take more load. This results in an approximate 30% reduction in breaking strength.

19 x 7 cable

- Special construction
  - Requires caution to not impart shock loads
  - Do not impart twist
  - Inspect often

Wire Rope Material

- 302/304 Austenitic Stainless Steel
  - Non-magnetic when annealed
  - Para magnetic as a result of the wire drawing process
  - Work hardenable
    - – Converts Austenitic Structure to a Martensitic structure
  - Corrosion resistant
  - Susceptible to stress corrosion cracking when exposed to chlorine

Wire Rope Fabrication

- Starts as thick annealed wire or billet
- Drawn down through multiple dies to form each specific wire size required, thus work hardening it and making it paramagnetic
- Wire is preformed and spun into strands specific to each component of the final rope to eliminate internal stress on the wires
- <u>Strands preformed and spun into the final wire rope assembly to eliminate deformation under load</u>
- Individual assemblies cut off, there should be no unraveling or loosening of the assembly.
- The Ball is swaged to compress it on the cable and it locks in the positioning of the preformed strands if done properly
- Proof tested to 1980 lbs
- Drum end terminated by electric arc or another ball swaged on end
- Degreased
- Painted
- Re-greased so it will meet the requirements of the mil spec
- The cable is in the final state and operation of the hoist does not change the state of the cable unless it is incorrectly made.

Mil-W-83140

- Requires the cable be made for the intended purpose
  - Must be thoroughly lubricated
  - Must stay tight
  - Must be free from loose wires, loose strands or other defects
  - Must resist kinking and snarling
  - Must resists corrosion

Cable Strength vs Energy

- 3/16 Cable Static Test Strength Values
- Min. Static Ultimate Strength 3300 lbs
- Min. Static strength after fatigue 2100 lbs
- Max. force before Static damage =1980 lbs
- Rescue Hoist Energy Absorption Factors
- Length Extended
- Condition of Cable
- Free Fall Height and load

Wire Rope Endurance Specifications

- Mil-W-83140 Type I (19x 7)
  - 3/16” 2100 lbs residual min. breaking strength

- 150 000 reversals over a small pulley with tension applied
- 3/16 -- 1.781 inch pulley @ 45 lbs

Wire Rope Balance

- Inner and outer strands are wrapped around the central strand.
- Inner and outer strands oppose each others tendency to twist.
- Proper balance insures equal load sharing between the inner and outer strands.
- Unbalanced rope tends to loosen up.
- Unbalanced rope fails earlier.

From Wire Rope Manufacturer

- “Do NOT use class 19x7, 18x7, 17x7, or 24x7 wire rope attached to a swivel or have one or both rope ends rotate freely under load. <u>Doing so will result in a loss of rope strength of between 30% to 40%. This is NOT a non-rotating rope.”</u>

- “PLUS, regular type 19x7 does not spool very good on multiple layer drums; there is too much strand interlocking causing excessive rope abrasion.”

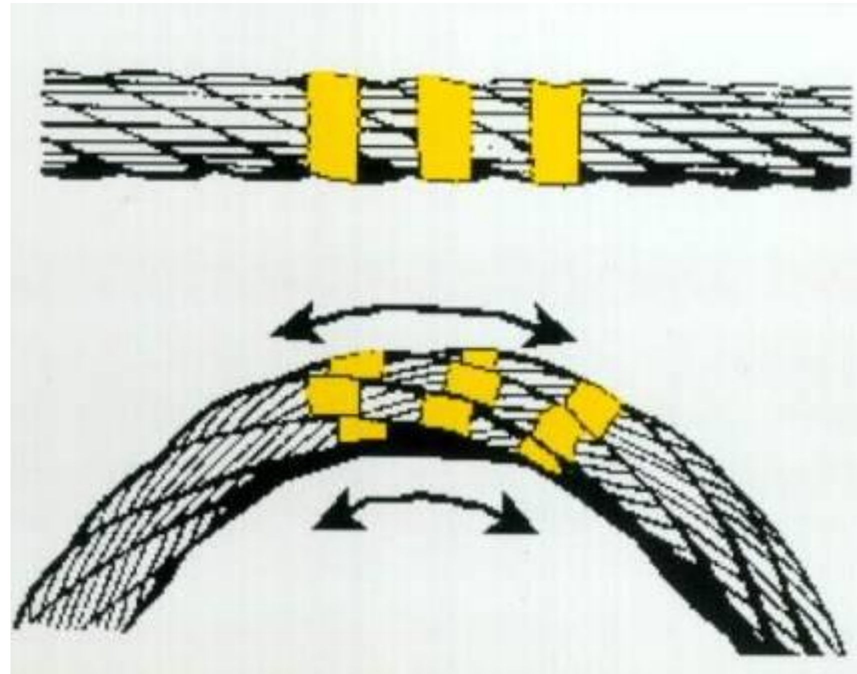
- This is especially a problem at the <u>drum turnarounds on Rescue Hoists</u>

Fatigue

- All 19 x 7 wire ropes fatigue from the inside out
- Aggravating factors
  - Loosely homed hook
  - Lack of lubrication
  - D/d ratio of bending over sheave and around drum
- Worn out guide rollers accelerate fatigue

Fatigue

- All wire ropes are subject to fatigue and internal abrasion
- When bending over a sheave, the distance rope wires travel is greater on the topside than on the underside leading to internal wear

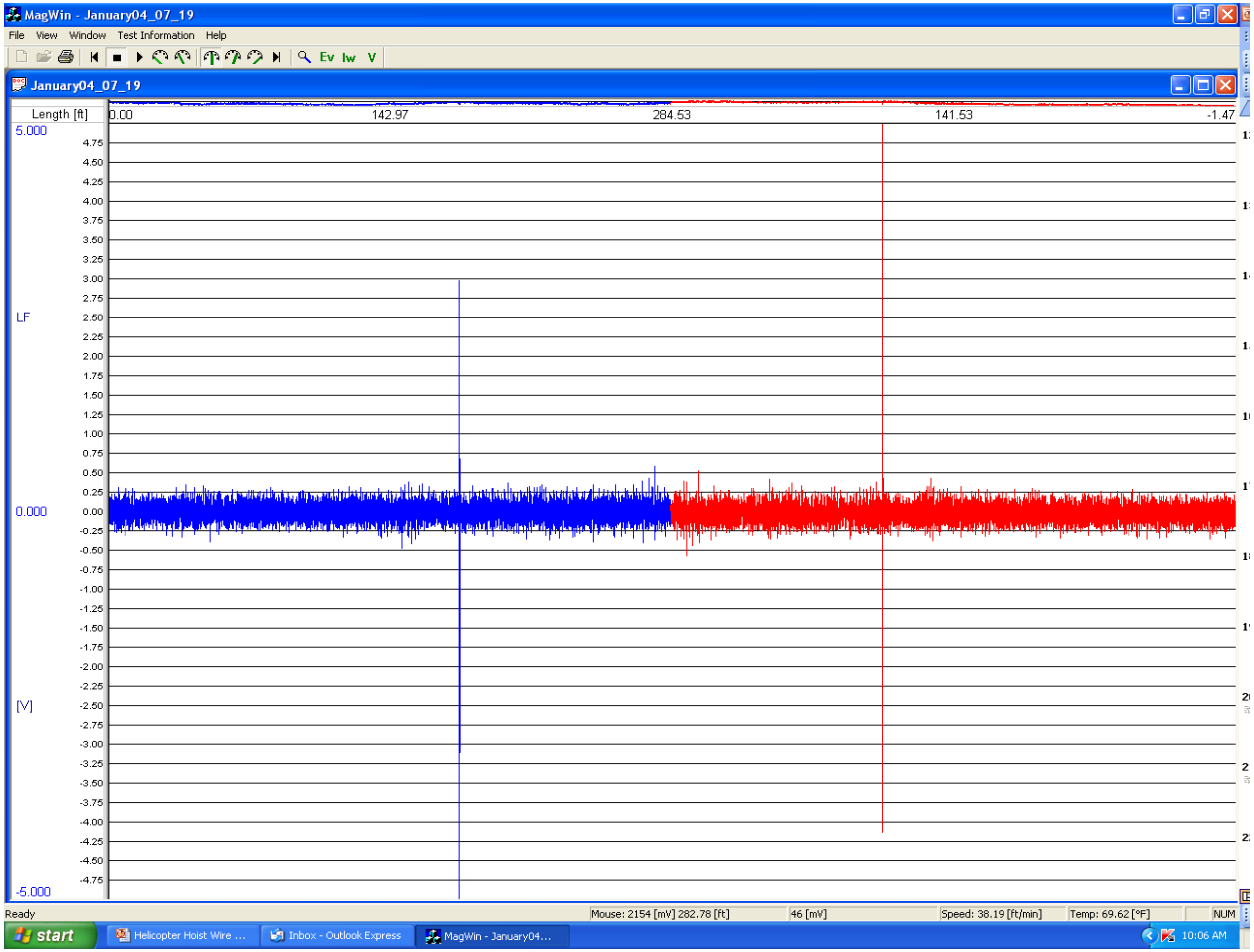


Lubrication is critical to reduce internal wear of the strands

From wire rope manufacturer

- "Using the rope to it's maximum fatigue life will cause the rope to deteriorate from the inside out. Sudden rope failures may be the result. However, (rescue hoists) are operated on a much less severe duty cycle and it is not expected that 19x7 has to be replaced because of inner rope fatigue but because of other mechanical damages."
- The rope does not deteriorate in a linear fashion, but will retain most of its strength and then deteriorate quickly at the end of life

Effect of wrapping on a multilayer drum



Broken internal strand at turnaround from 3rd to 4th layer

Effects of Lubrication

- **A ‘dry’ rope unaffected by corrosion but subject to bending fatigue, is likely to <u>achieve only 30% of that normally attained by a ‘lubricated’ rope.</u>**
- Most wire ropes should be lubricated at regular intervals (including cleaning) in order to extend safe performance.
- Ensure that any in-service lubricant dressing penetrates into the core of the rope.

Wire rope test methods vs. reality

- During testing all loads applied are with both ends of the wire rope fixed.
- The speed of separation of the heads is limited to 1 inch per minute
- In usage the lower end of the rope is allowed to rotate, i.e. unload the outer strands
- Therefore the actual possible breaking strength is less then published minimums
- Approximate ultimate *static* load for 3/16” is 2750 lbs

Safety Range

Best Case
Fne=.6 x2750 lbs=1650lbs -Static load no dynamic effects
Tight and Lubricated cable
new –good condition

Semi Worst Case
Fne= .6 x 2100= 1200 lbs
Still Tight and Lubricated cable
end of service life approximately 1500 cycles

Worst Case
Fne= unpredictable
Loose strands-all load goes through internal strands
<u>No appreciable service life</u>

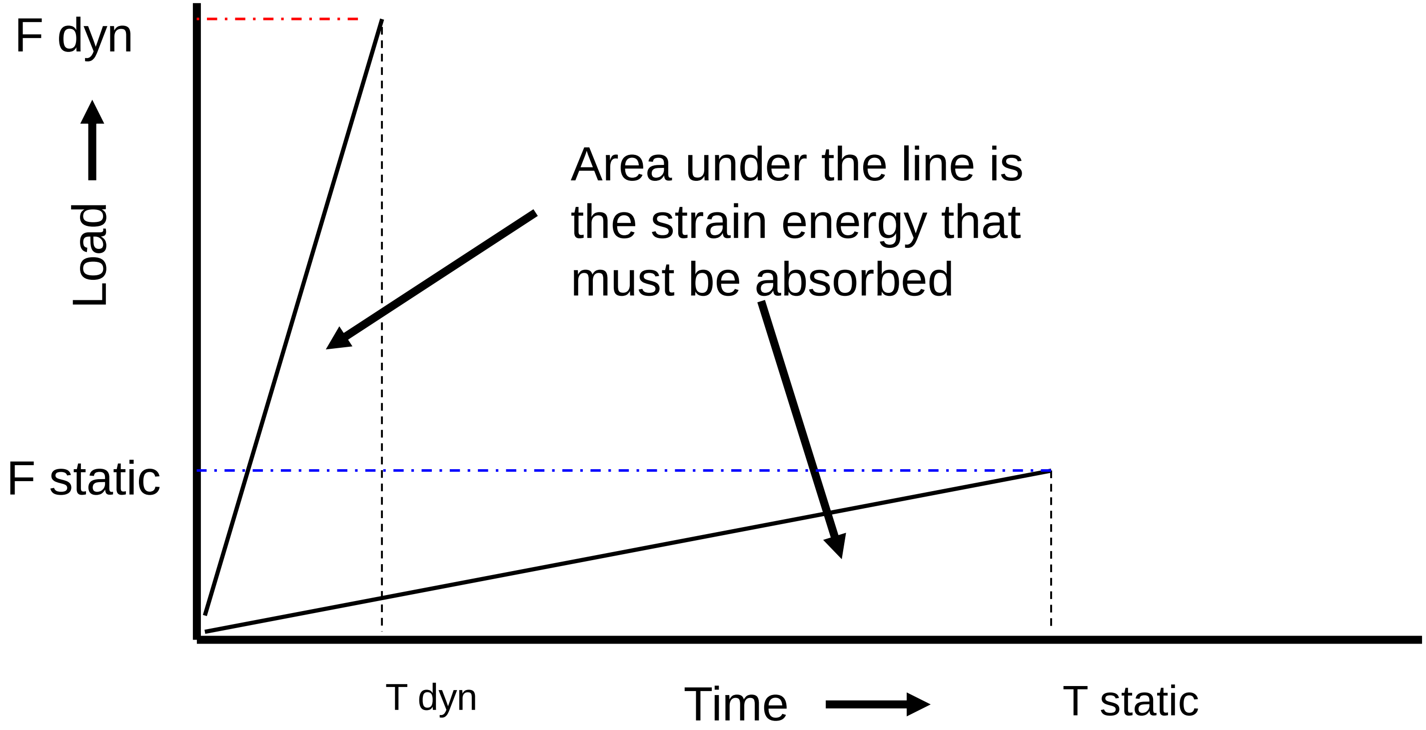
Catastrophic Case
Dynamic induced force exceeds cable's ability to absorb the energy- cable fails and separates

Static-vs-Dynamic (Shock) Loading

- Static loads are slowly applied
- Dynamic loads are rapidly applied load
- Resulting Dynamic load is a function of the overall stiffness of the system- Helicopter-mount-hoist-cable-strop-body- wind -waves

Dynamic Tensile Overload

- Happens over a very short period of time
- When F dynamic exceeds Fne damage occurs

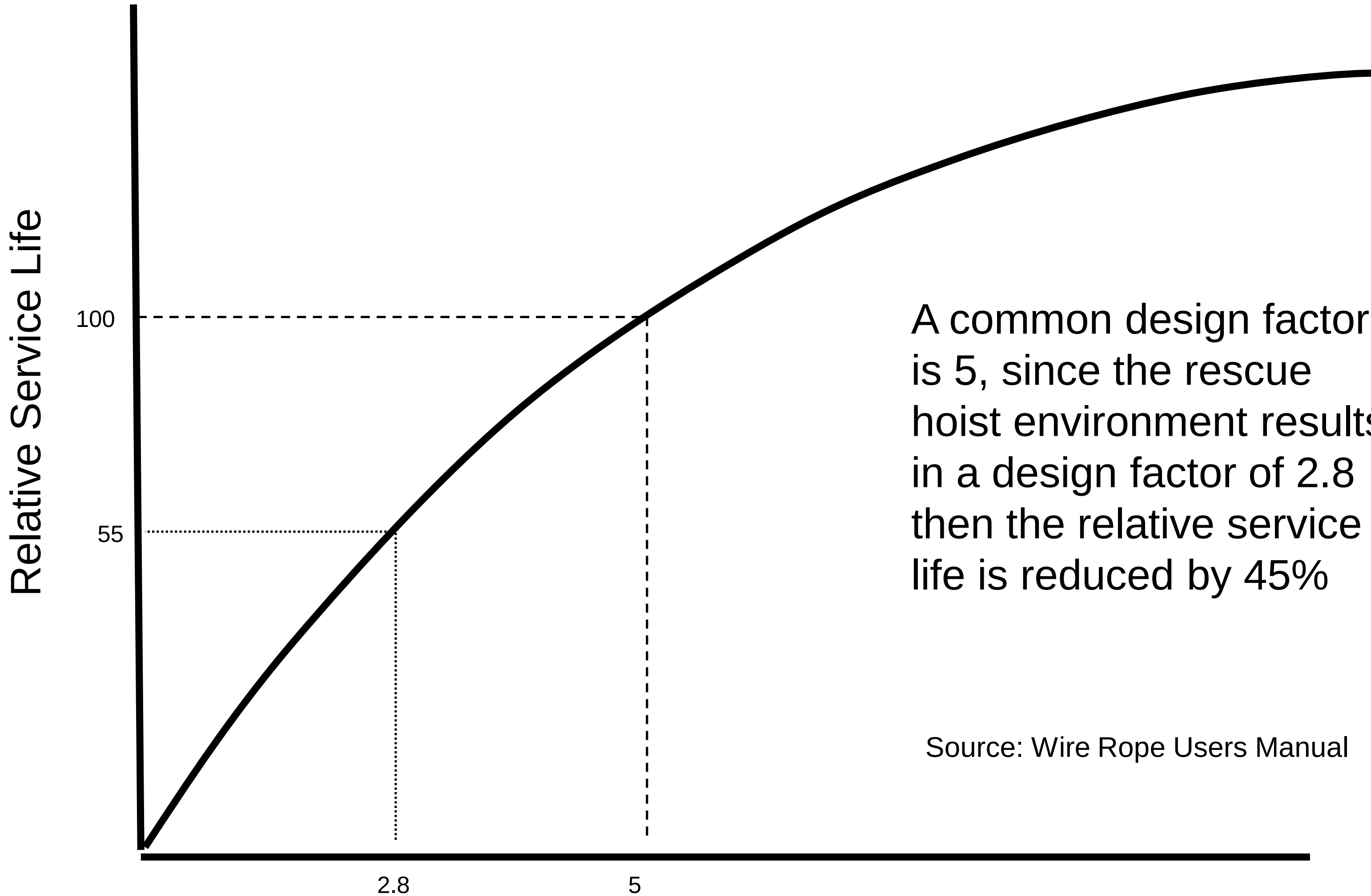


Actual Design Factors

- Never exceed load is 60% of minimum breaking strength
- .6 x 2750= 1650 lbs= F ne
- Design factor = 1650 lbs/ load
- For 600 lbs, Static Design Factor= 2.75:1

- Caution: The minimum SF should be 5:1 for a 19 x 7 rope with a swivel on the end

Relative Service Life



A common design factor is 5, since the rescue hoist environment results in a design factor of 2.8 then the relative service life is reduced by 45%

Source: Wire Rope Users Manual

Catastrophic Tensile Failure

- Most unlikely form of cable failure but the most deadly
- Two types to be discussed
  – Static tensile overload
  – Dynamic tensile overload

Static Tensile Overload

- Can result from snagging the hook
- As the load slowly develops in the wire rope it stretches
  - when the amount of stretch exceeds the ropes capacity to stretch it starts to deform plastically (non recoverable)
  - continued stretching results in total separation of the wires releasing all of the stored energy in cable

Wire Rope Stretch

- Constructional Stretch- the initial adjustment of lay as wires adjust under load
  - Is eliminated during the proof testing of ball end
- Elastic Stretch- Elastic Deformation
  - 3/16 ----.334% of length at 600 lbs or 8 inches at 200 feet

- DEC 09

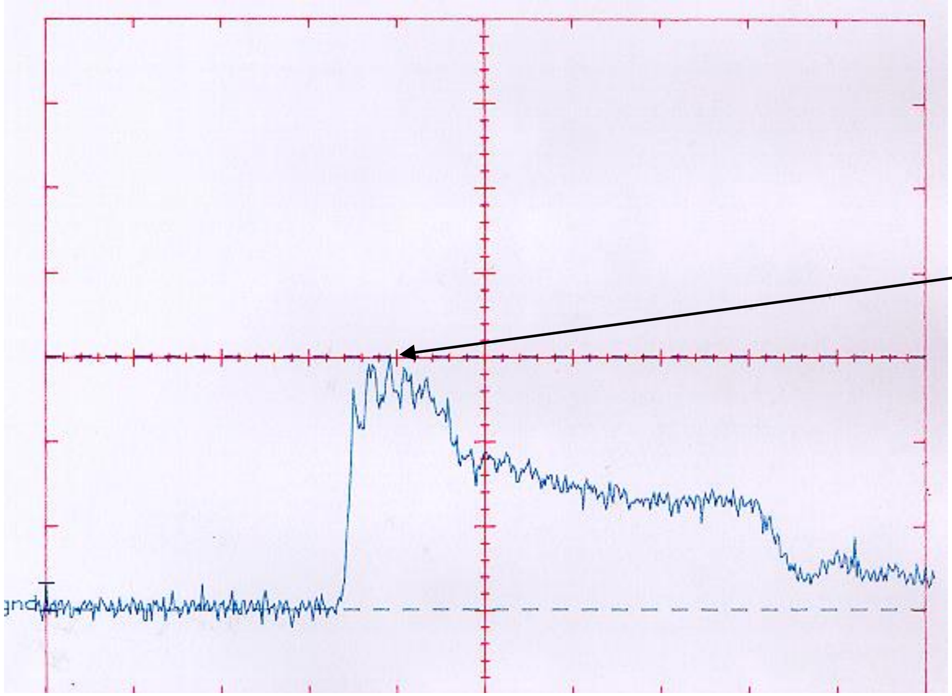
- SUBJ: RELEASE OF THE FINAL ACTION MEMO (FAM) FOR THE ADMINISTRATIVE
- INVESTIGATION AND THE FINAL DECISION LETTER (FDL) FOR THE MISHAP
- (SAFETY) INVESTIGATION FOR THE COAST GUARD AIR STATION BARBERS
- POINT CLASS "A" AVIATION INCIDENT INVOLVING HH-65C CGNR 6505 ON 04
- SEP 2008
- 1. SYNOPSIS. AT 2011 (HST) ON SEPTEMBER 4TH 2008, AIR
- STATION BARBERS POINT COAST GUARD HELICOPTER NUMBER (CGNR) 6505 WAS
- TAKING PART IN A NIGHT HOISTING TRAINING EVOLUTION WITH STATION
- HONOLULU MOTOR LIFE BOAT (MLB) 47317 APPROXIMATELY SIX MILES SOUTH
- OF HONOLULU, HI. CGNR 6505 WAS CARRYING 4 PEOPLE: TWO PILOTS, ONE
- FLIGHT MECHANIC AND ONE RESCUE SWIMMER. CGNR 6505 WAS IN THE
- RECOVERY PHASE OF A HOIST FOLLOWING A STANDARD DELIVERY OF THE
- RESCUE BASKET WITH TRAIL LINE TO THE MLB WHEN THE MISHAP OCCURRED.
- AS THE HELICOPTER MANEUVERED OVERHEAD, IT DESCENDED AS THE MLB ROSE
- ON A SWELL. THE RELATIVE MOTION CREATED EXCESS SLACK IN THE HOIST
- CABLE. DESPITE THE EFFORTS OF THE ATTENDING MLB CREWMEMBER, THE
- EXCESS CABLE ENTANGLED ON THE MLB ENGINE ROOM DEWATERING STANDPIPE
- ON THE AFT BUOYANCY CHAMBERS FORWARD FACE. AS THE MLB RODE DOWN THE
- SWELL AND THE HELICOPTER MANEUVERED TO REGAIN ALTITUDE, THE CABLE
- BECAME TAUT, PHYSICALLY PULLED THE HELICOPTER DOWN TO THE RIGHT AND
- THEN PARTED UNDER TENSION AT THE ENGINE ROOM DEWATERING STANDPIPE.
- THE CABLE PARTING INDUCED AN UNUSUAL ATTITUDE RECOVERY (EXTREME YAW
- TO THE LEFT), DURING WHICH THE MAIN ROTOR BLADES CONTACTED THE
- HOIST BOOM ASSEMBLY.

- THIS CREATED A SIGNIFICANT OUT OF BALANCE
- CONDITION THAT CAUSED SEVERE VIBRATIONS FOR THE REMAINDER OF THE
- FLIGHT. THE MAIN GEARBOX SUSPENSION SYSTEM WAS ALSO COMPROMISED AT
- THIS POINT FROM THE FORCES OF EXTREME DYNAMIC LOADING. DESPITE THE
- SEVERE VIBRATIONS, THE AIRCREW RECOVERED FROM THE UNUSUAL ATTITUDE,
- AND IN THE PROCESS, FLEW AWAY FROM THE WATER. THEY ALSO MADE
- SEVERAL MAYDAY CALLS THAT WERE OVERHEARD BY THE MLB CREW, SECTOR
- HONOLULU, AND HONOLULU INTERNATIONAL AIRPORT AIR TRAFFIC CONTROL
- TOWER. APPROXIMATELY THREE MINUTES LATER, THE DAMAGE TO THE
- AIRFRAME WAS COMPOUNDED BY DETERIORATION OF COMPONENTS OF THE ROTOR
- SYSTEM, FURTHER DEGRADING THE AIRWORTHINESS OF THE HELICOPTER. THE
- AIRCRAFT DEPARTED CONTROLLED FLIGHT AT APPROXIMATELY 500 FEET AND
- 40 KTS AND ENTERED AN UNCONTROLLED DESCENT TO THE SURFACE. ALL
- FOUR PEOPLE ONBOARD CGNR 6505 WERE KILLED AND THE AIRCRAFT WAS
- LOST.
- THE PRIMARY PURPOSE
- OF THE ADMINISTRATIVE INVESTIGATION WAS TO MAKE FINDINGS AND
- PROVIDE INFORMATION UPON WHICH TO BASE DECISIONS AND TAKE ACTION.
- THE SOLE PURPOSE OF THE MISHAP INVESTIGATION WAS TO DETERMINE THE
- CAUSAL FACTORS AND UNDERLYING CONDITIONS THAT CONTRIBUTED TO THEM.
- BOTH THE FAM AND THE FDL SUMMARIZE ACTIONS TAKEN SINCE THE ACCIDENT
- AND TASK VARIOUS COAST GUARD PROGRAMS WITH REQUIRED ACTIONS TO
- IDENTIFY/AVOID SIMILAR HAZARDS AND THEIR CONSEQUENCES IN THE
- FUTURE.
- 3. CAPT THOMAS NELSON, LCDR ANDREW WISCHMEIER, AMT1 JOSHUA NICHOLS,
- AND AST1 DAVID SKIMIN MADE THE ULTIMATE SACRIFICE WHILE SERVING OUR
- NATION. IT IS UP TO ALL GUARDIANS TO REFLECT ON OUR LOSS, TO DO
- EVERYTHING POSSIBLE TO ENSURE THAT WE ACT ON WHAT WE HAVE LEARNED,
- AND TO PREVENT THIS TYPE OF TRAGEDY IN THE FUTURE.
- 4. ADMIRAL T. W. ALLEN, COMMANDANT,

Mitigating factor- Overload Clutch

- Prevents the hoist cable from absorbing enough strain energy that it breaks, and then possibly rebounding into the rotor blades

600 lbs dropped 42 inches with 42 inches of slack



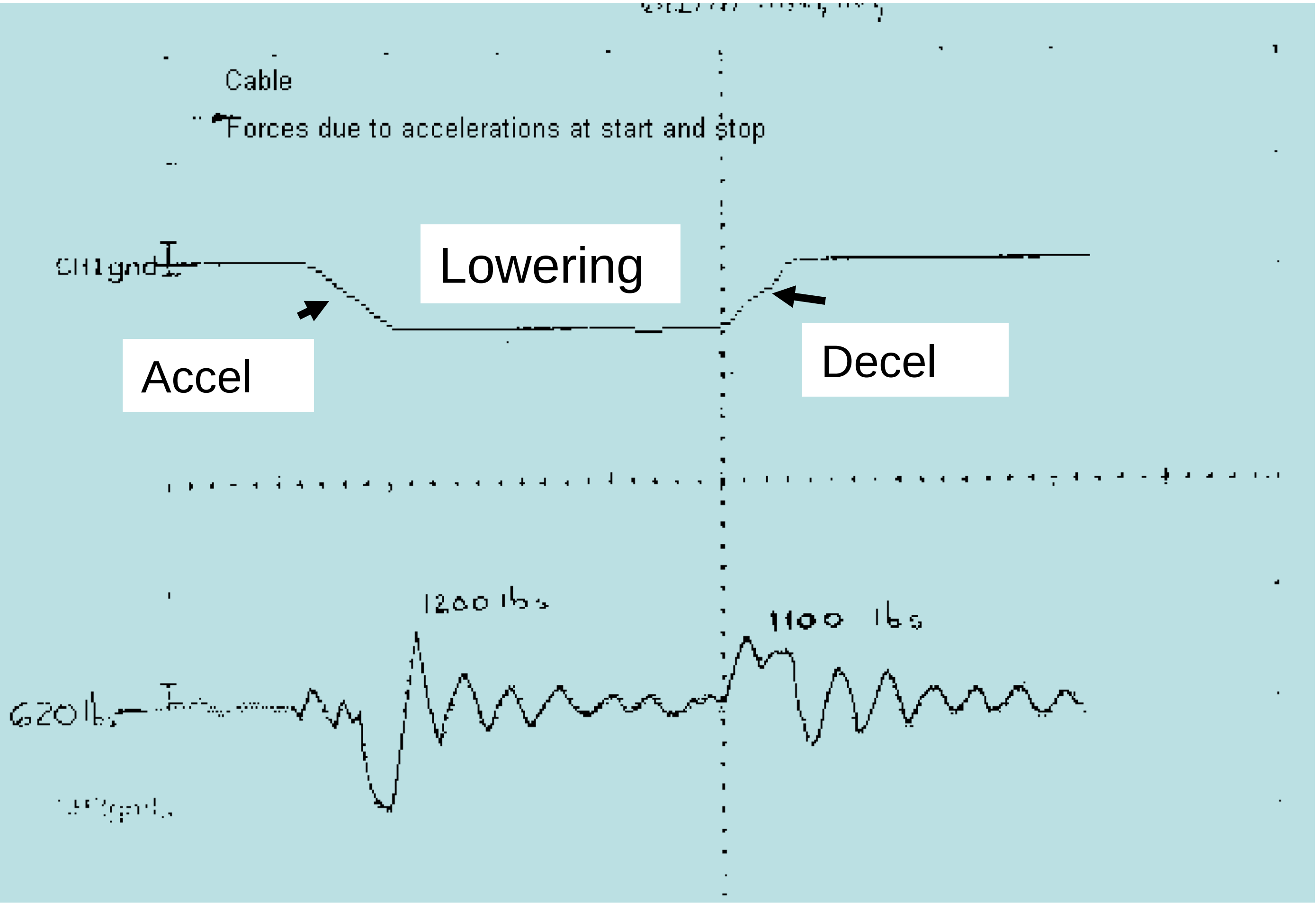
F ne =1650 lbs

F max =1505 lbs

Dynamic Loading

- Dynamic loads are rapidly applied load
- The instant a moving body is stopped, its kinetic energy is completely transformed into the internal strain energy of the resisting system

Normal induced cable loading



Kinetic Energy

- Is a function of the mass of the falling object and the time it is allowed to freefall
- $K_e=1/2\ mv^2$
- The longer the fall the greater the velocity
- The longer the fall kinetic energy increases as the square of the velocity
- When the kinetic energy exceeds the work energy a spring is capable of absorbing the spring fails

Dynamic Tensile Overload

- Energy Absorption Factors
  - Cable length extended
  - Condition of cable
  - Free fall height and load
  - Spring rate of the remaining parts of the system
- Resulting Dynamic load is a function of the overall stiffness of the system-Helicopter-mount-hoist-cable-strop-body- wind - waves

Work Energy of cable is a function of how long it is

- For 3/16 dia. Cable max strain is .334% of length extended

@ 5 feet

Work energy of the cable is
$W=1/2\ kx^2$

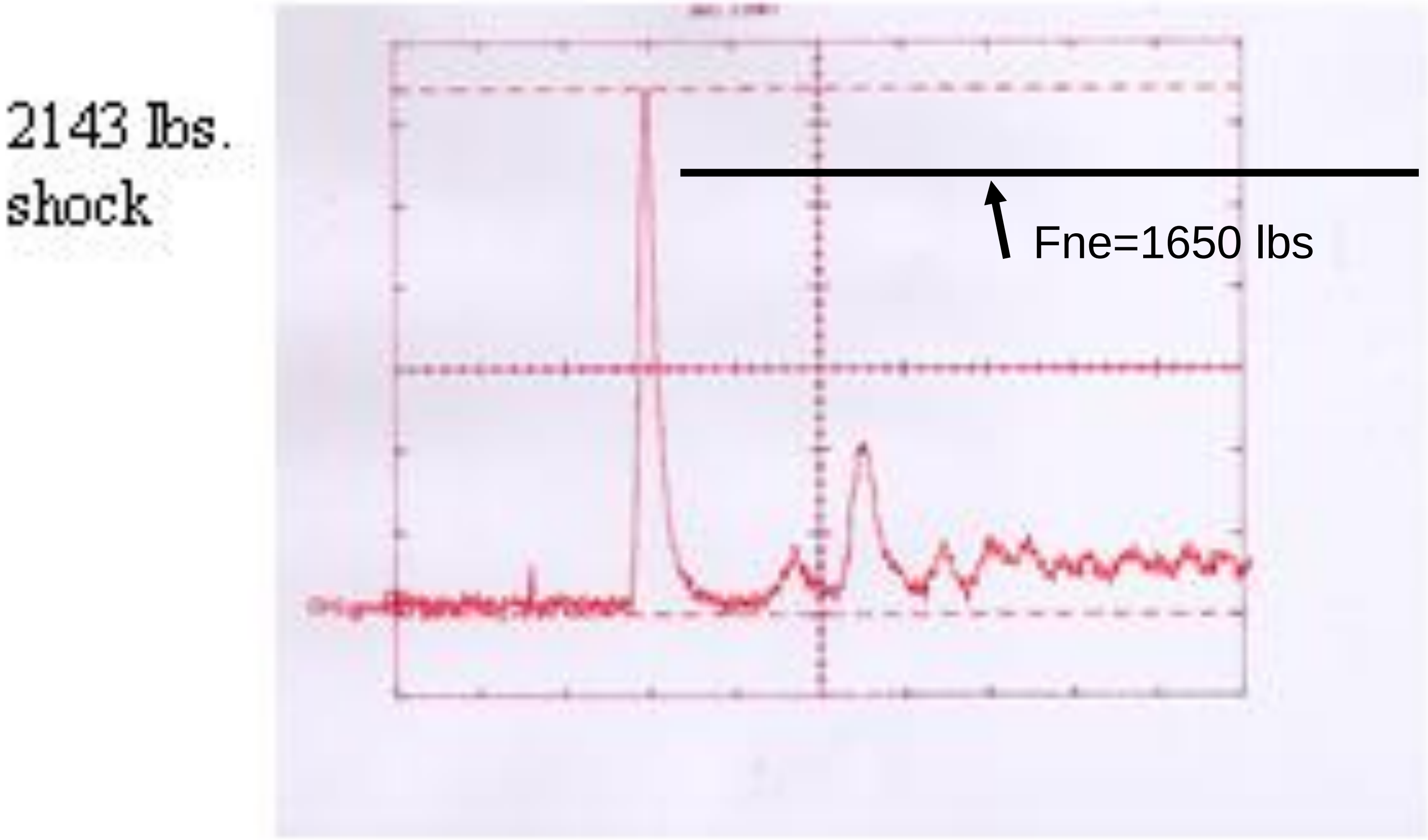
Stretch= .2 inches before damage

@100 feet

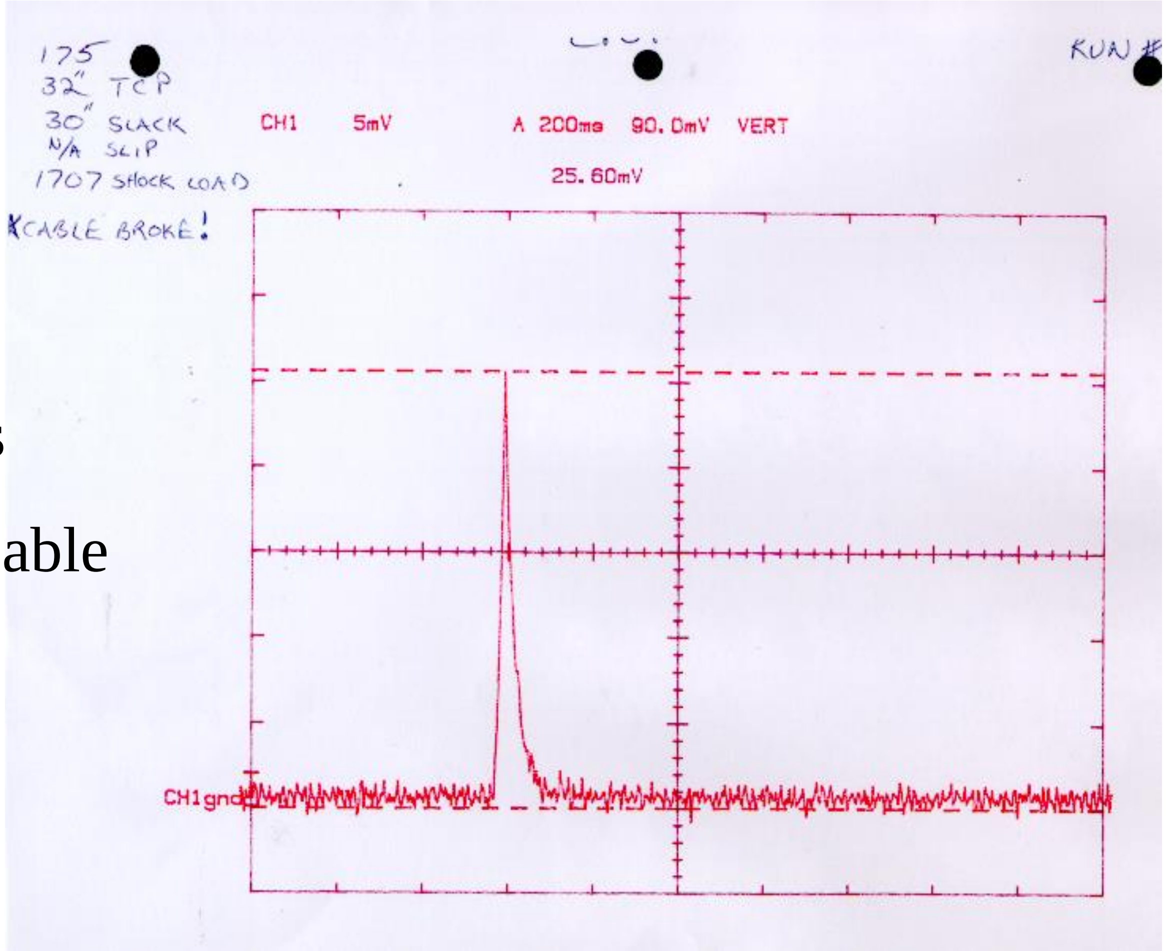
$$W_{100\ ft} = 15.96 \times W_{5ft}$$

Stretch= 4 inches before damage

175 lbs. dropped 27 inches with 32 inches extended.



175 lbs dropped 30 in. with 32 in. extended.



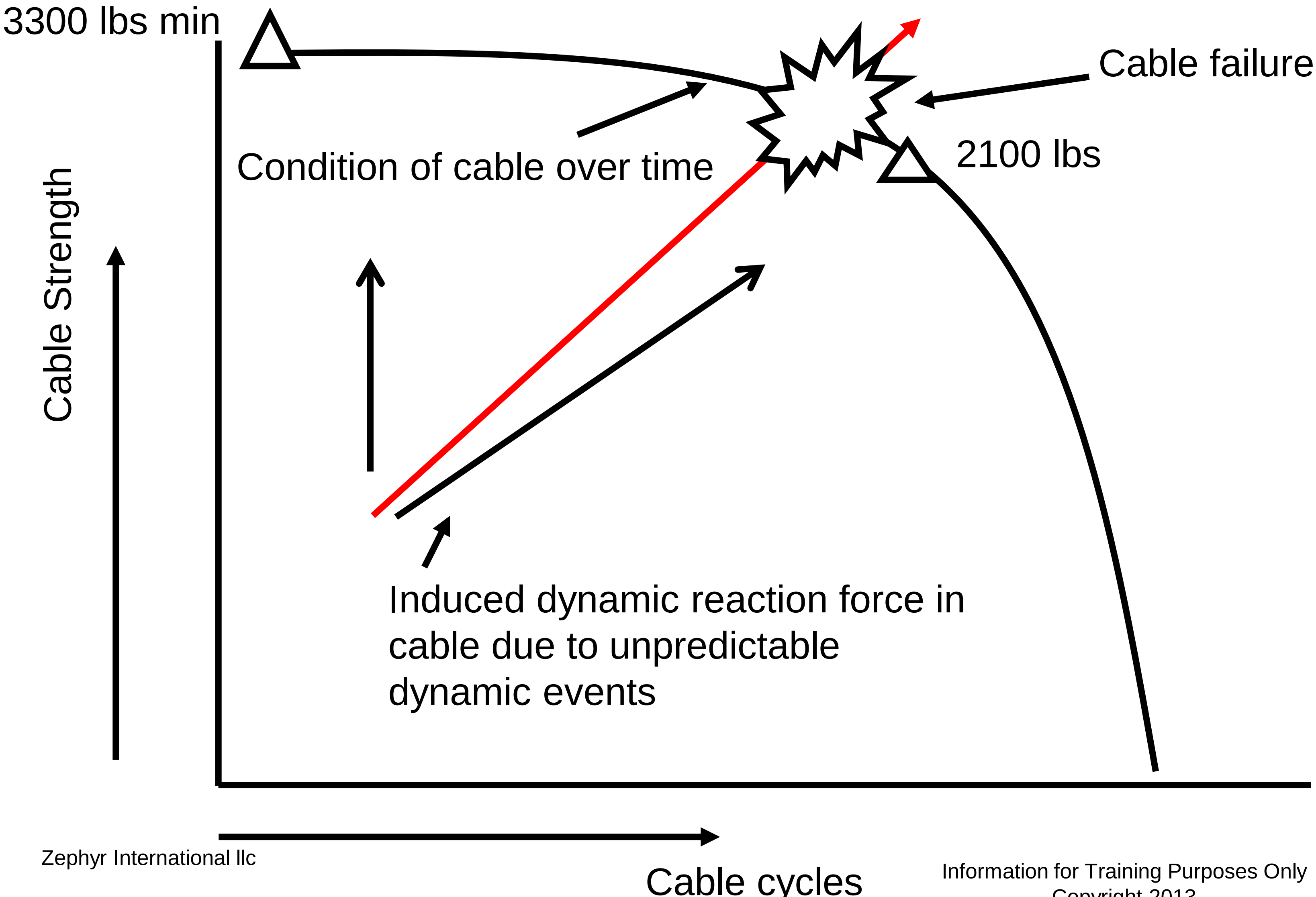
1707 lbs

Broke Cable

A wire rope can fail

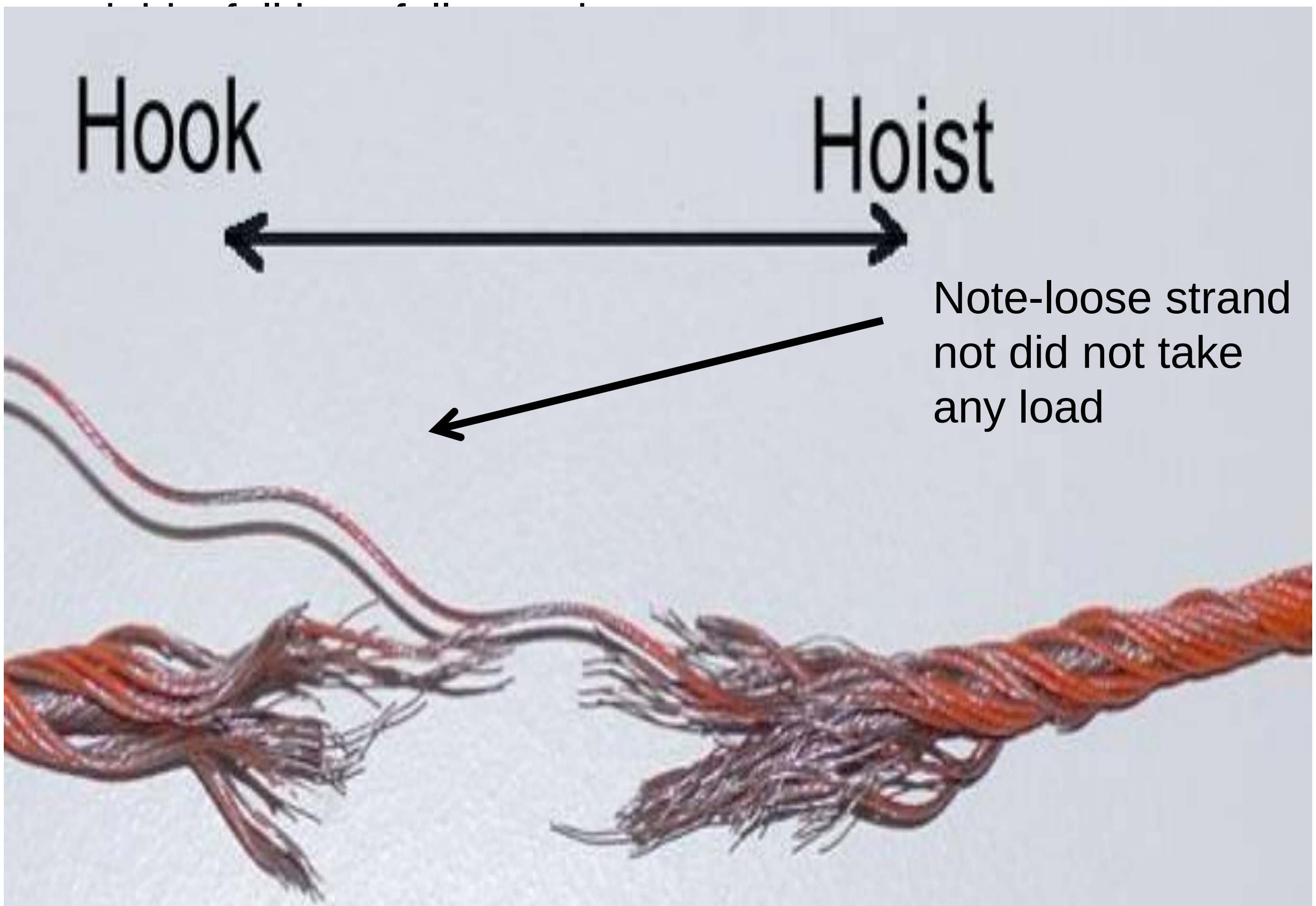
- If condition of cable deteriorates
  - Due to Kinks, abrasion, fatigue, previous shock damage to wire rope core
- And the induced dynamic load exceeds the cables strength
  - The Induced load is a function of cable absorbing the kinetic energy of the mass on the end of the cable

Strength vs. Condition

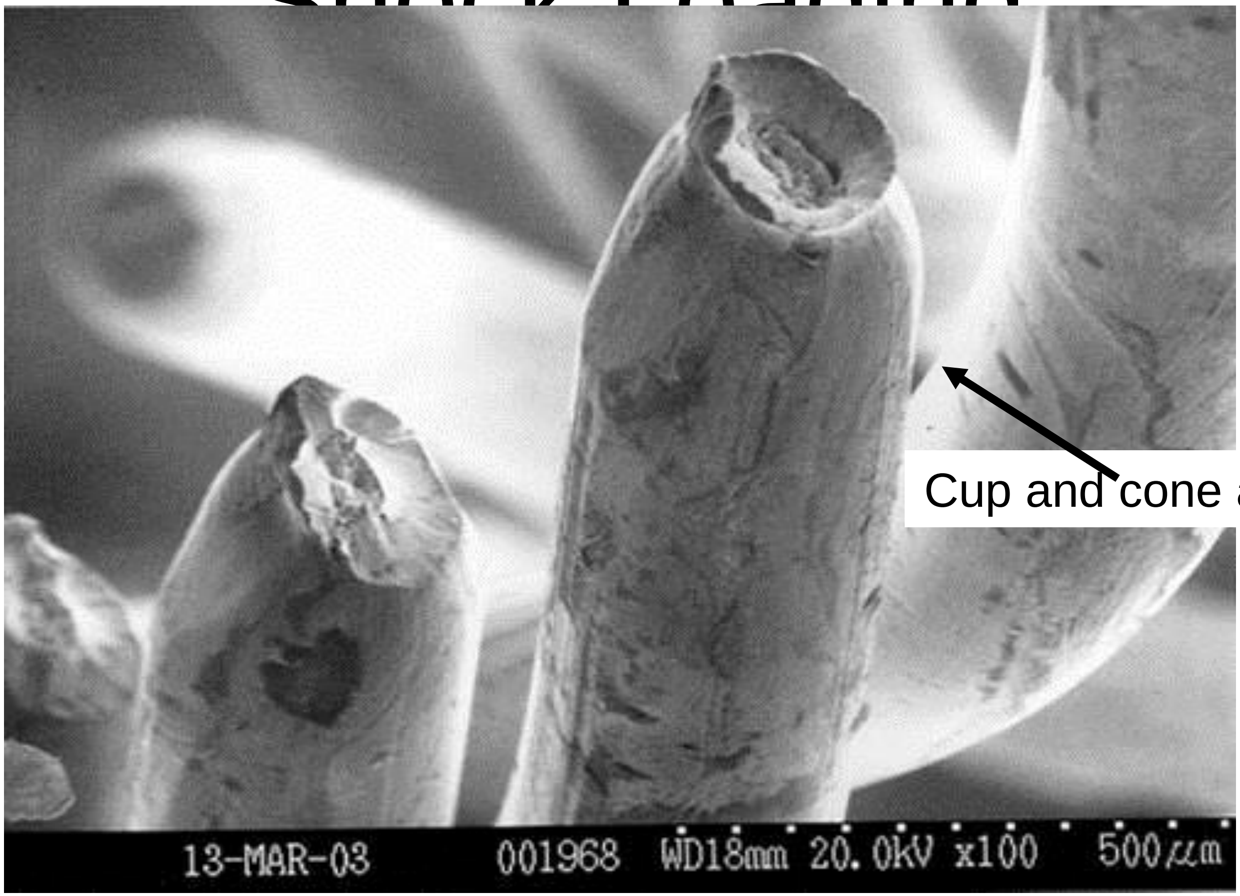


Extreme Shock Loading

Can also happen due to the rotational energy of the motor if



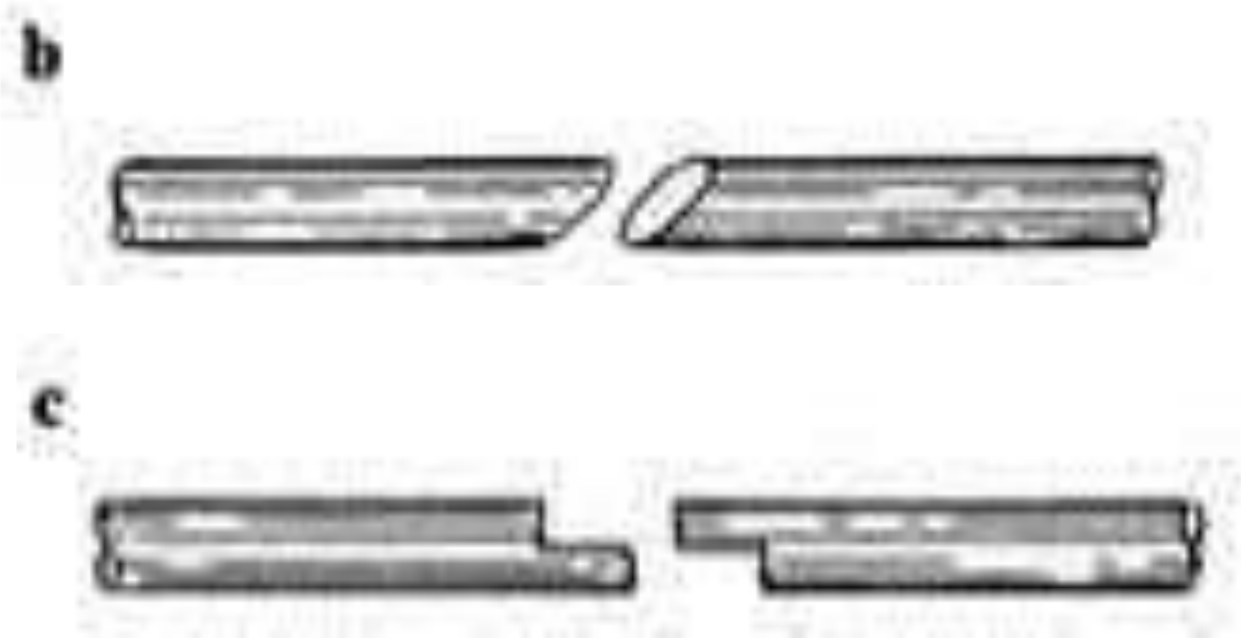
Shock Loading



This cable was broken when the hook caught the skids of the helicopter before the hoist went into slow down.

Broken Wires

Shear-tensile fracture (b) occurs in wire subjected to a combination of transverse and axial loads. Fatigue breaks are usually characterized by squared-off ends perpendicular to the wire either straight across or Z-shaped (c).



Wire Rope Failure Modes Summary

- Torsional unbalance due to:
  - Improper cable manufacturing
  - Worn or corroded hook bearing
  - Sudden release of the load
- Abrasion due to:
  - Rubbing against airframe , skids, rocks,
  - Improper levelwind adjustment
- Fatigue due to:
  - Low homing loads
  - Wrapping on drum or over guide pulleys
- Tensile Failure due to:
  - Static tensile overload
  - Dynamic tensile overload
  - Sudden load release

Torsional Imbalance

- Outer strands not balanced by the inner strands
- Can be the result of a worn, dirty, defective hook bearing
- Rotating load seriously accelerates torsional failure with bad bearings
  - Can twist a cable apart or loosen a cable up
- Birdcaging is common result- loosening
- Shear failure can result- tightening

Sudden Release of Load

- Can result from rescuer hitting the ground quickly, or using quick release mechanism while in the air.
- Can result in a rebounding of the internal wire rope core and upsetting the torsional balance of the wire rope, thus creating a birdcage.

Abrasion

- Reduction in the local breaking strength of the cable due to reduction in material cross section.
- Creation of high heat due to friction.
- Can result in cutting enough strands that the remaining strands can not hold the hold .

Fatigue

- May be indicated by broken wires.
- May not be detectable.
- Can result in sudden catastrophic cable failure
- Assuming a cable is well maintained its <u>cycles must be recorded</u> in order to replace the cable before it fails as a result of fatigue.
- Non lubricated cables will fail due to fatigue before lubricated cables.

Tensile Failure

- Static loads are slowly applied.
- Dynamic loads are rapidly applied load.
- Resulting Dynamic load is a function of the overall stiffness of the system-Helicopter-mount-hoist-cable-strop-body- wind –waves.

Cable Inspection

- The purpose of the inspection is to insure the cable is capable of performing without failure until the next inspection.
- Post flight inspection is critical if damage has occurred during a mission.
- Commonly OEMs require an inspection every 30 days.
- The rescue hoist environment requires that inspections be carried out frequently and by trained individuals.

Conditioning a new cable

- Conditioning is the process of installing the cable and allowing it to be acclimated to the smaller rescue hoist drum, while flexing the cable to limber it up so it does not foul up on the drum.
- It should be done with a low load and at slow speed, while gradually increasing the load to 2% to 10% of the working load limit.

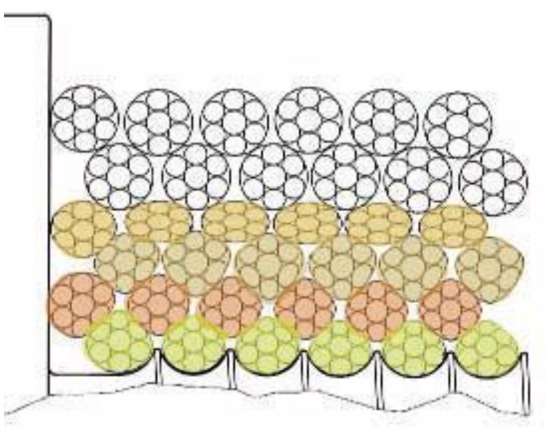
Also referred to as “Seasoning” the cable

Salvaging

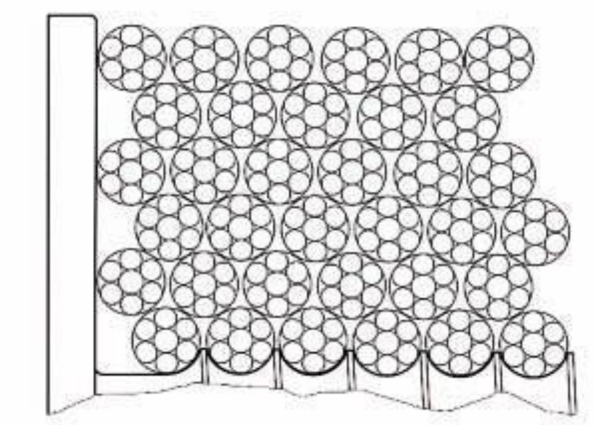
- Salvaging involves flying the helicopter and extending the cable all the way in and out with a heavy load.
- <u>Salvaging is not the same as conditioning.</u>
- A cable that gets loose is due to improper manufacturing.
- Salvaging a loose cable temporarily tightens to outer strands.
  - They will soon return.
  - The attempt to salvage a cable costs more then a new cable.

Pretensioning a cable

Restores tension to the lower layers of cable to prevent crushing and abrasion when a heavy load is lifted.



The first 4 layers have lost their tension and begin to deform and get crushed by the hard wound top layers. Regular pretensioning of ALL layers will
minimize the crushing effect.



Rope is installed with proper pretension onto the drum. All layers are hard wound and retain their round shape.

Also referred to as "Reseating" the cable

Cable Replacement Criteria

- Broken Wires
- Broken Strands
- Kinks
- Necking Down
- Abrasion
- Corrosion
- High Heat Exposure
- Suspected Shock Loading
- Birdcaging
- Loose Strands
- Milking

Broken Wires

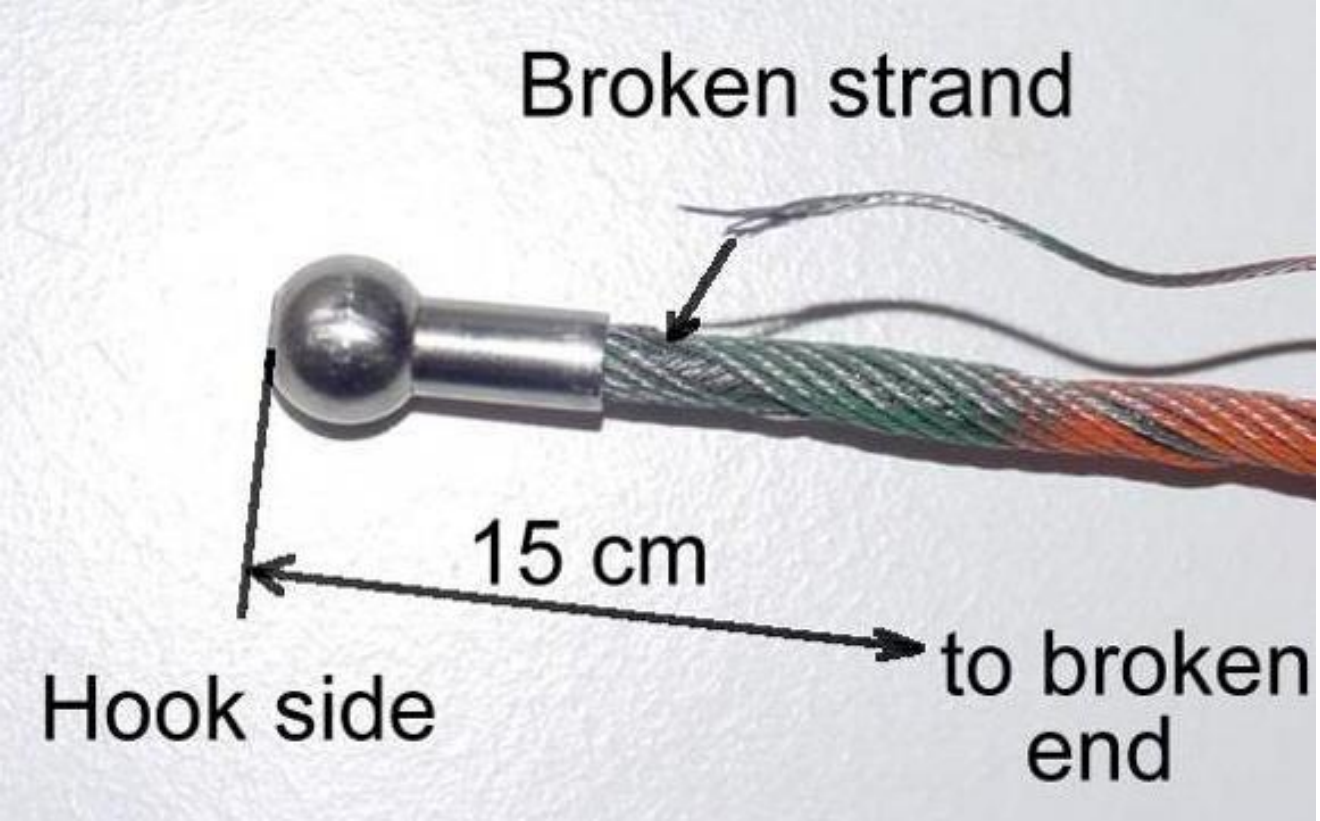
Both OEMs require replacing the cable if one broken wire is found.

Neither OEM addresses internal broken wires.

Broken wires found in flight do not necessarily require terminating the lift.

They do require replacement at the earliest convenience.

Broken Strands



Broken strands found in flight require immediate termination of the mission.

They can jam the hoist

Kinks

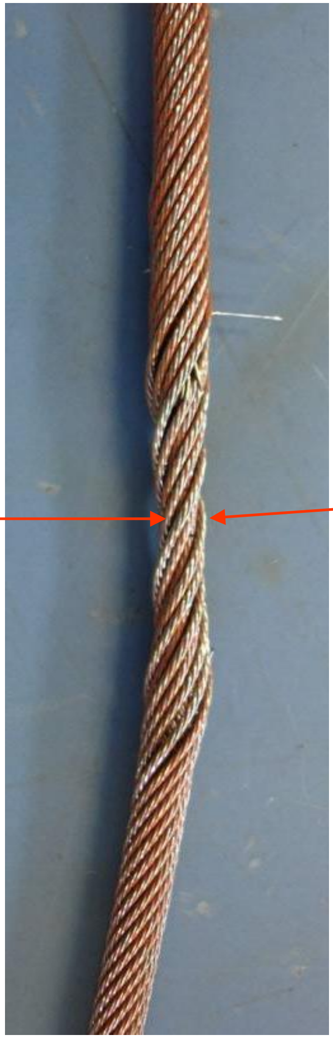
Kinks can lead to the hoist cable loosening on the drum by rolling out from under the tensioner idler rollers.

Any kink that can not be straightened by hand requires immediate replacement of the cable.

Necking Down

Cable when new is between .188 and .194 inches in diameter

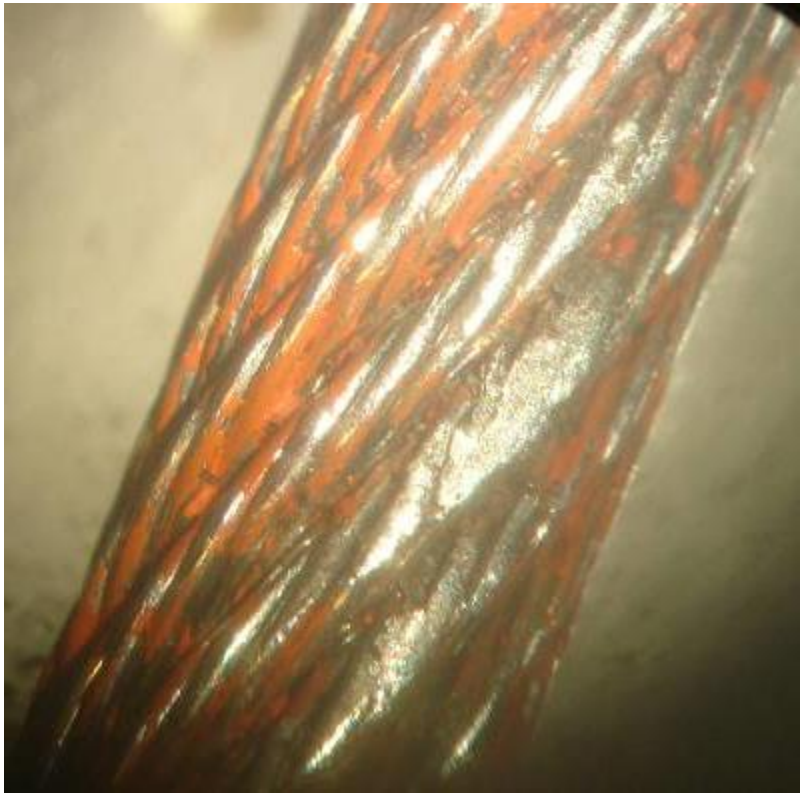
Replace the cable if at any position the cable diameter is less .185



Necking down can be an indication of a serious defect such as a broken internal strand or strands,

Immediately terminate the lift if discovered in flight

Abrasion

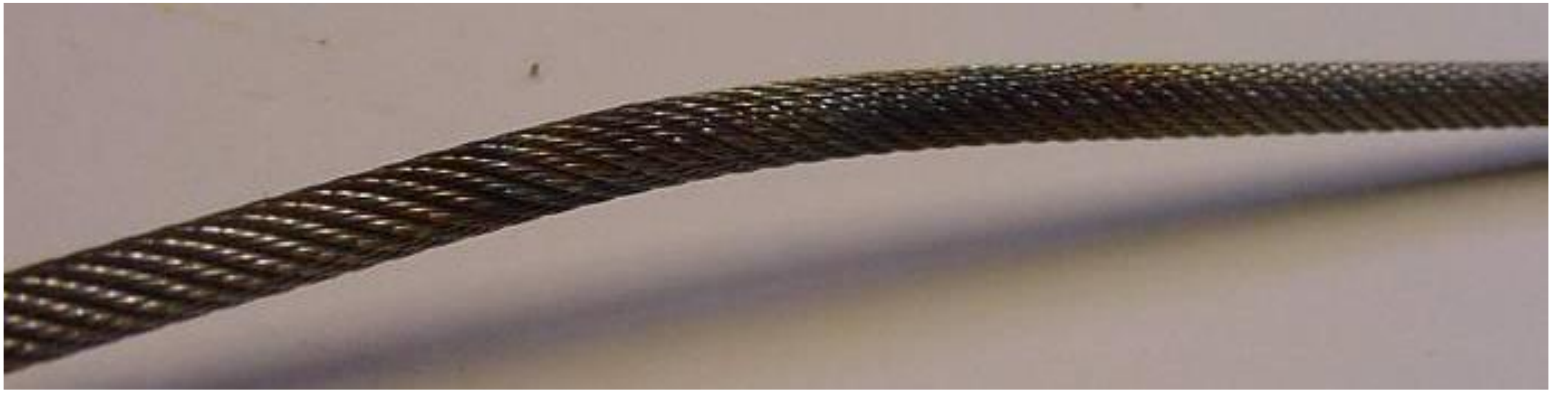


Abrasion that results in broken wires requires replacement of the cable at the earliest convenience.

Dirt Contamination

Dirt or sand contamination should be avoided and the cable cleaned thoroughly if encountered.

High Heat Exposure



Exposure to high heat softens the wire rope and can lead to catastrophic separation under load.

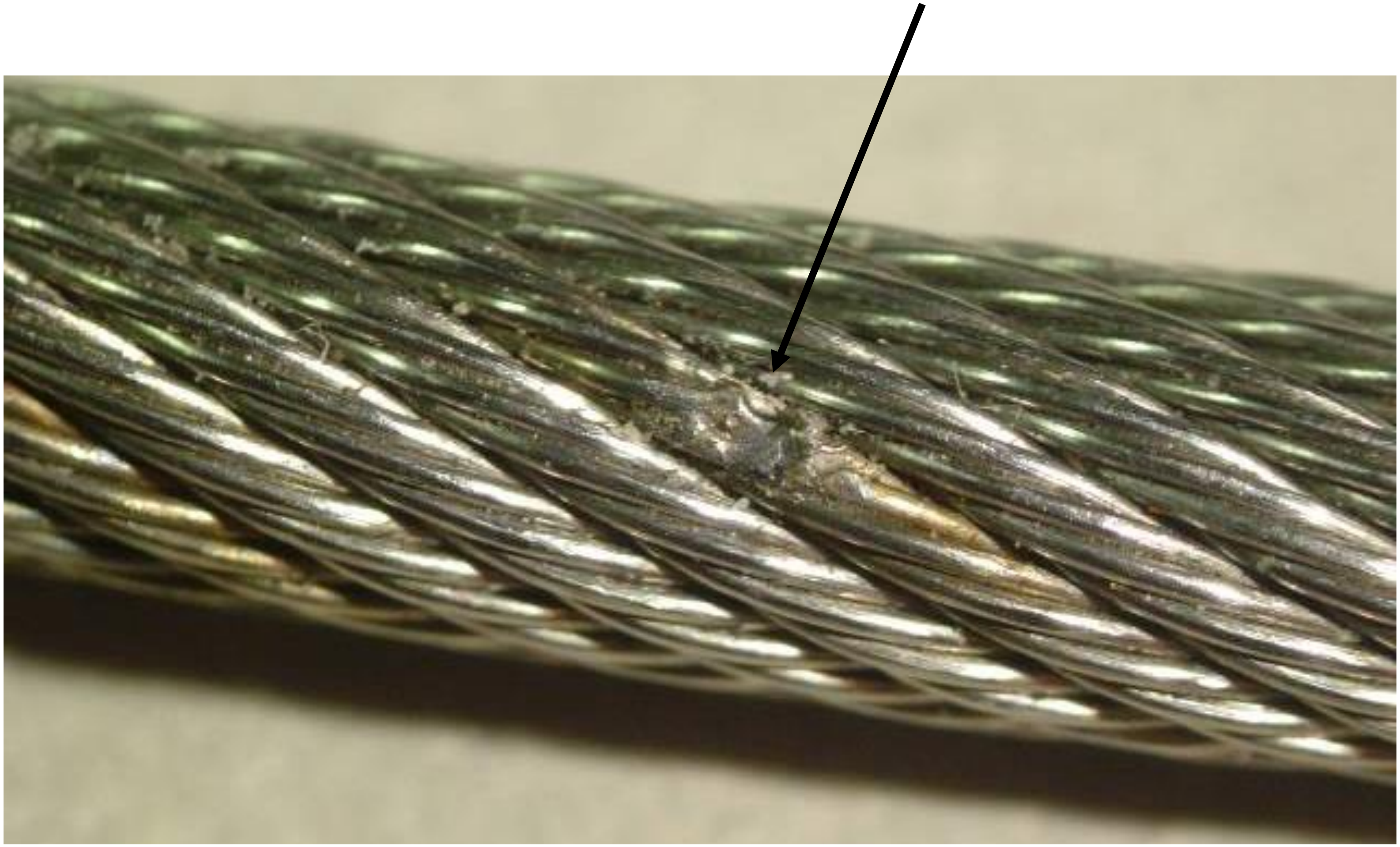
If bluing is noted then immediate replacement is required.

How in the world?

- Can a rescue hoist cable get so hot that it is annealed

- Answers:
  - Welding !
  - Lightning strike !?
  - Static Discharge !?!

Welding due to static discharge ??



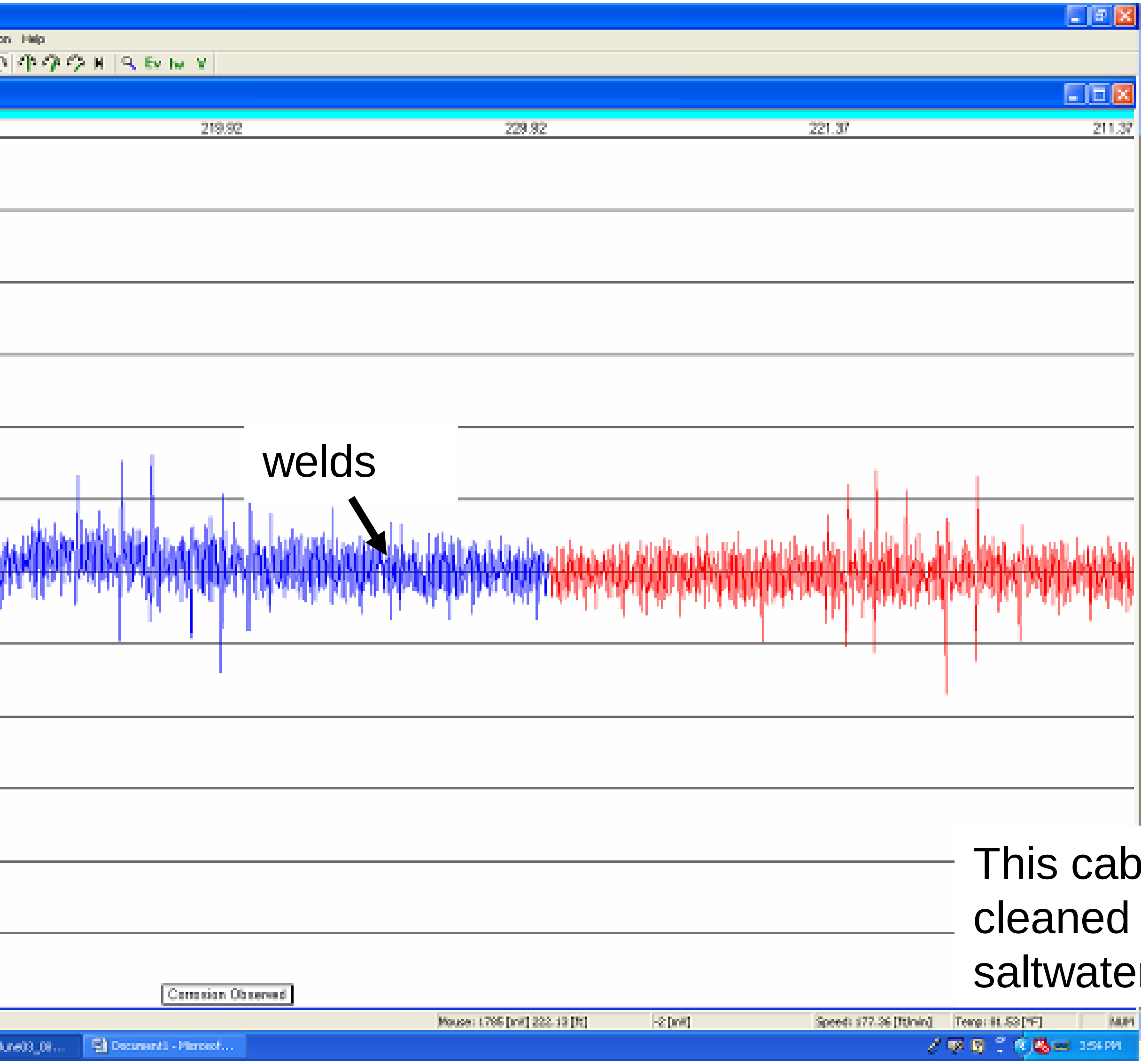
Resulted in soft wires and carbide precipitation

Corrosion

Sometimes a stain will appear on the outside of the cable that indicates internal corrosion.

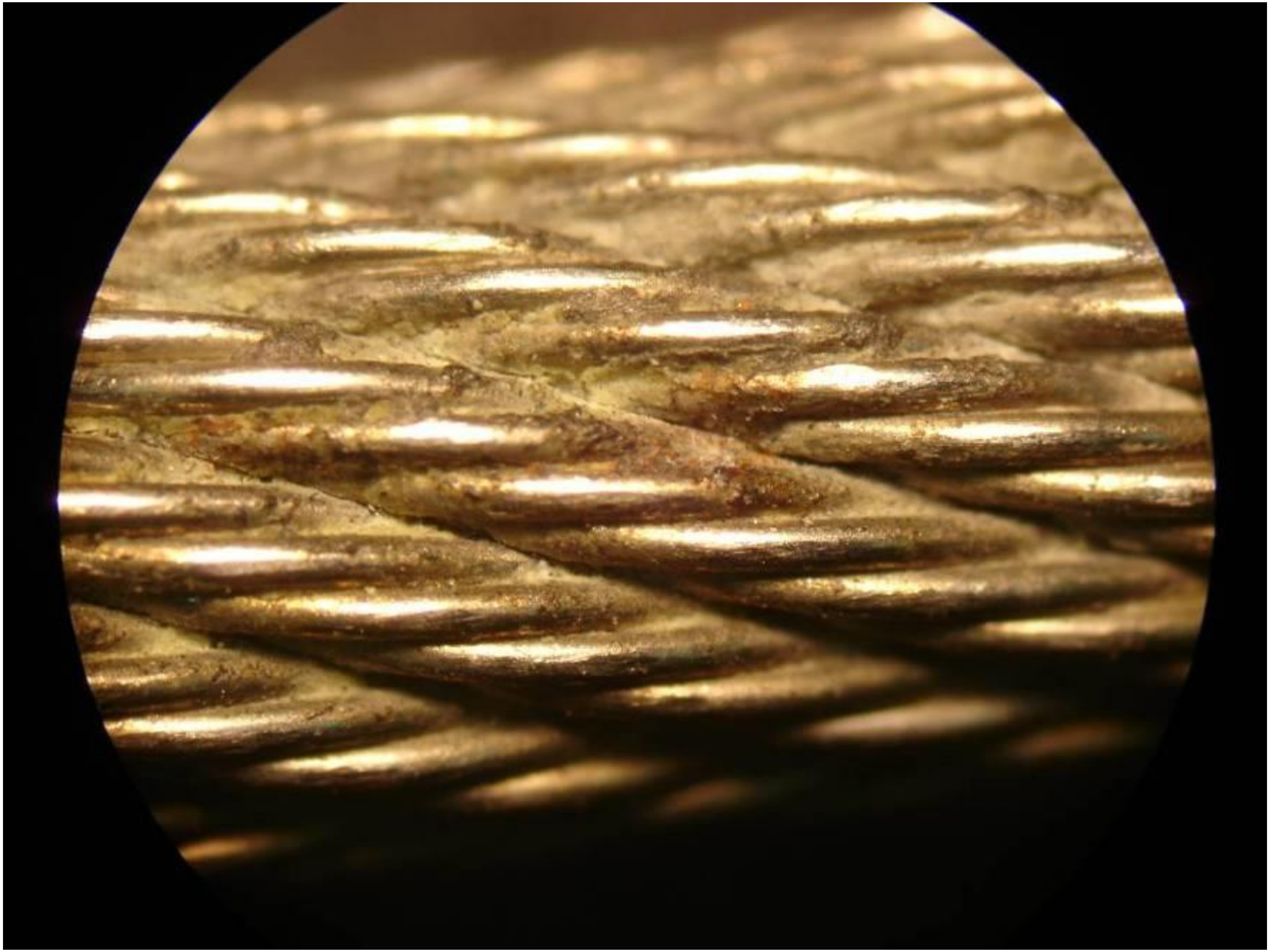
Internal corrosion can result from welding wires during manufacturing and using wire rope that is non-lubricated.

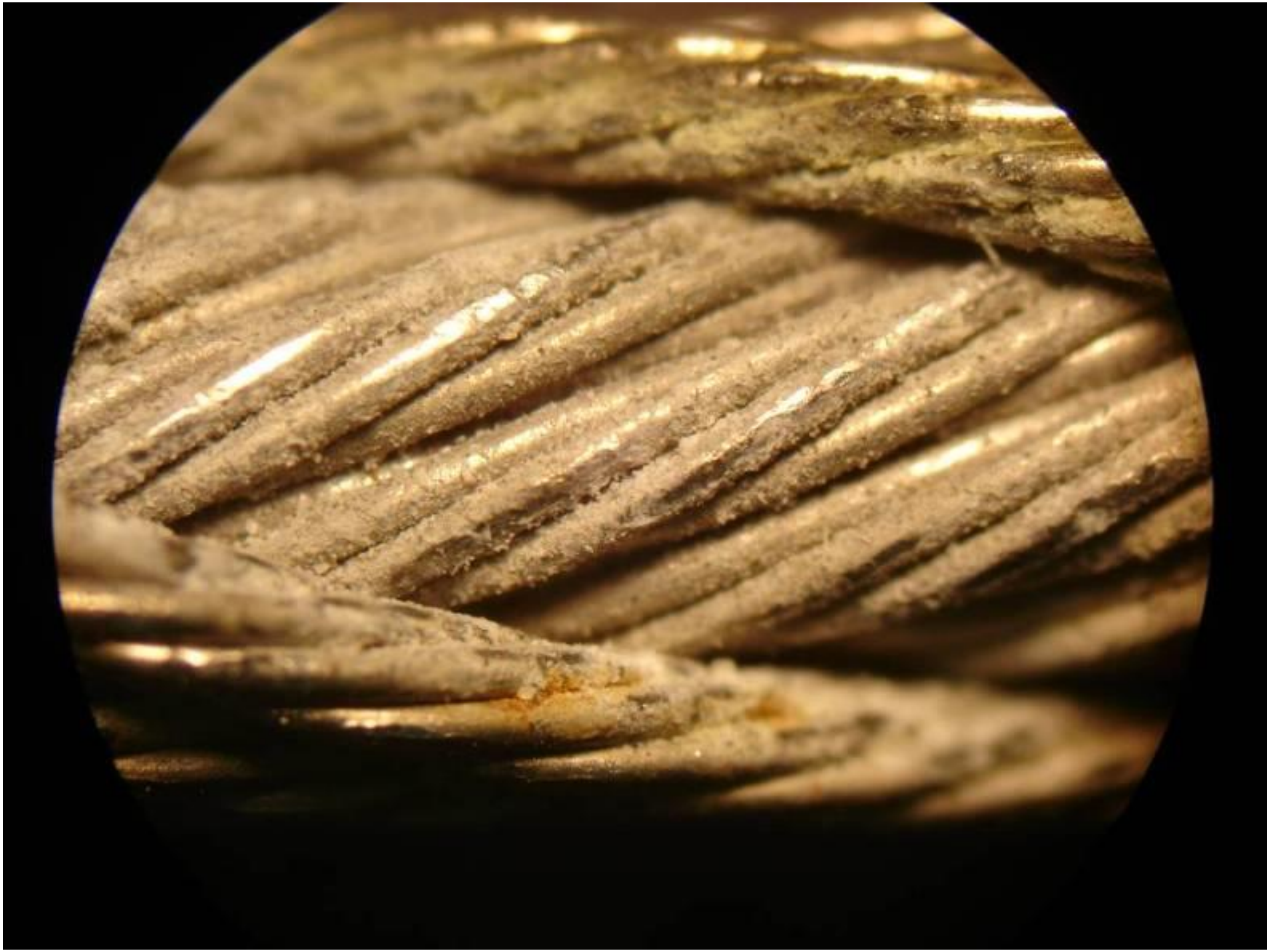
inment

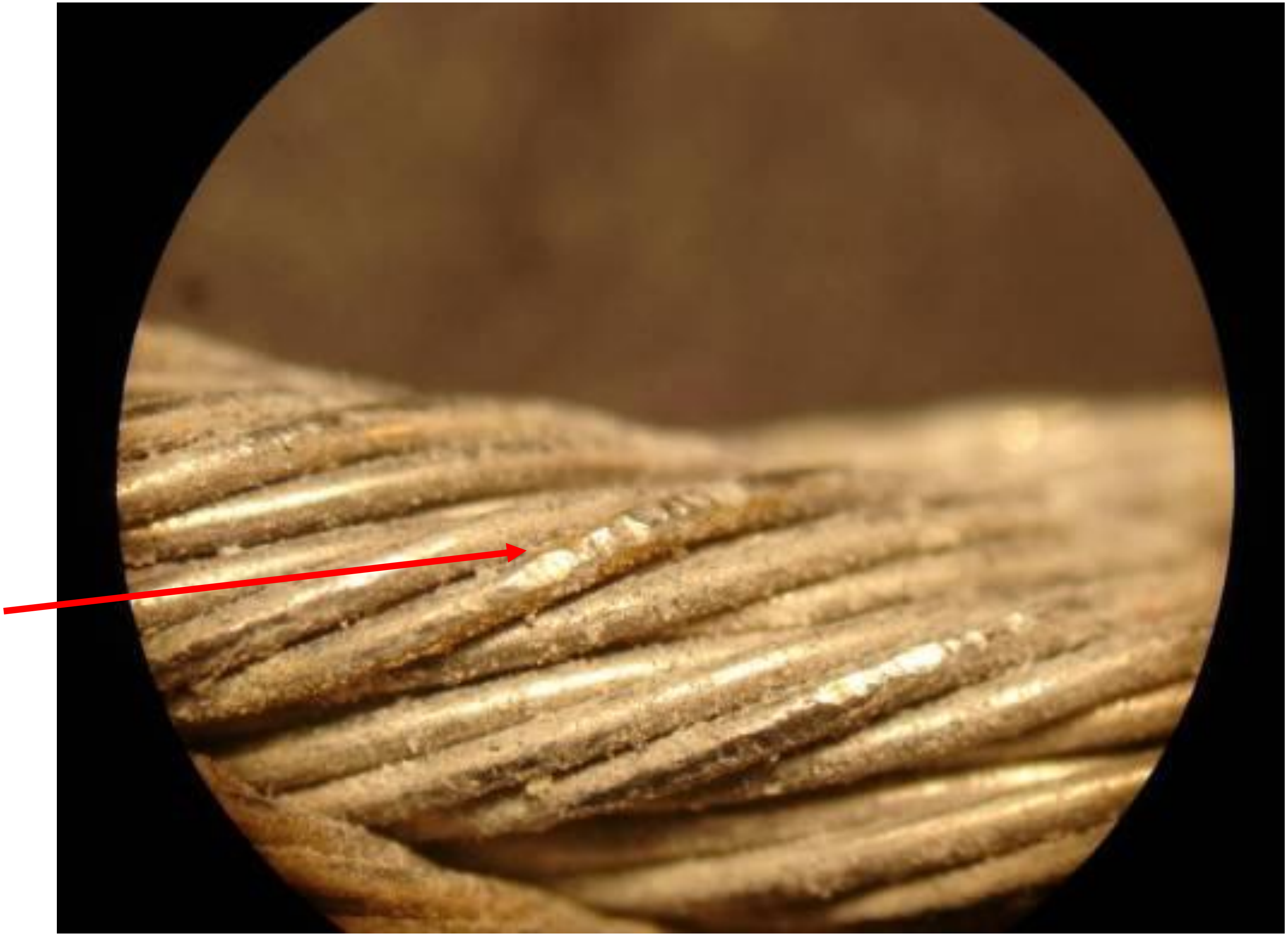


This cable with welds was not cleaned thoroughly in a severe saltwater environment.

Above data was acquired by using the Zephyr MagSens.





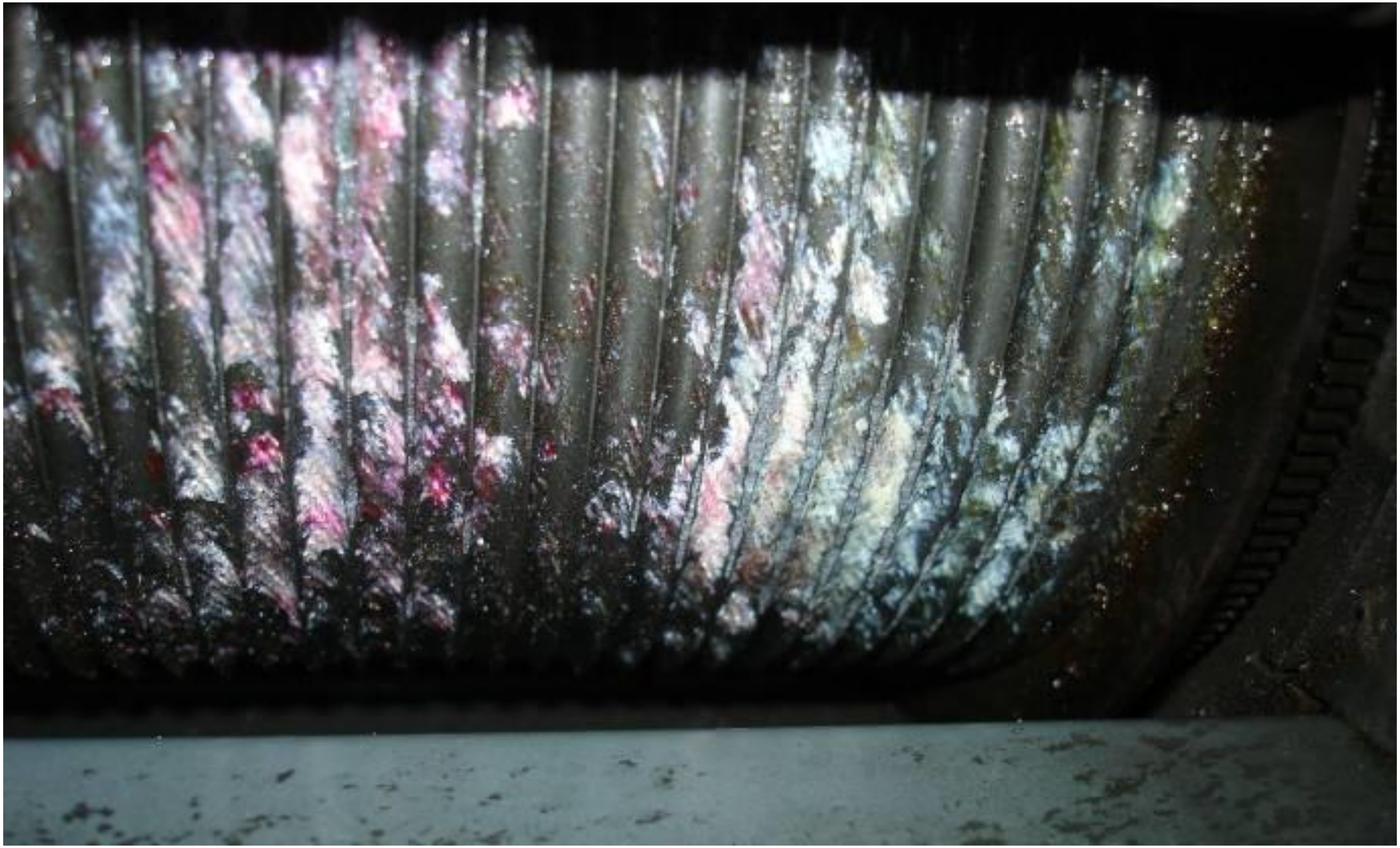


Picture at 30 x shows wire in internal strand that has been welded and is soft with evidence of carbide precipitation around it.

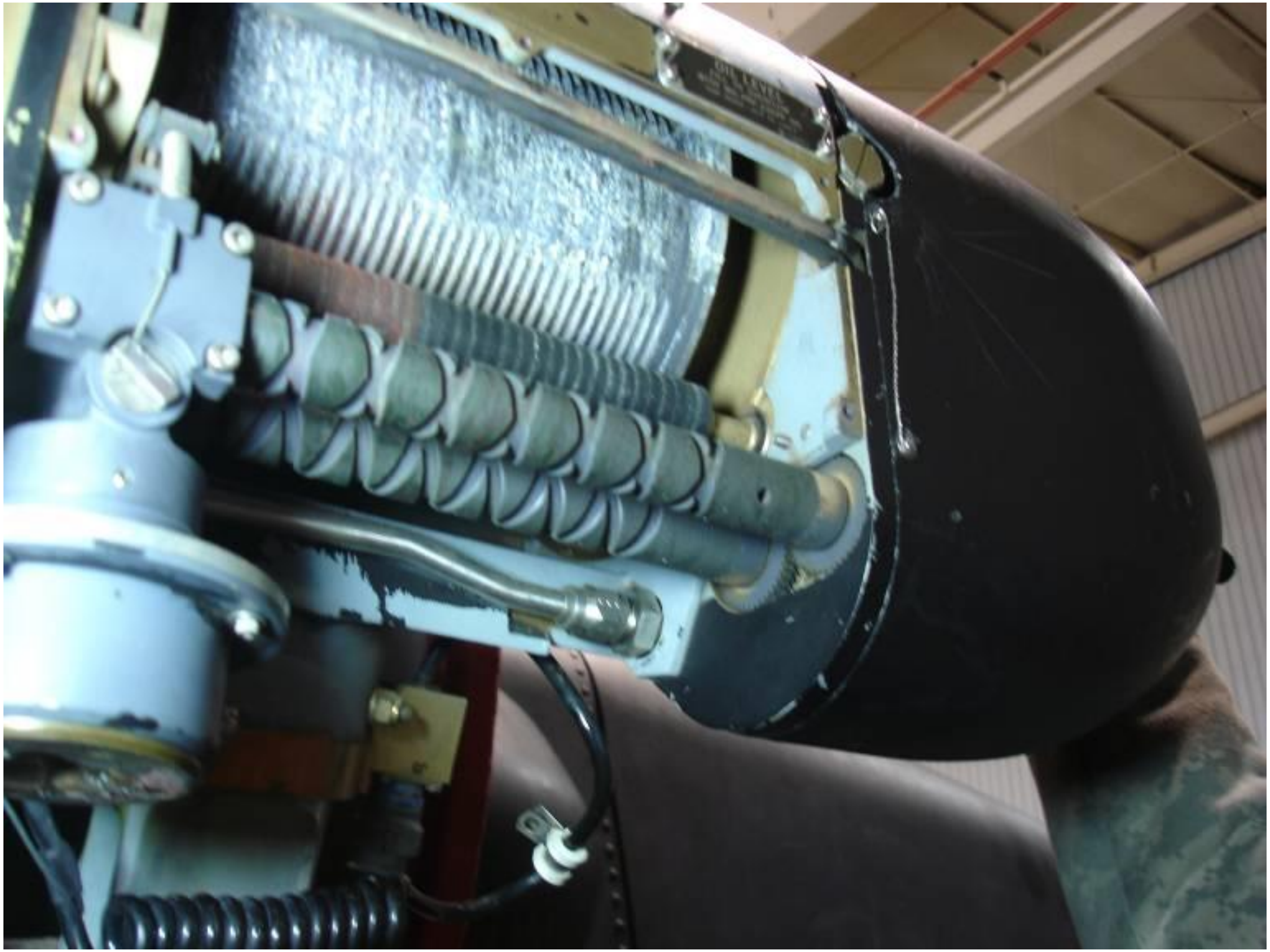
Corrosion

- Dissimilar metals corrosion leads to drum damage.
  - Due to aluminum and stainless steel in direct contact.
- Carbide Precipitation leads to weakened cable.
  - Due to welds in the wire rope.

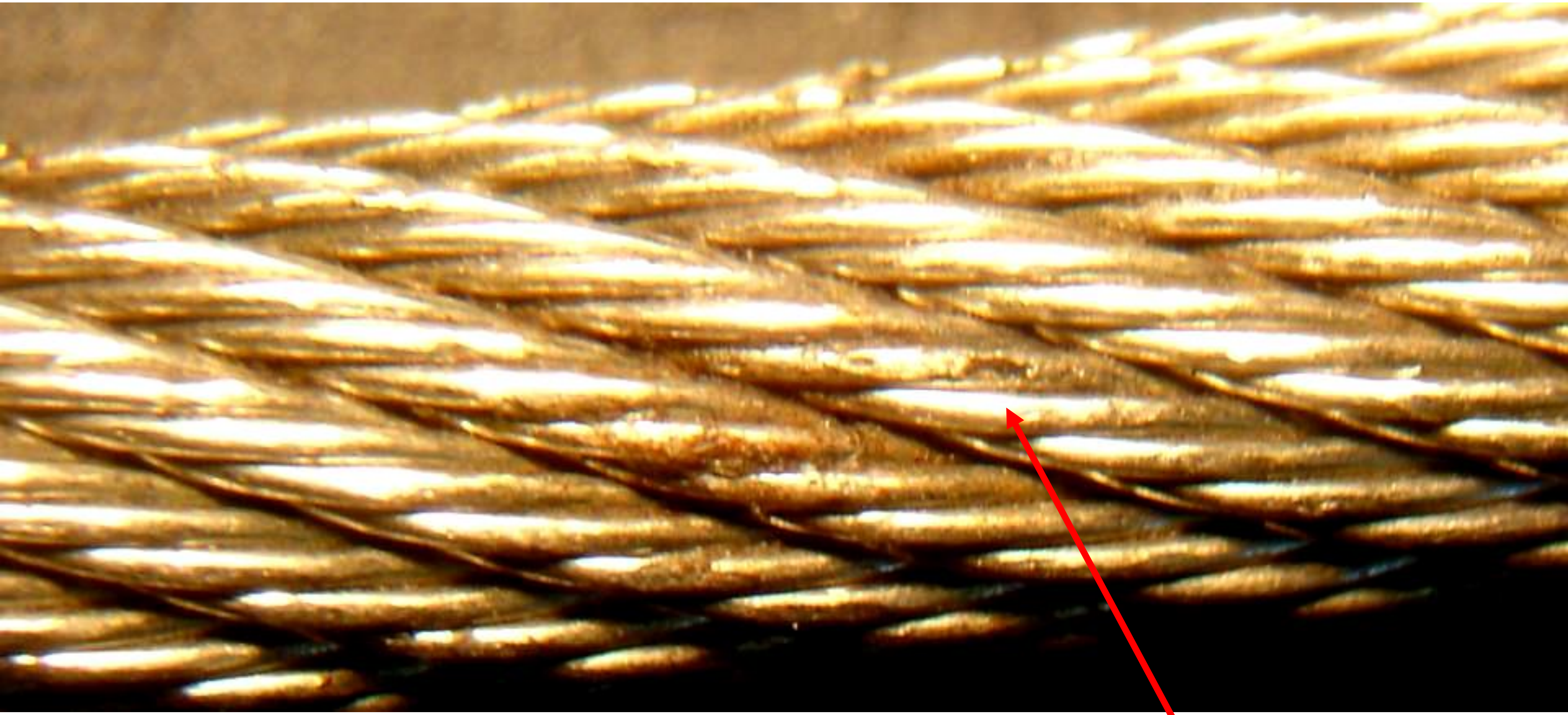
Corroded Drums



Corroded Drums



Corroded Wires



Welded wire corroded away

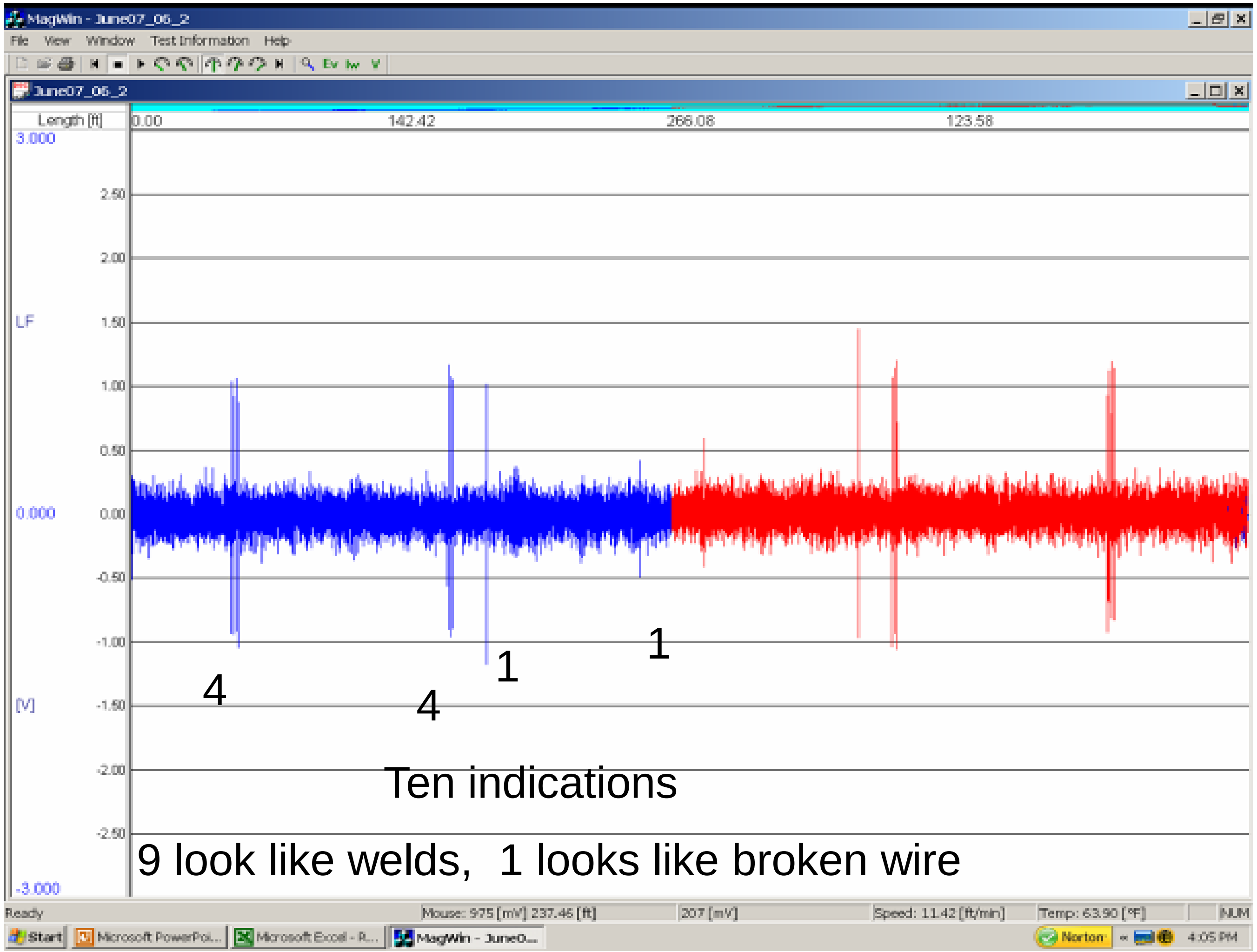
Internal Welds

- Lead to carbide precipitation

Welded Wires are common

- 1960’s era specification allows them

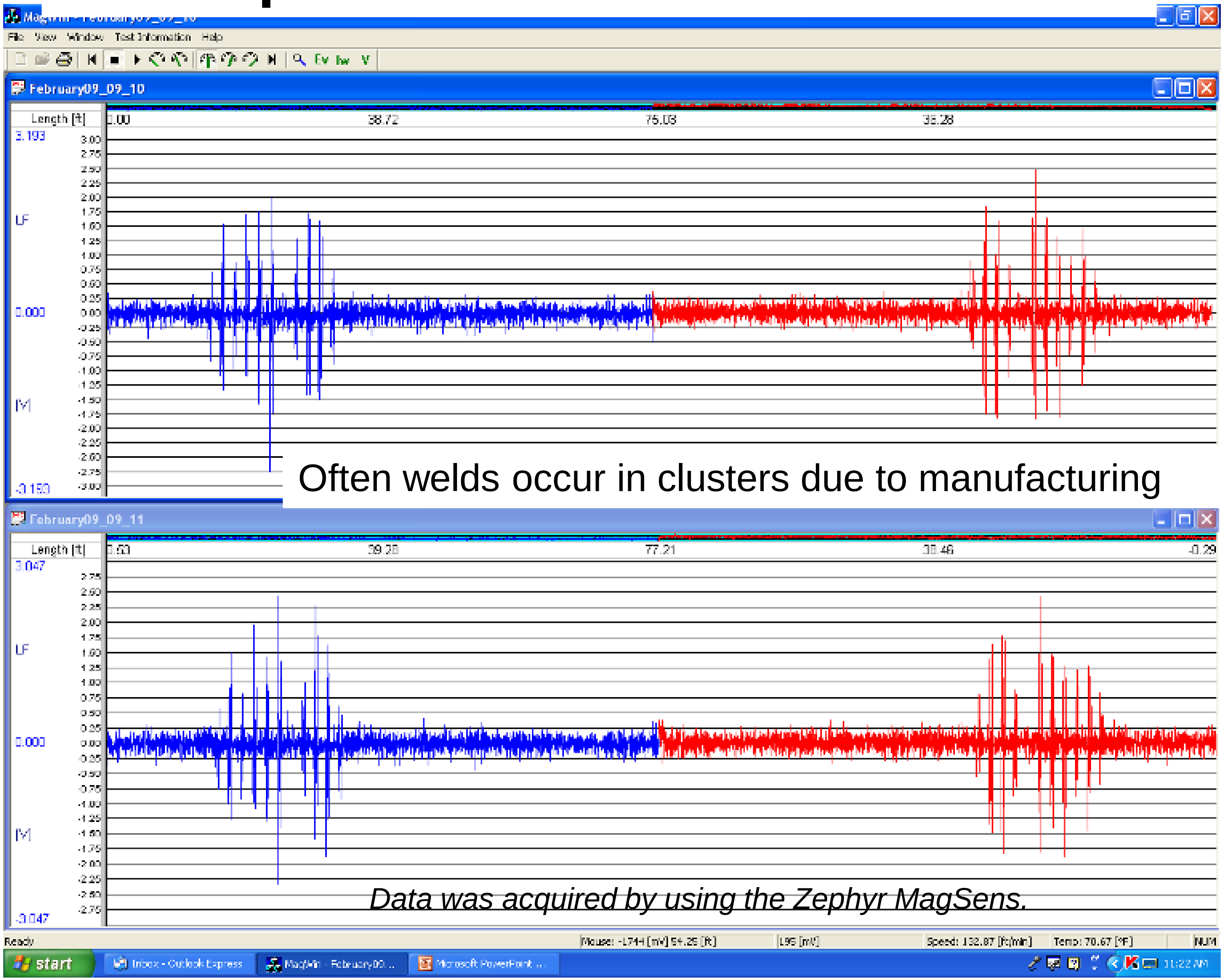
Welded Wires



June 7 2006

Above data was acquired by using the Zephyr MagSens.

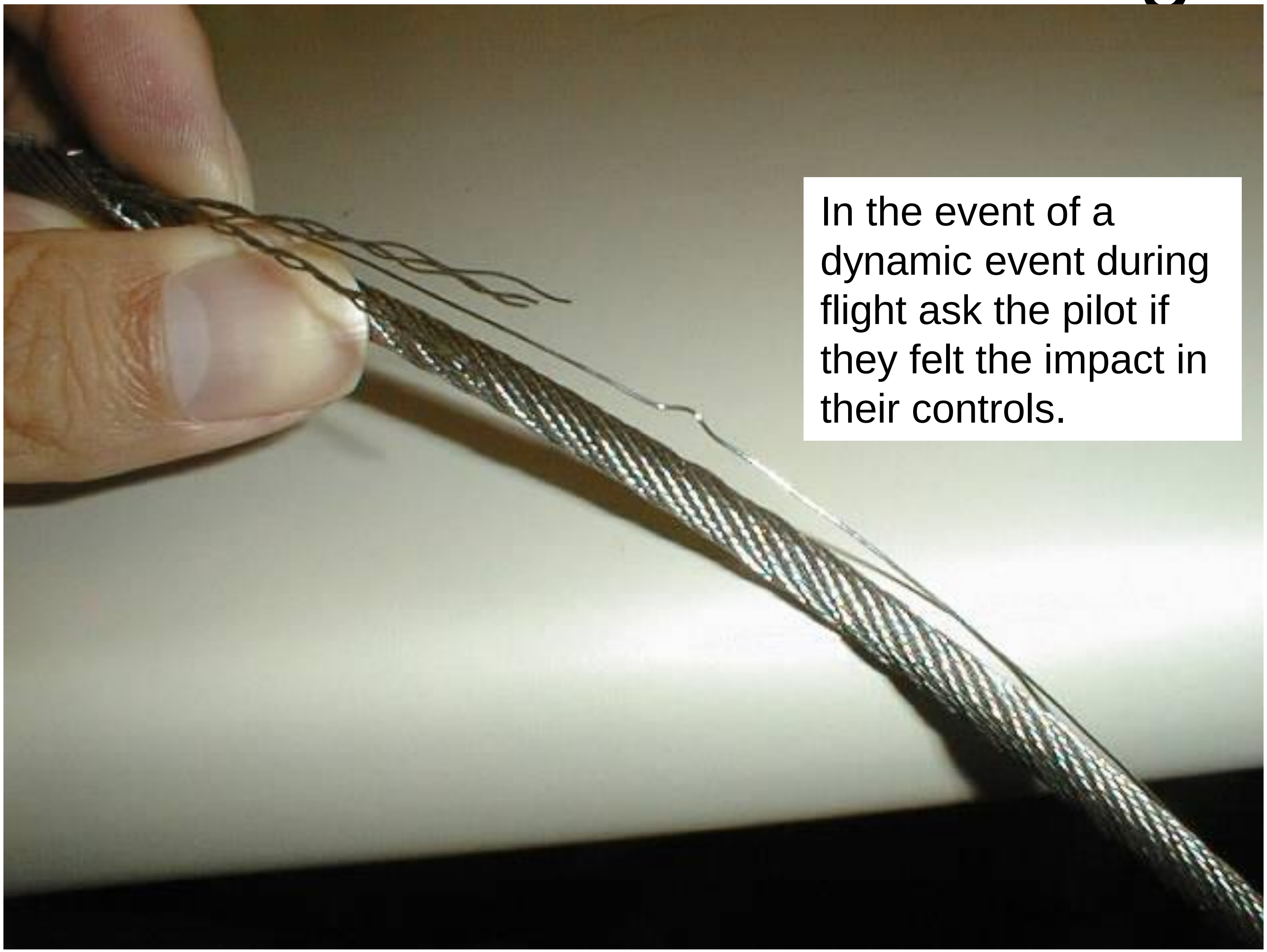
Multiple Corroded Welds



Opportunities

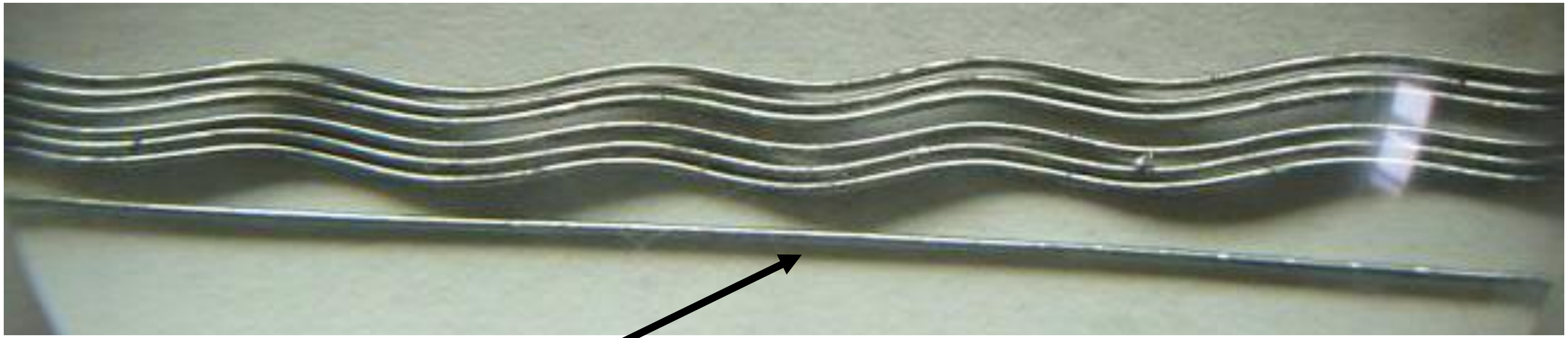
- Welds should be detected and eliminated in the manufacturing process using available technology and processes.
- 2013 -1965= 48 year old process is obsolete.
- Rescue hoist cables should be manufactured to the highest level of reliability.
- They also cost a lot of money!

Minor Shock Loading

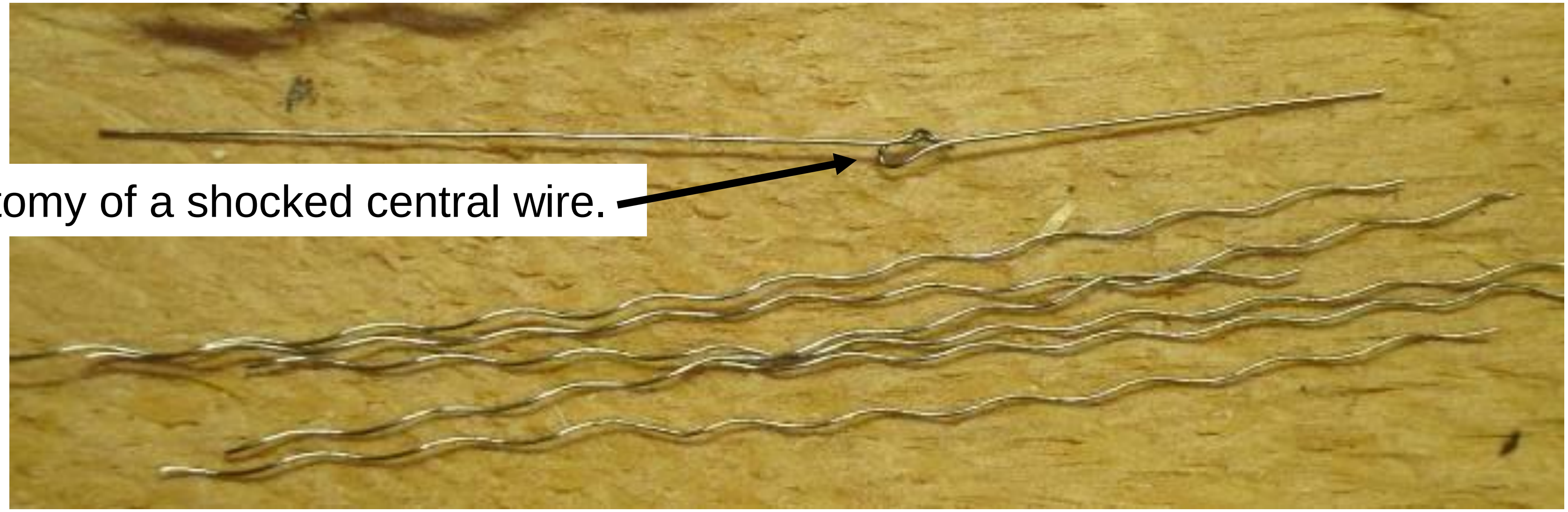


In the event of a dynamic event during flight ask the pilot if they felt the impact in their controls.

Anatomy of the central strand

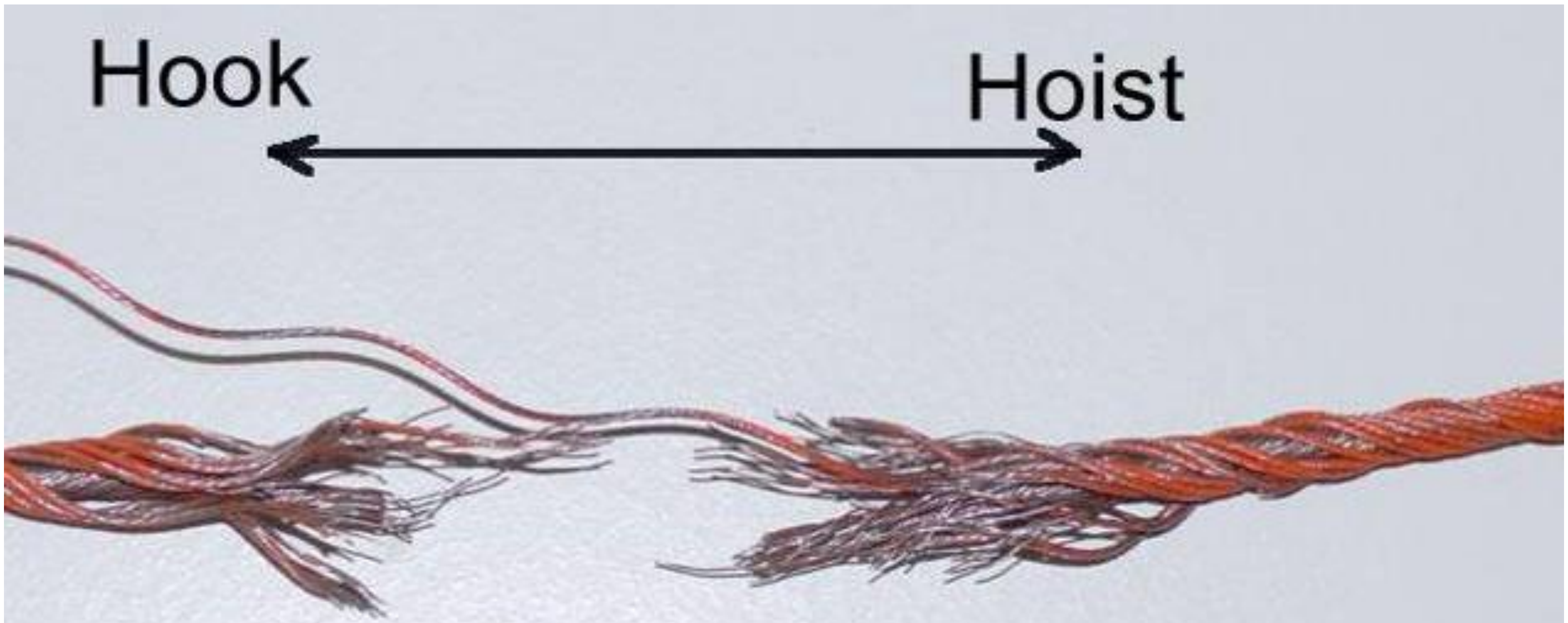


Only one wire is perfectly straight in entire cable



Anatomy of a shocked central wire.

Extreme Shock Loading



This cable was broken by the hoist's electric motor and failure to slow down.

Birdcaging

A "birdcage" can be caused by sudden release of tension and the resulting rebound of the rope's core. These strands and wires will not be returned to their original positions. The rope should be replaced immediately.

Birdcaging can also be caused by failure of the hook attachment bearing to rotate under load thus transmitting torsion into the cable itself.

Loose Cable Construction

Under normal circumstances the wire rope should not be able to be untwisted by hand.

All the dynamic load goes through the central strands when the cable is loose, immediate replacement is required.

Loose Strands

Loose strands are due to improper balancing and socketing during manufacture, they can not be tightened up and must be replaced.

Loose outer strands jammed in hoist.

Loose Cables

This cable was just installed. Some cables have started loosening with as little as 15 cycles.

Loose Cables

- Loose cables are a result of manufacturing and operations..
- The rash of loose cables started in 1999.
- Original “Approved” manufacture went out of business.
- The new cable manufactures are improving their processes.
- Repeated cycling of the hoist under no load exacerbates the problem.
  - Never unreel the cable completely on and off the cable during preflight without a load!
  - Hand tensioning exacerbates the problem by milking the cables outer strands.

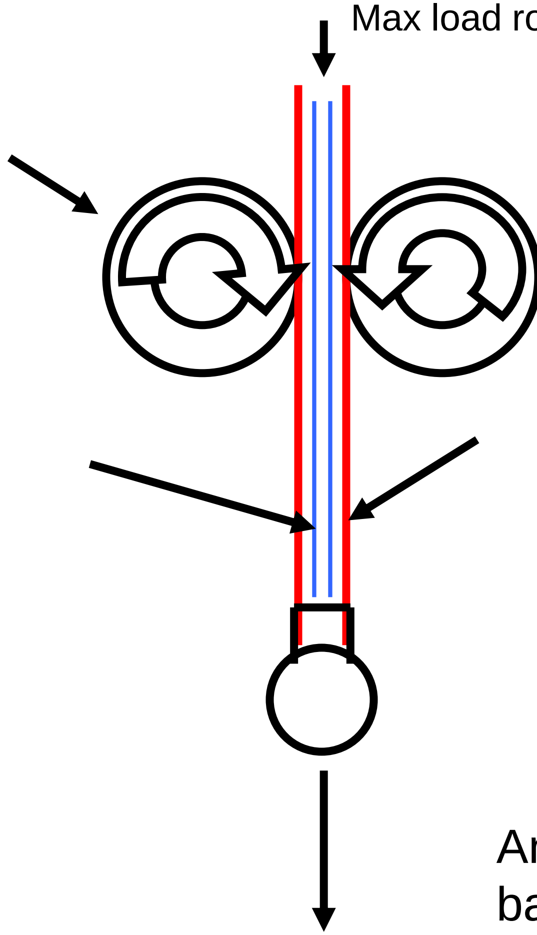
Why Cables get loose

- Manufacturing effects
  - Outer layer must be tight and remain tight over its installed life.
  - Premature loosening is the result of the way the cable has been made.
- Operational Effects
  - The rescue hoist tension rollers have an effect.
  - The operational spectrum has an effect.

No Load Lowering

Max load rollers can exert is approximately 22 lbs

Cable is being driven by the tension rollers



Inner strands lag behind the outer strands unless the outer strands are very tightly made

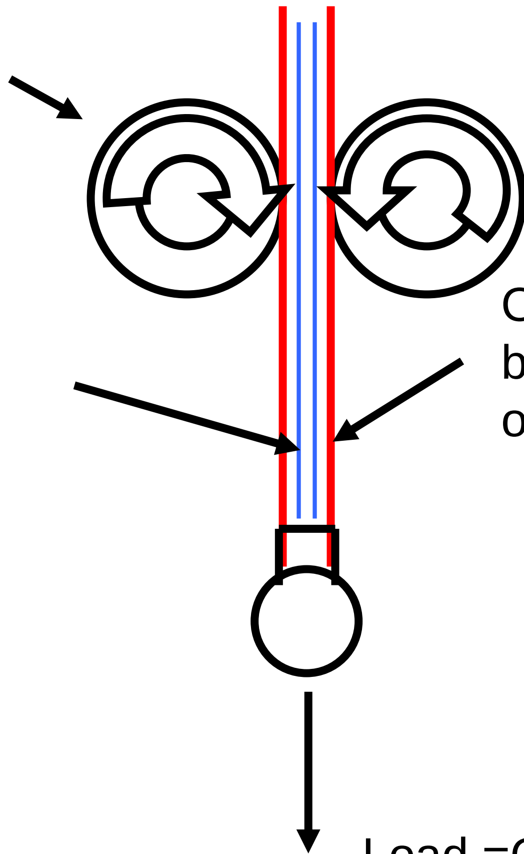
Outer strands are pulled down by the compression of the tension rollers and the coefficient of friction at the interface

Any looseness is pushed towards ball end

Load =Zero

Loaded Cable Lowering

Tension rollers
are idling



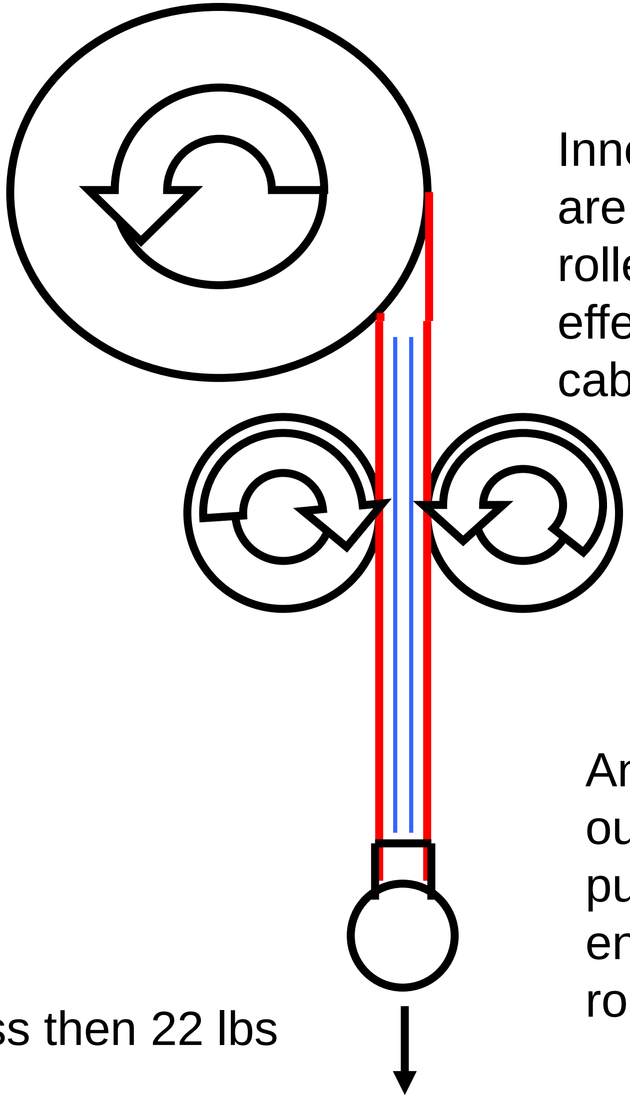
Inner strands are pulled down by the load via the compression of the ball end fitting

Outer strands are pulled down by the load via compression of the ball end fitting

Load =Greater then 22 lbs

No load Raising

Tension rollers retard the outer strands while the cable is wrapped on the drum with approximately 20-30 lbs depending on how far out the cable is

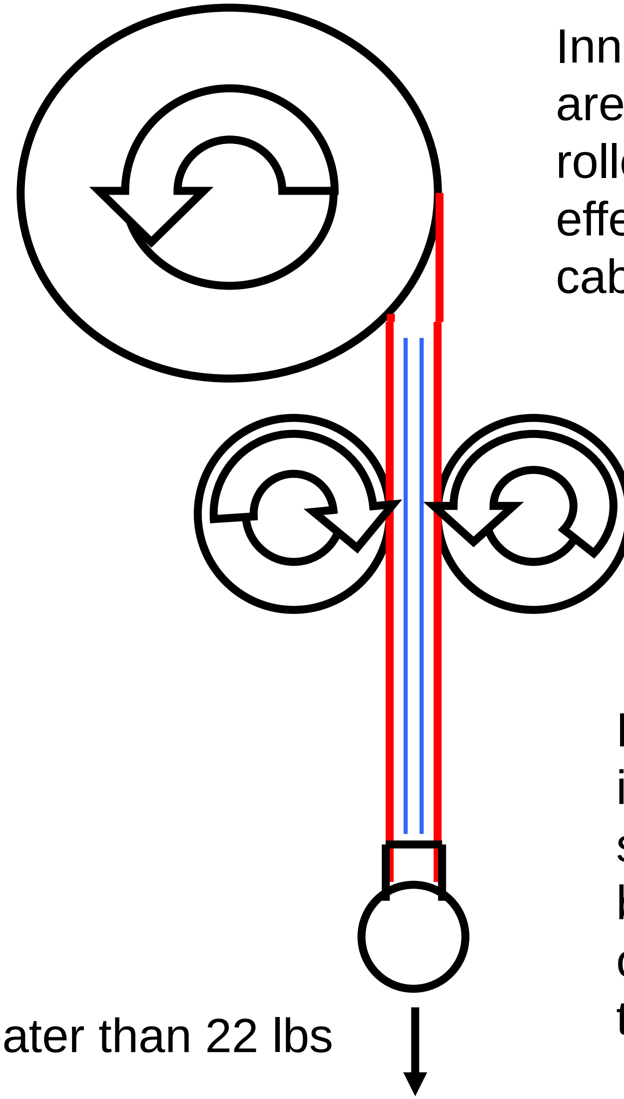


Inner and outer strands are tensioned above the rollers by the capstan effect of wrapping the cable around the drum

Any looseness of the outer strands are pulled toward the ball end by the tension rollers

Load = less then 22 lbs

Loaded Cable Raising



Inner and outer strands are tensioned above the rollers by the capstan effect of wrapping the cable around the drum

Tension rollers are effectively idling

Equal tension of the inner and outer strands is generated by the compression of the ball end and the load

Load = greater than 22 lbs

Cable Milking

This is a common end of life phenomena and is due to the action of the hoist tension rollers on the outer strands over a long period of time, when this appears after a long life the cable may be starting to fatigue, it should be replaced.

Guidelines for rejection

- According to the hoist OEM's one broken wire is cause for rejection.
  - But they implicitly mean a broken wire that is on the outside diameter of the cable.
  - Therefore if an indication is found (with the MagSens) that looks like a broken wire, but it is not visible, there is no mandatory cause for rejection, but the frequency of inspections should increase.
  - If increasing the load (with the GSE) produces a larger signal then the cable should be replaced.
- Knowledge of the original condition of the cable allows one to discern between a weld and a broken wire or broken strand defect.

Guidelines for rejection

- Indications that appear to be welds are not cause for rejection.
  - However welds that show an increasing signal over time should be monitored often.
  - An increasing signal should be cause for rejection, the cable is starting to corrode.
- Weld indications usually differ from a broken strand indication.

Comments relative to cable strength

- A single broken wire has no impact on the cable static breaking strength.
- Isolated corrosion due to welds has limited impact on static breaking strength.
- Broken strands have a serious impact on static breaking strength.
- Saline residuals leading to corrosion has an adverse impact on static breaking strength.
- Severe abrasion has a serious impact on static breaking strength.
- High heat has a serious impact on static breaking strength.
- Cable loosening has an adverse impact on static breaking strength.

Caution!

- Cables rarely fail due to static tensile failure.
- Cables regularly fail to dynamic tensile overload.
  - That is the reason, no defects are tolerated by the conscientious inspector.

- Never take the cable's condition for granted !

Comments relating to rejection criteria

- Rejection criteria has been established over the years to protect the users and the OEMs.
- Many different concerns lead to establishment of rejection criteria.
  - Cable fouling on drum
  - Personnel safety (cut hands from broken wires)
  - Accident prevention
    - Zero tolerance

Conclusion

- Never take the cables structural integrity for granted !
- Broken wires are indications of larger problems that may need to be corrected.
- The wire rope has 133 individual wires.
  - Most of the wires are not visible from the outside.
- Inspect the cable as if you are the one hanging on it!
- <u>When in doubt; throw it out.</u>

Another concern

- If winding the cable into a drum or onto the ground in an uncontrolled manner.
  - Take your time
  - Pay close attention to the cable
  - Or this could happen to you!

Thank You

- Zephyr International LLC designs and manufactures ground support equipment and products that reduce life cycle costs dramatically, while enhancing the safety and reliability of maintenance of the rescue hoist and the wire rope cable.

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