NDT TECHNOLOGIES, Inc.
Wire Rope Nondestructive Evaluation
Know Your Ropes. Know What. Know Where. Know Why.

Wire Rope Failures, Who is Accountable?

Preface

Wire ropes are both, **safety critical** **and** **single points of failure**.

1. A **safety-critical system** or **life-critical system** is a system whose failure or malfunction may result in one (or more) of the following outcomes:
   - death or serious injury to people
   - loss or severe damage to equipment/property
   - environmental harm
2. A **single point of failure** (**SPOF**) is a part of a system that, if it fails, will stop the entire system from working. While SPOFs are undesirable in any system, high-value offshore and most other ropes are SPOFs that cannot be eliminated.

Failures of high-value offshore and most other ropes – which are **safety critical and single points of failure** – are completely unacceptable. Besides loss of life, they can cause catastrophic losses in the seven, eight or, maybe, nine figures range. Therefore, wire ropes are also **mission critical**. Here

3. **Mission critical systems** or **business critical systems** are defined as systems whose failure will cause extreme losses for a business.

These huge losses can significantly affect the bottom line and the reputation of even major corporations. They should and will eventually draw the attention of upper management

In spite of their mission critical importance, wire ropes are frequently considered low-tech commodities without much interest. Failures are frequently considered and accepted as "inevitable."

While appropriate rope inspection methods, discard criteria and maintenance procedures are available, they are frequently not applied. Entire operations are jeopardized by an unexplained and sometimes perplexing reluctance to use proper wire rope safety procedures. Traditional preventative maintenance and replacement schedules -- if followed at all -- typically are based on some form of in-service visual inspection and/or MRT inspections more often than not with instruments of dubious performance by inspectors with questionable skills combined with a large amount of educated or blind guesswork.

Wire Rope Failures

When human survival is at stake, acceptance of second best is a risk that nobody can afford to take. Wire ropes often provide a lifeline for industry in hostile and demanding conditions. Any person involved in the management of wire rope, can be held accountable if and when it fails. A good understanding of wire ropes, their design, characteristics, failure modes and inspection procedures is the basis for developing good maintenance strategies to ensure safety and reliability. Therefore, if you are directly or indirectly responsible for maintenance, inspection, or the safe use of wire rope this article is a must-read.

In 1998, a crane load line broke while lifting the south topside module of the **Petronius platform**, dropping the module into the Gulf of Mexico. The cost was estimated to be around 116 million US dollars.

Figure 1. The Heavy Lift Vessel DB-50 is shown here lifting the North module of the Petronius compliant tower into place. The ill fated South module is visible in the background.

In 2014, a 2.3-kilometer section of steel pipe at the Roncador oil field off the coast of Brazil was dropped after a **160 mm diameter rope of an A&R winch** failed. The loss was around 55 million US dollars.

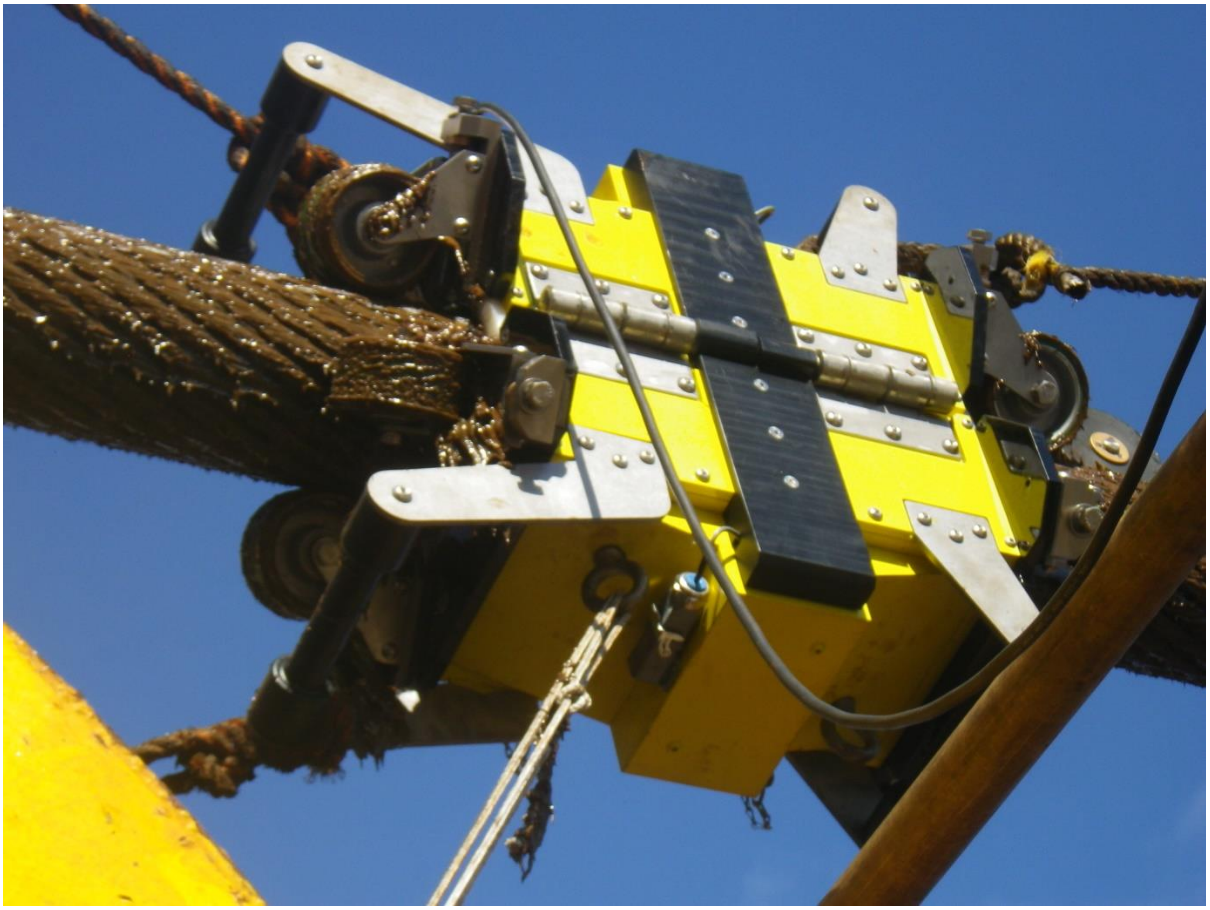


Figure 2. Magnetic Testing (MRT) of 160 mm diameter A&R Winch Rope

From 1999 to 2013 more than 60 people have been killed as a result of wire ropes breaking and more than 65 associated injuries.

James Dawes of Topeka, Illinois, was killed in 2008 after being struck by the boom of a Link-Belt crane; the accident was caused by the boom hoist wire rope breaking. The crane rope had been inspected, but a report said that the inspector failed to reject the rope showing a high number of visible wire breaks.

In 1999 a ropeway in the French Alps snapped causing 21 deaths. In 2003, a ropeway wire rope snapped and 7 people died and a further 42 were injured. In 2007 a crane wire rope snapped at New Delhi's metro, the entire structure tumbled down crushing workers underneath, six people were killed and 13 more were injured. In 2009 26 people were killed and 5 people were injured when a rope failed in a mine and a further 6 people were injured when a lift rope broke inside London's Tower Bridge.

Underground Coal Mine Fatality in West Virginia: On Tuesday, October 27, 2009, a 56 year old trackman was fatally injured. While the hoist was traveling up the slope, the hoist rope broke. This allowed the brake/mantrip car, mine locomotive and loaded rail car to run away down a 16 degree, 1,750 foot slope. The victim was at the bottom of the slope. Two miners were in the brake/mantrip car when the rope broke. They jumped out of the car and received non-life threatening injuries.

Failed end of the wire rope (car side) following the accident.

Failed end of wire rope (hoist drum side) following the accident.

Figure 3. Underground Coal Mine Fatal Hoisting Accident, October 27, 2009

Why Do Wire Ropes Fail and Who Can Be Held Accountable?

The reliable and safe use of wire rope is crucial for onshore and offshore operations. Therefore, wire rope safety is (or should be) a constant concern of wire rope operators and safety authorities.

While appropriate rope inspection methods, discard criteria and maintenance procedures are available, they are frequently not applied. Entire operations are jeopardized by an unexplained and perplexing reluctance to use proper wire rope safety procedures. Traditional preventative maintenance and replacement schedules -- if followed at all -- typically are based on some form of in-service visual inspection combined with a large amount of guesswork.

Modern wire ropes deteriorate internally with no externally visible signs. This has caused all too many rope failures. Therefore, wire ropes are often discarded long before the end of their useful service life. This means that, literally, tens of millions dollars' worth of expensive and perfectly good wire rope is discarded annually. At the same time, this wasteful and overcautious approach by no means assures wire rope safety.

Most wire ropes are covered with grease, which makes visual inspection -- even for surface deterioration -- impractical. Plastic sheathing precludes visual inspections for many ropes.

Considering the replacement cost of your ropes and equipment together with the tremendous damage caused by rope failures, can you really afford to guess the condition of your wire ropes?

Magnetic rope testing (Q&A): What sets NDT Technologies apart from the competition? High resolution and noise free signals!

Much more dependable than visual inspections, magnetic rope testing (MRT) is a reliable non-destructive evaluation/examination (NDE) procedure used for the in-service inspection of wire ropes.

NDE methods allow the detection and evaluation of external as well as internal rope deterioration. This allows the inspection of a rope's entire cross-section to the core.

MRT drastically increases wire rope safety. At the same time, it promises significant annual savings.

Founded in 1980, NDT Technologies, Inc. is the only manufacturer of magnetic wire rope test equipment in the United States. We offer a complete line of MRT NDE instrumentation for ropes with diameters up to 6½ inches (165 mm).

Many offshore wire ropes, such as subsea construction ropes and mooring ropes, have large diameters (>100 mm) and lengths in excess of 2000 m. These ropes are expensive and frequently represent seven figure investments. They are also known as *high-value offshore ropes*. These ropes usually have densely-packed non-rotating multistrand constructions or they consist of spiral strand, frequently with plastic sheathing.

High-value ropes are safety critical and single points of failure. In contrast to smaller and less expensive ropes, they can no longer be considered disposable items, and they call for reliable and highly accurate inspection methods.

These ropes usually degrade internally with no visible indications. Internal deterioration modes include

- ▷ interstrand nicking that will eventually develop into clusters of internal broken wires and
- ▷ corrosion including corrosion pitting.

External deterioration includes

- ▷ winding-on-drum damage.

Urgently needed, suitable inspection equipment and procedures are now available – especially for the quantitative characterization of internal rope deterioration.

To meet these critical requirements, advanced and accurate inspection techniques – both, instrumentation and signal analysis methods – for densely packed, high-value offshore ropes have been developed by NDT Technologies, Inc.

This '*New Generation"* line of wire rope NDE equipment is now available for the inspection of even the largest of these high-value offshore ropes and of spiral strand with diameters up to 165 mm.

The capabilities of *New Generation* NDE equipment include

- ▷ A dependable and consistent relationship between the condition of wire rope and NDE results.
- ▷ Noise free *high-fidelity* signals that allow the accurate measurement of a rope's loss of metallic cross-section caused, for example, by corrosion and wear
- ▷ Reliable detection and quantitative characterization (measurement) of rope deterioration such as interstrand nicking, internal clusters of broken wires, internal corrosion including corrosion pitting.
- ▷ Rope retirement standards that are geared to wire rope NDE can be developed and specified. These discard criteria will be based on quantitative defect characterization,
- ▷ Test data interpretation that is readily understood, and can be rationally explained and communicated.

New Generation wire rope NDE equipment offers extraordinary performance.

For example, among all competitors, only our instrumentation can dependably inspect rotation-resistant and non-rotating multi-strand and IWRC ropes, an important category of ropes that includes most crane ropes.

These ropes usually develop – and fail from – internal deterioration such as inter-strand nicking and clusters of broken wires and/or internal corrosion including corrosion pitting. Failure of these ropes is frequently "unexpected" with no external indications of internal rope deterioration.

Our wire rope NDE instrumentation has the unique capability to reliably detect and quantitatively characterize (measure) these types of internal rope degradation.

With the limited capabilities of our competitors' equipment, for these ropes the inspector must usually resort to guessing – either educated or blind. Therefore, he is liable to make rope retirement decisions that will be either dangerous or wasteful.

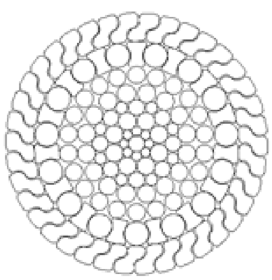
Here are examples of MRT nondestructive examinations.

Example 1. MRT NDE of a 32 mm locked coil rope, left hand lay

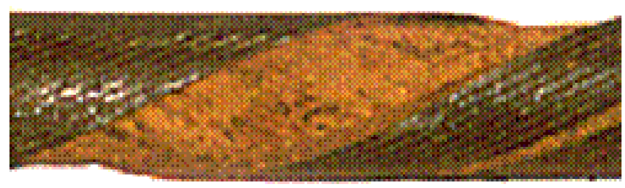
This rope was examined during Round Robin experimental magnetic wire rope inspections at the Health and Safety Laboratory in Sheffield, England in 2001.

The rope was mounted on an external mobile winch for approximately 10 years after 3 months earlier use on a friction winder installation. The rope showed clear evidence of external corrosion, variable along the test length. Using retirement criteria that are appropriate for visual inspections, this rope would have been rejected for further use. Due to its service history the rope was not believed to contain any internal local defects.

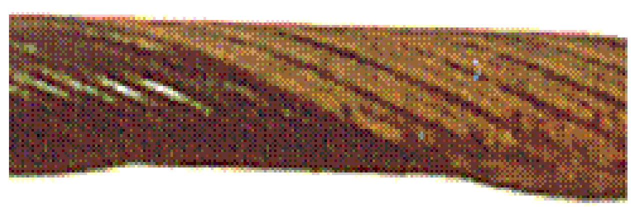
Figure 4 illustrates the rope construction and the extent of corrosion. After dismantling, the rope showed severe corrosion on the outer layer and also significant corrosion on the second layer. The third layer showed less corrosion, and from the fourth layer onward the rope appeared undamaged, because lubricants were still present. No local defects were found.



Typical 32 mm locked coil construction



Corrosion in the first and second layer of the rope



Corrosion in the second and third layer of the rope

Figure 4. 30 mm locked coil rope after dismantling

The MRT NDE chart of Figure 5 shows variable corrosion, corrosion pitting and, possibly, broken wires. The deterioration to the left of the chart is caused by winding the rope on the drum with the worst deterioration occurring where the rope changes layers while winding on the drum as indicated.

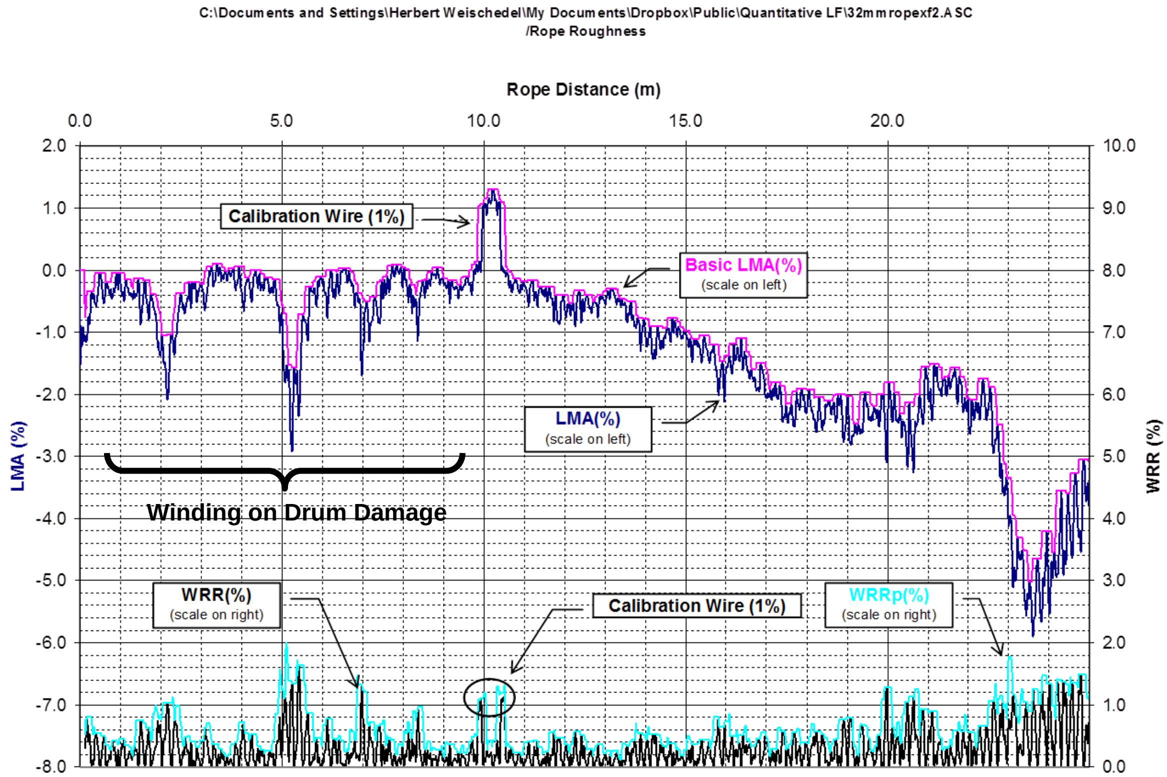


Figure 5. 30 mm locked coil rope MRT NDE chart

Example 2. Nondestructive safety evaluation of a hoist rope

<u>General Information</u>

This inspection was performed at the Seven Foot Slope Mine, Alfred Brown Coal Company by the United States Department of Labor, Mine Safety and Health Administration (MSHA). The Seven Foot Slope Mine operates in Schuylkill County, Pennsylvania. The mine incorporates a 7/8 inch diameter, 6 x 25 FW RRL IWRC wire rope into the supply and personnel hoist. The rope was installed in March 2000 and a magnetic NDT was conducted by MSHA in June 14, 2011. The length of the slope was approximately 315 feet.

<u>Test Set-up and Procedures</u>

The LMA-125 sensing head manufactured by NDT Technologies Inc. was used to conduct the wire rope testing. Data was recorded by a strip chart recorder, and it was also captured with the use of data acquisition software and a laptop computer. The digital information was stored for further analysis.

The instrumentation was standardized using a 1/8-inch diameter rod. The rod, when removed from the test head represented a 3.2% loss of metallic area for the rope.

The rope was tested just above the collar of the slope. The gunboat started at the bottom of the slope and was raised until it reached the top allowing approximately 315 feet of rope to be tested. During the test, the average rope speed was approximately 50 feet per minute. In addition to the NDT evaluation, caliper measurements were also made from various locations in the rope.

<u>NDT Results Limitations</u>

This type of NDT is a relative test that compares the "best" section of rope to the "worst" section. The loss of metallic area reported is the loss relative to the best portion of the rope and should not be interpreted as the loss of metallic area relative to a "new" rope.

<u>Results</u>

Figure 6 is a chart showing the loss of metallic area (LMA) and local flaw (LF) outputs from the test conducted on the hoist rope. The Maximum LMA of approximately 13.5 percent was identified at a point approximately 50 feet from the gunboat. The LMA identified was consistent with corrosion, wear and possible broken wires. A localized LMA of approximately 11.0 percent was identified approximately 150 feet from the gunboat. The localized loss was indicative of broken wires. This section of rope was marked for cutoff and immediately removed from service. No broken outer wires were identified.

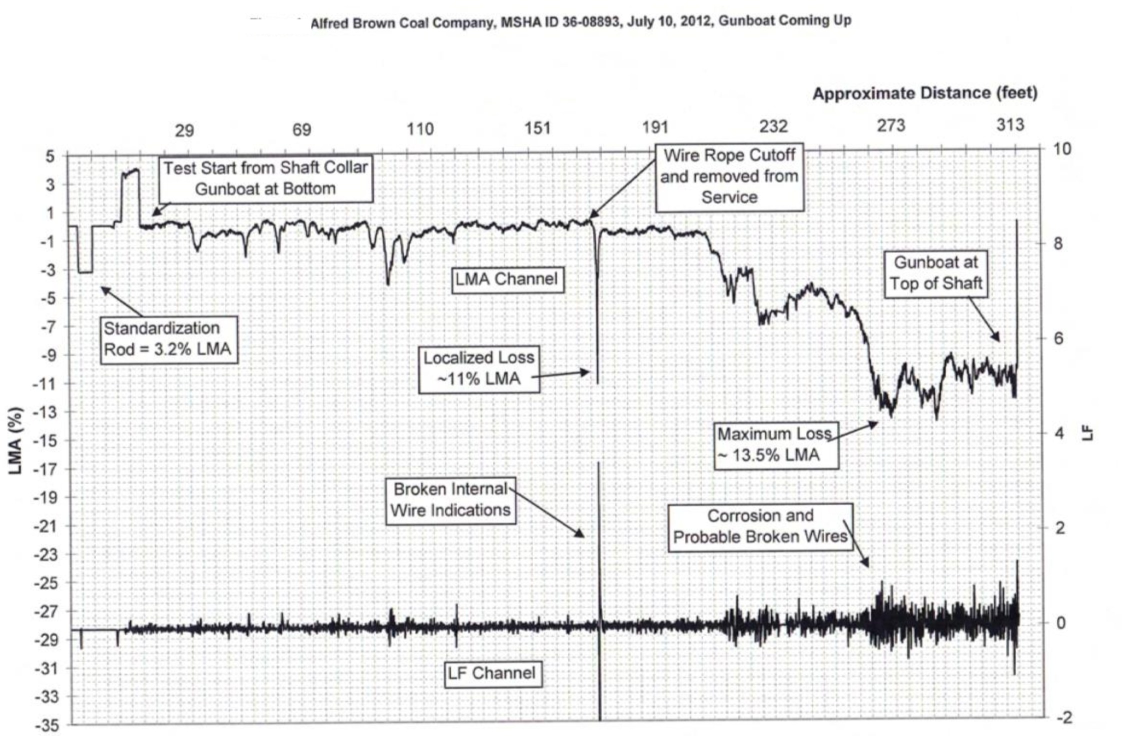


Figure 6. 7/8 inch diameter, 6 x 25 FW RRL IWRC wire rope MRT chart

Figure 7. 7/8 inch diameter, 6 x 25 FW RRL IWRC wire rope after disassembly

The retired portion of rope was disassembled by removing the outer strands from the rope. As this process occurred, a section of the IWRC fell out of the rope. All of the wires in the core of the rope had deteriorated due to corrosion. This section of the hoist rope is shown in Figure 7.

Conclusions and Recommendations

Based on the test results obtained from NDT, approximately 150 feet of hoist rope were immediately retired from service. A visual examination of the damaged portion of the retired hoist rope was conducted at the mine site. No broken outer wires were identified. The outer strands of the affected portion of the rope were removed to expose the damage to the core. Based on disassembly of the rope and on the visual examination, it was apparent that this section of hoist rope met the retirement criteria specified by Title 30 CFR 75.1434 (a), (d), and (h).

The Offshore MRT Market – Systemic Problems

The offshore MRT market is in a dismal state.

Just like other markets, the offshore MRT marketplace is a tangled web of obfuscation, confusion, human inertia, and divergent and conflicting commercial and personal agendas, including Specmanship and the most bizarre and brazen flimflam artistry.

While highly accurate NDE instrumentation (from NDT Technologies) and trained and certified inspectors are available, inspections are often performed haphazardly with second rate instrumentation by unqualified and untrained inspectors.

Juxtapose this to the fact that wire ropes, in general, and high-value offshore ropes, in particular, are safety critical and single points of failure. Rope failures – many of them catastrophic, with injuries or loss of life and/or tens or even hundred million dollars in losses – are all too frequent (see here and here)

Question: Is it really more important to protect commercial and personal interests and sensitivities, rather than prevent the loss of lives and avoid annual losses of – potentially – hundreds of millions of dollars?

The human factor root causes of wire rope failures are manifold and can range from ignorance to criminal negligence.

The MRT community and the associated market consist of three different segments performing different functions and with diverse responsibilities:

1. **The Principals: Wire rope owners and users**

   Wire Rope Principals must use **due diligence** to choose the suitable NDE equipment together with qualified and certified inspectors.

   Because decision makers and opinion leaders in the wire rope community are ultimately responsible for the safe use of ropes, they can be held accountable for rope accidents. As an aside, bad decisions can also have devastating career repercussions!

   Because huge losses in the **50** or **100 million dollar range** will seriously affect the bottom lines and reputations even of very large corporations, upper management should – and will – become aware of wire rope safety and – most likely and hopefully – will try to eliminate hazardous corporate organizational deficiencies.

   Principals should employ at least one expert – with an advanced engineering degree – thoroughly familiar with wire rope safety, deterioration modes, and, especially, MRT. But beware of **self-appointed, self-anointed "experts."**

2. **In-house inspection departments and third-party inspection companies**

As a rule, wire rope Principals prefer to delegate their wire rope inspection responsibilities to third parties like wire rope manufacturers, offshore service companies, crane maintenance companies, wire rope riggers, or to on-board personnel of construction vessels.

The problem is that these companies frequently see MRT as just another business opportunity. They try to maximize profits and reduce costs by using equipment that is "good enough" and inspectors with little or no technical education.

This is a penny-wise-and-pound-foolish business model and a catastrophic corporate strategy.

Considering disastrous potential losses in the **50** or **100 million dollar range**, the cost of inspections is very minor, and using the most qualified and highly educated inspectors together with the best equipment available should be a no-brainer.

3. **Instrument manufacturers**

Instrument manufacturers are responsible for providing qualified up-to-date inspection hardware and software. They must perform R&D and innovate. They also must provide inspector training and certification.

At NDT Technologies, we have **36 years of R&D experience** building MRT NDE equipment and developing advanced software algorithms for evaluating the condition of wire ropes. Compared to our competitors, our magnetic wire rope NDE equipment offers **extraordinary performance.**

For example, only our instrumentation can dependably inspect rotation-resistant and non-rotating multi-strand and IWRC ropes that deteriorate from internal corrosion and internal broken wires in clusters. This important category of ropes includes large high-value offshore ropes.

All MRT equipment is based on conceptually simple and easy to understand**.** **magnetic flux leakage principles.** Furthermore, **information on magnetic wire rope test equipment** has been readily available in the patent and technical **literature.** This situation has led many a budding inventor to see an easy business opportunity.

Here is how it works.

Just slap some magnets and sensors (especially Hall sensors) together, and you will get some sort of a signal. Get a patent. Add some **specmanship,** some hype, a website**,** and – voilà – you have a business.

Typically, this kind of equipment is characterized by **extremely noisy** and **low-fidelity** LMA signals. These **Pseudo-**LMA signals do not at all measure loss of metallic cross-section, and they cannot be calibrated.

Furthermore, LF signals are not quantitative and not useful for estimating the number of broken wires in clusters, interstrand nicking, and the severity of corrosion pitting. These signals do not allow a rational interpretation, with inspectors having to resort to guessing – educated or other.

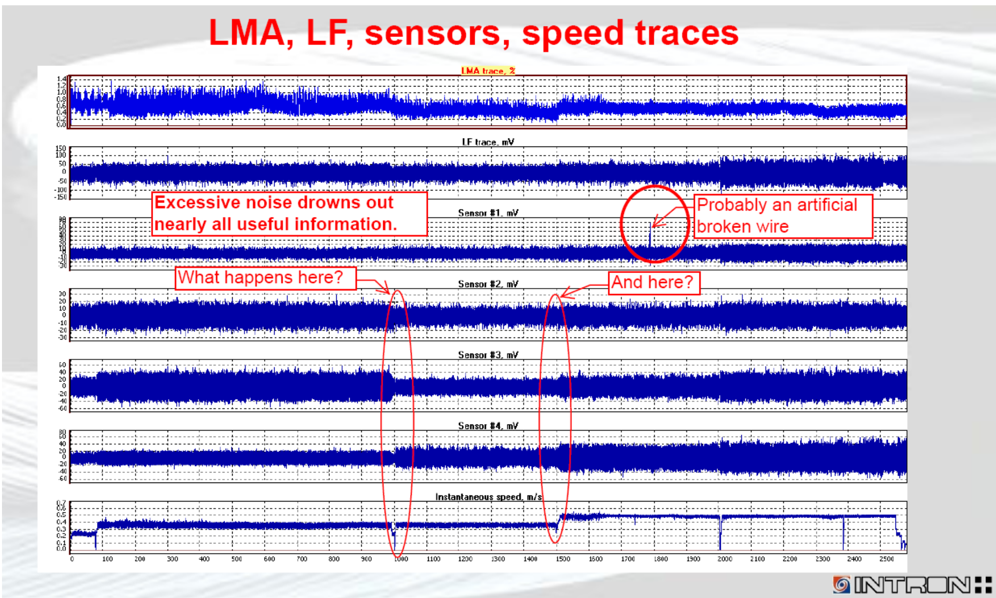


Figure 8. Noisy and low-fidelity signals

To illustrate this situation, please refer to Figure 8 and to these links: here and here.

Over the past 50 or so years, a great many instrument configurations have been and are being concocted **by all too many inventors and companies.** Most of this equipment has appeared and, eventually, disappeared from the market.

From the above observations and not unexpectedly, some novice and naïve entrants into the MRT NDE market have recently surfaced – including rather nicely thought-out websites (please click **here** and **here**).

Due Diligence

Wire Rope Principals are ultimately responsible for the safe and economical use of ropes. They must use due diligence to choose qualified NDE equipment, certified inspectors, and third-party inspection companies.

Due diligence evaluations require information on instrument performance and inspector qualifications be made available to all interested parties without restrictions. These facts must be freely scrutinized and openly discussed in the wire rope community.

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PS:

A seasoned engineer, with 36 years of R&D experience in the field of nondestructive wire rope examination, I would be pleased to assist with due diligence investigations.

I have considerable **academic and professional credentials**. From many experiments, I am thoroughly familiar with our competitors' technology. I hold **8+ patents** covering not only our own but also improving on our competitors' technology.

NDT Technologies is more than willing to publish and disclose test results and other information and expose them to open discussions (for example, please open the following links: **here**, **here**, and **here**).