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Wire Rope Non-Destructive Testing - Survey of Instrument Manufacturers

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Wire Rope Non-Destructive Testing - Survey of Instrument Manufacturers

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SUMMARY

This document reports a study to supplement the HSE project on Non-destructive testing of wire rope (Tytko, Chaplin & Ridge, 1999). The earlier study was undertaken in order to assess the reliability of a limited number of different sets of wire rope non-destructive testing equipment in terms of identifying and quantifying rope degradation (wire breaks; abrasive wear; plastic wear; corrosion and slack wires).

The results from the earlier project indicated the confidence which might be placed in NDT technology when quantifying for different rope constructions, categories of defect appropriate to typical uses, i.e. the minimum level of defect which can be detected and the reliability with which the degradation can be quantified.

This study has identified 26 NDT companies, of which seven were selected for a more detailed review, and who were asked to complete questionnaires concerning operation of both NDT sensor heads and the associated recording electronics. The companies chosen represent a wide range of technologies and nationalities, providing equipment designed for a range of rope applications, and are considered likely to include all those which might be used in the UK.

There is a limited range of wire rope NDT instruments which are likely to be used in the UK, however, there are no agreed performance specifications for such instruments. It is essential that the operator of the NDT device understands the principles of operation of that particular device and is familiar with the limitations of the equipment.

This is especially true of the calibration processes, which need to be understood especially in relation to whether “static” or “dynamic”. NDT operators need to be aware of other influences (such as rope tension or external magnetic fields) which can affect calibration. The level of understanding required for effective and reliable rope inspection assisted by NDT goes beyond the initial guidance, as to its use and operation, given in instructions provided by the instrument manufacturers.

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1. INTRODUCTION

This document reports a study to supplement the HSE project, report number OTO 1999 032, on Non-destructive testing of wire rope (Tytko Chaplin & Ridge, 1999).

The earlier study was undertaken in order to assess the reliability of different sets of wire rope non-destructive testing equipment in terms of identifying and quantifying rope degradation. To this end a set of four different rope constructions were selected which represented a broad range of ropes in use in the offshore environment. Lengths of these ropes had realistic damage artificially (and hence quantifiable) induced in them, before testing using the different sets of NDT equipment in otherwise identical test conditions. Defects investigated included wire breaks (both internal and external); abrasive wear; plastic wear; corrosion and slack wires.

The results from the earlier project indicated the confidence which might be placed in NDT technology when quantifying for different rope constructions, categories of defect appropriate to typical uses i.e. the minimum level of defect which can be detected and the reliability with which the degradation can be quantified.

This study has reviewed different sets of equipment which are available for use for the non-destructive testing of wire ropes on a world-wide basis. Inevitably, the list will not be exhaustive, as there may be companies of which the authors are not aware, or who have been founded since this report was written, however, they will be representative of the type of equipment currently available on the market. This report lists twenty six companies who either design, manufacture or market NDT equipment (see section 3).

Of the companies listed in section 3, seven were selected for a more detailed review, and were asked to complete questionnaires concerning operation of both the NDT sensor head and the associated recording electronics. The companies chosen represent a wide range of technologies and nationalities, providing equipment designed for a range of rope applications, and were considered likely to include all those which might be used in the UK.

The following section describes the main principles of the operation of magnetic NDT equipment. Section 3 provides an overview of the different sets of equipment available, seven of which are reviewed more closely in Section 4, as mentioned above. Section 5 presents the discussion and conclusions of this study.

2. NDT TECHNOLOGY - PRINCIPLES OF OPERATION

NDT devices for inspecting wire ropes have been in use for well over fifty years. The only really effective technology that is in current use depends on the magnetic properties of the steel wire rope. The background to this technology has been described by Cordon (1988), Weischedel & Chaplin (1992), Chaplin & Smith (1993) and many other references which discuss the use of NDT equipment. (The proceedings from a recent conference in Kraków on the use of NDT contains papers indicating the state of the art in many aspects of this technology (Chaplin ed., 1999). Wire rope NDT is used extensively in the routine inspection of mine hoist ropes throughout the world. It is also used for inspecting both track and haulage ropes in rope-ways, particularly in mountain installations (cable cars and ski lifts). It is in the context of these applications, especially mining that the technology has been developed. Increasing concern for establishing the long-term integrity of offshore ropes used in a number of applications (particularly in mechanical handling equipment) has led to extension of this type of rope NDT technology to the offshore industry.

The principles of operation for electromagnetic wire rope NDT systems employ:

- measurements of fringe fields near the surface of the rope to detect local defects such as broken wires, corrosion pitting, local wear.
- measurements of changes in magnetic flux passing through a short length of rope to quantify changes in metallic cross section.

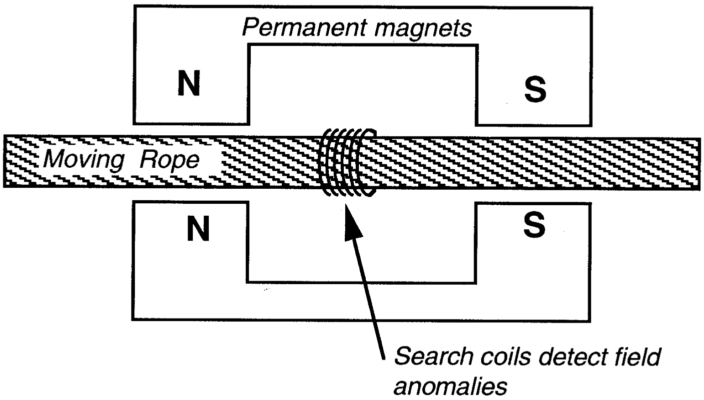

Figure 2.1
Typical electromagnetic NDT head

The layout of a typical instrument is shown in figure 2.1. The identification and classification of local defects depends largely on the subjective interpretation of an analogue signal by an experienced operator coupled with the information from rope traces (figure 2.2 shows a typical trace obtained from testing a degraded rope). It is advisable to compare readings with a “signature” trace taken when the rope was new or first installed, and then subsequent traces, to assess more accurately any degradation which has developed in the rope.

Area change measurement, while nominally quantitative, also requires an element of interpretation, particularly where it is indicated over a short length.

The most effective way in which rope NDT is currently used is as a means of improving the reliability of the initial identification of the location of significant degradation along a rope. It should be noted that instrument manufacturers are increasingly seeking to automate both the analysis and archiving of the NDT trace. Recent developments have seen the use of custom designed electronics and custom written software for use on proprietary computing equipment.

Regular NDT inspections provide a powerful tool in monitoring the rate of degradation of a rope. [Regulations for deep South African mine hoist systems require routine NDT at 3 month intervals, using equipment that has been certified as suitable, used by operators qualified as competent (SABS 0293:1996).] Under consistent conditions a rope in perfect conditions will show a trace that is a reproducible "signature" determined by its complex helical structure. The quality of a trace is improved by avoiding vibration and maintaining a steady speed (these considerations are much more important that maintaining a high speed).

Figure 2.2

Typical LMA (above) and Local Fault (LF) traces for a severely degraded rope

Rope NDT is especially valuable in aiding the rope examiner when inspecting a long rope which is covered in heavy grease or marine growth. However, the technology has not yet reached the stage of development where the acceptance or rejection of a rope can be automated. However the underwater inspection of rope using a remotely controlled NDT system is feasible (Bavins, 1988 and Noble Denton, 1996). For conventional six strand ropes, the NDT evidence can be supported by video of damage locations; for spiral strand constructions with polymer sheathing, the protection from corrosion will provide a "clean" signal that will be easier to interpret. More sophisticated computerised analysis of signals will also enhance comparison of subsequent signals.

Development of rope NDT systems to provide more detailed information will be motivated by the need for interpretation of signal without visual back-up. This involves simple development, not innovation.

2.1 CONSIDERATIONS RELEVANT TO LOCAL FAULT (LF) MEASUREMENT

The distance along the rope over which local faults influence the external field, is usually such that wire breaks which are close together cannot be differentiated explicitly. This "spatial sensitivity" varies between different instruments. The effect is a particular problem when wire breaks are internal; for example in a multi-strand rope with hundreds of internal breaks per metre, the effect on the trace tends to seem just a magnification of the new rope signature.

Most instruments cannot give any indication of the distribution of wire breaks around the rope. Since there is a considerable difference between the effects of the same number of breaks concentrated in one strand, as opposed to uniformly distributed, this is an important limitation, but can be easily overcome when visual inspection can complement the NDT.

Recently, work has been reported from the University of Stuttgart into the development of a test head which has an annular array of two sets of 30 Hall effect sensors (Nussbaum, 1999). This system in combination with computerised processing of the data can provide a graphical representation of stray field around and along the rope which can separate closely spaced wire breaks.

2.2 CONSIDERATIONS RELEVANT TO LMA MEASUREMENT

A measurement of the changes in the total flux passing through the rope can provide a quantitative indication of changes in metallic cross section area. A variety of different techniques has been developed by designers of rope NDT devices for making this measurement. The most significant effect of these differences in technology relate to the threshold length over which these area changes are indicated accurately. This threshold length can vary from as little as 10 mm to 750 mm. The effect of differences in threshold length will be to have a significant impact on the performance of different instruments. It can be seen in figure 2.2, by looking at the LMA trace, that the LMA sensors may detect local faults. However, unless the air gap between local faults is long enough (and this threshold length is dependent upon the instrument in use) the true value of LMA will be attenuated (Tytko et al., 1999).

Area loss signal changes with the saturation flux density of steel. As a result, LMA signal can change with rope tension. So in situations (such as deep water mooring) where tension will change along the rope, an allowance may be necessary for this effect.

One problem that the manufacturers of rope NDT devices have not been addressing is that of calibration using realistic degradation. This relates particularly to the problem of interpretation of area loss measurements. Current methods of calibration involve using steel rods or wires drawn through the device alongside the rope: this provides an absolute measure of area loss signal, but has no relationship to the nature of area loss as it would be distributed in a used rope. This procedure is further questioned as the LMA sensitivity of some instruments is affected by rope motion. A static calibration in which the rod is withdrawn from alongside a stationary rope gives a different response to a calibration in which the rod is attached to a moving rope (Golosinski & Tytko, 1998).

Wear or corrosion never affects individual wires uniformly along their length. A typical distribution in a crane or mooring rope would involve concentration in outer wires where they come to the crown position on the outer strands. Under these conditions the rope examiner is interested in the cumulative effect of the degradation to all outer wires. Manufacturers of NDT instruments are unable to indicate whether this cumulative effect is what their instruments will measure, or whether the value recorded relates to a cross-section “snapshot” measurement (figure 2.3). The earlier work in this study has indicated that NDT equipment gives a measurement of the “snapshot” area, rather than the critical effective area (Tytko et al., 1999 and Chaplin et al., 1999).

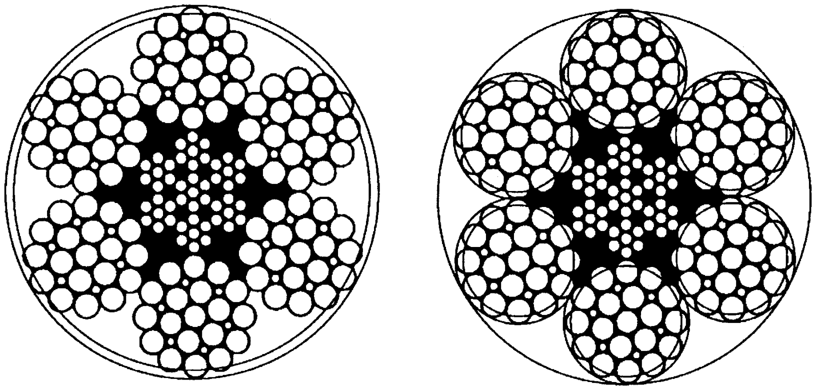

Figure 2.3
Measured nominal LMA (left) and effective LMA for a uniformly abraded rope

2.3 TYPES OF MAGNETS IN USE

Various means have been used over the years to magnetise ropes, which include:

- permanent magnets;
- a direct current passing through circumferential coils;
- an alternating current passing through circumferential coils.

The first of these three methods requires that the permanent magnets provide sufficient flux passing through the section of rope (being inspected) effectively to saturate the steel. This ensures that the flux associated with local defects is displaced outside the rope where it can be detected (rather than displaced into adjacent wires, where the effect will go unnoticed). Direct current magnetisation systems operate on the same principle of saturation, and have only been used by a few instrument manufacturers, when it was perceived that permanent magnets could not generate sufficient flux. The DC electromagnet systems are no longer relevant due to the availability of much more powerful permanent magnets than in the past. Although permanent magnets (and especially permanent rare earth magnets such as Neodymium-Iron-Boron (Nd-Fe-B) or Samarium-Cobalt) are more costly than DC electromagnet systems, they enable a lighter system to be employed than one using heavy lead/acid batteries.

Alternating current systems, which essentially employ the rope as the core of a transformer, were favoured for inspecting triangular strand mine hoist ropes used in the very deep shafts of South African gold mines. The South African technology for these AC instruments became highly developed, but is now being overtaken and displaced by permanent magnet systems.

Realistically systems which will be most commonly encountered are those NDT test heads which use permanent magnets.

2.4 TYPES OF SENSORS IN USE

Although there has been a trend towards acceptance of permanent rare earth magnets as the best form of magnetising the rope, there is a wide range of sensors employed by various manufacturers for identifying local faults and quantifying area changes including:

- circumferential coils;
- saddle coils;
- return flux coils;
- “flux gate” coils;
- Hall effect sensors in various locations.

Coils in use with a steady magnetising flux have the disadvantage that the current generated is proportional to the speed of the rope passing through the measuring head. This problem is overcome in the electronic signal processing by attenuating the system gain in proportion to speed, but consequently there is a minimum speed below which the attenuation is inoperative and the signal suffers in consequence. Typical minimum speeds are in the region of 0.25 to 0.5 m/sec. Lower speeds may be accommodated through modifications to the electronic system. Hall effect devices, which generate a current proportional to the intersected flux, are speed insensitive and can therefore operate down to very low speeds, but require some subtle magnetic circuit design to be certain to capture the stray field. Hall effect sensors may also be more expensive and historically have been less stable than coil based systems.

Another potential problem area relates to the integration of signals from coils when computing loss of area. Historically this has depended upon analogue integrator circuits requiring high long term stability to ensure that drift does not influence the signal. Digital signal processing (DSP) offers an alternative route which might be an advantage here. In systems which facilitate transfer of the NDT signal to a computer a range of other advances have been introduced. These typically include archiving and retrieval of signals (which can be advantageous for making comparisons of new and old traces), as well as allowing expansion of segments of trace of particular interest. Processing of the signal can also yield benefits, but such procedures are not yet generally available. One category of such a development is the calculation of a single parameter to indicate rope acceptance or discard (Hamelin et al., 1997). Although presenting the advantages of simplicity, this approach is considered by many to be unsuitable for any but “standard” conditions. Other developments include the possibility of signal processing to extract additional information such as using a “rolling” Fourier transform technique to extract information on rope lay length (Tytko & Golosinski, 1998). Developments at the Technical University of Stuttgard have lead to a prototype instrument which captures the signals from an array of Hall sensors distributed around the rope which provides a map of magnetic field anomalies plotted over the unwrapped surface of the rope (see also Section 3.21) facilitating separation of closely spaced internal wire breaks.

The various combinations of these different sensors and magnetising methods have resulted in the technology becoming a patent lawyer’s delight. The current lack of any standards for qualification of equipment or operators has also lead to a degree of confusion, although this situation is changing by the introduction of quantitative standards on this subject in the USA (ASTM E1571-93); South Africa (Backeberg, 1993 and SABS 0293:1996); and, Poland (Hansel et al., 1992). Consequently there are numerous devices manufactured, mostly by fairly small concerns, in some cases with restricted availability due to patent problems, and also with far from uniform performance (or methods for defining and assessing performance).

However despite these apparent problems electromagnetic NDT is not only used for many rope applications, but is heavily relied upon when assessing the integrity of wire ropes and arriving at discard decisions in critical applications. The use of wire rope NDT is extending in terms of industries, countries and sophistication. However, the UK appears to be lagging somewhat behind in this area.

3. NDT EQUIPMENT MANUFACTURING COMPANIES/ORGANISATIONS

Table. 3.1

Main world producers of non-destructive magnetic wire ropes test apparatus

Producer and country	Detecting sensors Type	Technique	Recording & data processing	Designation of instrument
AGH Poland	Area/Local faults	Hall effect /inductive coils	Fully digital, PCMCIA memory	MD120 and GM series of heads
AATS South Africa	Area/Local faults	Hall effect	Dedicated computer	AATS Model 817
British Coal Great Britain	Area/Local faults	Coils and integrator	Gould termite paper chart recorder	Ropescan
DMT Germany	Area/Local faults	Coils with integrator	Built-in chart recorder, PC card	RTI 1
Dr. Brandt Germany	Area/Local faults	Coils with integrator	Built-in chart recorder, Gould	SPM-1, SPM-20 SPR
Druk Pak AG/EMSA Switzerland/Holland	Local faults	Hall effect	Paper recorder WK-150	Hand “Cable Spy”
E Kündig SA Switzerland	Local faults	Inductive coils	Gould-Brush chart recorder	PMK 75 and others
ETH Zurish Switzerland	Local faults	Coils	No data	No data
Halec SA France	Local faults	Coils	Gould chart recorder	Cable Test Halec SA
Heath and Sherwood Canada	Area/Local faults	Hall effect	Digital, computer processing	Magnograph II
Hitachi Building System Eng. and Service/Japan	Area	AC coils	Prototype	AC Elevator Rope Tester
Hitachi Building System Eng. and Service/Japan	Local faults	DC circuit, coils	Prototype	Magnetic Defect Sensor
Intron Plus Ltd. Russia	Area/Local faults	Hall effect	Build in Data Logger, computer processing	INTROS, MH & F series
Kanatop Electro-Mech Plant/Ukraine	Area only	AC electromagnet	External chart recorder	IISK-5
Laboratory Roman Martyna/Poland	Area/Local faults	Hall effect	Analogue, termite chart recorder	LRM-MH LRM-MR
Meraster Poland	Area/Local faults	Hall effect /inductive coils	Fully digital, PCMCIA memory	MD120 and GP series of heads
NDT Technologies USA	Area/Local faults	Coils and integratgor	DSP and/or built in chart recorder	LMA-125, 175 250, LMA-test
RAU	Area.Local faults	Coils & Hall flux reversal	Chart	RAU
Rotesco Canada	Area/Local faults	Flux gate/ inductive coils	Charter recorder/ computer hard drive	Rotescograph 2D and 2C-TAG88M
Shanghai Maritime University/China	Area	Flux gate	Prototype	
Technical University Stuttgart/Germany	Local faults	Magneto-inductive	No data	Casar and multiple sensor device
TÛV UK Ltd. Germany	Local faults	Coils?	Gould chart recorder	Wire Rope Test
VVUU Czech Republic	Area/Local faults	Hall effect	Fully digital	MID-series
Wire Rope Testers Inc. USA	Local faults	Inductive coils	Digital, laptop PC, Win95	The Rope Tester
ZEG - Tychy Poland	Area/Local faults	Hall effect/ coils	Analogue, termite chart recorder	DLS (not produced)

3.1 AGH

See Zawada NDT, Poland*[1]

3.2 AATS (ANGLO AMERICAN PLC. GROUP) SOUTH AFRICA*

The AATS magnetic non-destructive rope testing equipment was developed against the background of the gold mining industry (AATS are a member of the Anglo American plc group). Wire rope for hoisting in the South African gold mines has been employed since late in the nineteenth century and NDT has been in use since early in the last century. The Anglo American Corporation as the largest mining house in South Africa has devoted considerable effort to ensuring that effective NDT systems are available for the mines in which they have a controlling interest. This has become especially significant with the moves to greater depth. The current development of shafts of 3000 m and more will only be feasible with lower factors of safety. Operation at lower factors is only allowed with improved winder control and rope inspection by qualified rope inspectors using validated NDT instruments in combination with visual inspection.

Consequently, for a number of years, AATS have been developing their own NDT instruments, in-house, evaluating commercially available systems and sponsoring research and development in the field. One particular development has been “in-situ” (i.e. permanently installed) NDT systems (Venter, 1999). Two such systems are now operating and in each case are linked directly to the automated winder controller. The benefit of such a system is that the only major faults are really of interest, since the rope is being approved not for the next three months, but for the next few minutes.

The latest portable range of NDT heads which are surveyed in this report were developed from this initial “in-situ” system. The two systems have different ranges of performance, in that the smaller portable systems operator at a much lower maximum speed (2.5 m/s), they are however, more accurate in their measurement of LMA. Both the “in-situ” and “portable” test heads have in-house software for the evaluation of the raw test data.

3.3 BRITISH COAL, GREAT BRITAIN

See Lloyds Beal*

3.4 DMT, GERMANY

No information available.

3.5 DR BRANDT, GERMANY

This company manufactures a range of testing equipment, one area of which is concerned with wire ropes. The rope testing heads suitable for rope size up to ø160 mm are available. Commercial testing is performed by WBK (Westfaelische Berggewerkschaetkasse Seilprüfstelle), Bochum, who also collaborate in instrument development. The special large diameter test head, which uses ferrite magnets, is very heavy at around 1000 kg!

3.6 DRUK PAK AG/EMSA, SWITZERLAND/HOLLAND

The “CABLESPY” was developed by the Swiss company, Druk Pak AG, and is intended for use on cranes, hoists, ropeways and similar lifting equipment, measuring only local faults. The test heads which are suitable for ropes in the range ø8 to ø27 or ø8 to ø48 mm, are intended to be hand held and

[1] Companies which have been included in the fuller review in section 4 are marked with an asterix.

accordingly, the weight of the test heads is low, 3.7/6.5 kg respectively. The magnetisation flux of these instruments is inevitably much lower than most of their competitors.

3.7 KÜNDIG SA, SWITZERLAND

The development and operation of the Kündig test equipment is described in Kündig (1981). The PMK series of testing heads has four sizes, for ø40, ø70, ø90 and ø110 ropes. This series of test heads is designed for local fault detection only.

3.8 ETH ZURICH, SWITZERLAND

No detailed information available, but in-house design and construction solely for their own use.

3.9 HALEC SA, FRANCE

Halec SA offers a range of structural integrity inspection services and testing techniques (Radiography, ultrasound and magnetic). Their main work with wire rope NDT covers a full range of fixed or moving rope applications (cableways, funiculars, lifts, mine hoists, bridges, chimneys).

3.10 HEATH & SHERWOOD, CANADA*

A joint project by CANMET (Canada Centre for Mineral and Energy Technology) and the Noranda Technology Centre resulted in the development of the computer controlled wire rope tester, which has been commercially designated as the Magnograph®II. This instrument (figure 3.1) is manufactured under Noranda/CANMET license by Heath & Sherwood (1964) Ltd. The instrument set up has been automated and groundwork laid for computerised data evaluation (Heath & Sherwood, no date). The Manograph®II is based on the original Magnograph®, however, the magnetic circuit has been reduced in size and weight and the design improved. It is possible to retrofit old sensor heads so that they may operate with the new computer console.

A particular feature of the Magnograph® is that, operating solely on Hall effect sensors, it produces a signal independent of speed and is therefore able to operate at very low speeds.

Figure 3.1
Magnograph®II and data logger

The Magnograph® technology has been applied to a new version named PermaScan, which is aimed at permanent installations in mines, for on demand monitoring of hoist ropes. The PermaScan is undergoing field trials at time of writing and is not yet commercially available (Hamelin, Hofmeister & Leung, 1999).

3.11 HITACHI BUILDING SYSTEM ENG. AND SERVICE, JAPAN

No information available.

3.12 INTRON PLUS LTD., RUSSIA*

Intron Plus produces NDT inspection heads, INTROS, for a range of rope diameters from ø6 mm - ø64 mm, and for flat (balance type) ropes from 72 - 233 mm wide and 11 - 38 mm thick (figure 3.2). This range of small, light heads have a micro-controller inside the hand held unit. The test head may be used either in real time using an LCD display, or as a data logger for subsequent processing (using WINTROS software). Since the units are self contained, they are ideal for use on standing ropes. Typical applications include mine hoist ropes, on offshore platforms, cableways, cranes, lifts and bridges (Mironenko & Sukhorukov, 1998).

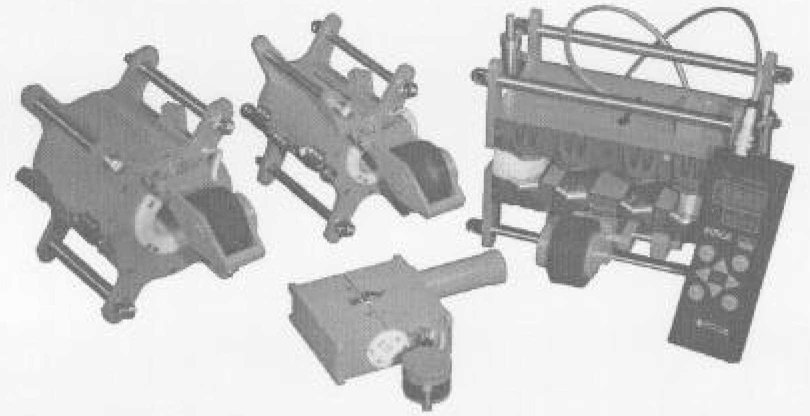

Figure 3.2
A selection of Intron test heads

3.13 KANATOP ELECTRO-MECH. PLANT, UKRAINE

No information available.

3.14 LABORATORY ROMAN MARTYNA (LRM ®), POLAND

Dr. Martyna manufactures testing heads for the inspection of both flat and round steel wire ropes. Designs exist to cover a testing range for round strand ropes of ø3 mm - ø150 mm, whilst flat ropes up to 500 mm wide can be accommodated. Data acquisition systems are also available. Typical applications are: hoisting ropes, towing and offshore mooring lines, lifting and ballast ropes, aerial ropeway and drilling ropes. See also Zawada NDT, Poland*.

3.15 LLOYDS BEAL, GREAT BRITAIN*

The Ropescan equipment, as shown in figure 3.3, was developed in the British Coal research laboratory at Bretby for inspecting mine-hoist locked coil wire ropes in coal mines. This equipment is now owned by Lloyds Beal Ltd., who offer rope inspection services. The electronics for this system have recently been "re-packaged" but with no functional change from the original analogue design. Poor electronic design does not do justice to the effective magnetic circuit and primary sensor system (Tytko et al., 1999). The equipment itself is not commercially available.

Figure 3.3
Ropescan sensor head and electronic set

3.16 MERASTER

See Zawada NDT, Poland*.

3.17 NDT TECHNOLOGIES, USA*

This company is owned and operated by Dr. Herbet Weischedel. The equipment (figure 3.4) has a good reputation, although research by Tytko et al., (1999) showed it to be less effective at identifying internal defects than two other instruments tested. However, in the results of tests presented by Dohm (1999), a superior performance was reported.

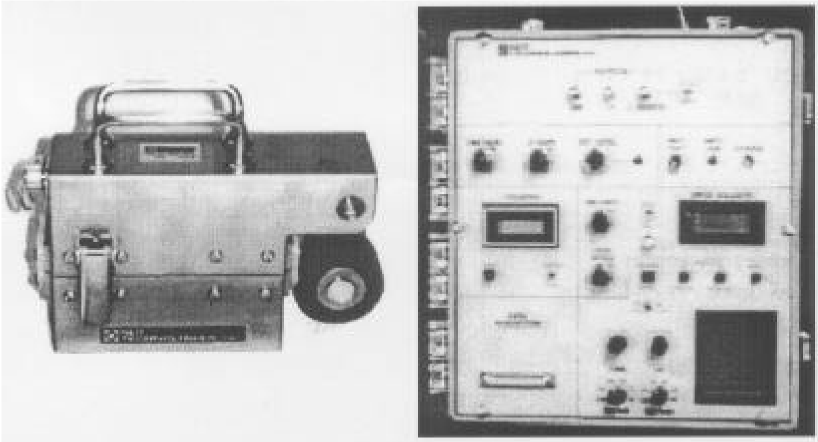

Figure 3.4
NDT Technologies sensor head LMA 125 and CC-03 (rev.A) signal console

3.18 RAU - DR. SWANEPOEL, SOUTH AFRICA

With support from Anglo American, Dr. Swanepoel at the Rand Africaans University in Pretoria, has designed a highly sophisticated magnetic NDT system which features field reversal achieved by two sets of magnets. This allows a much more effective area loss measuring system with stronger signal and consistent calibration. At present, it is only available in the RSA.

3.19 ROTESCO, CANADA*

This equipment (figure 3.5) was initially designed for mine hoist use in Canada, but has since expanded into all types of applications and rope constructions for use throughout the world. The company boasts over 30 years experience in the design, manufacture and operation of magnetic NDT equipment for wire ropes, and in the testing of steel wire ropes that are utilised in many applications.

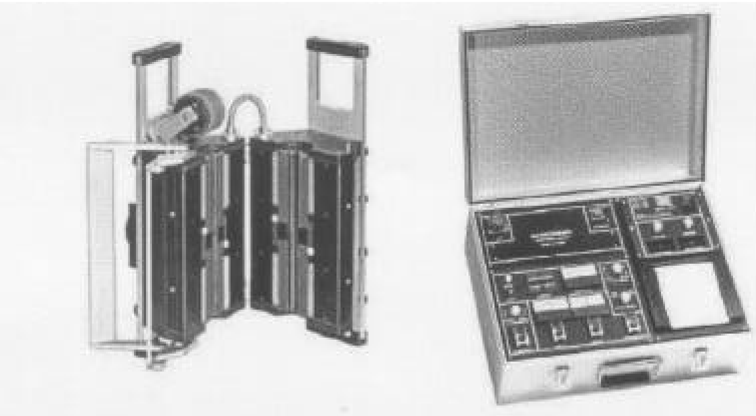

Figure 3.5
Rotesco sensor head R300-3 and console model 2C-TAG88M

Figure 3.6
Computerised Rotescograph console model 2D

Rotesco has also completed the development of the computerised Rotescograph console, Model 2D, shown in figure 3.6, above. The computerised Rotescograph incorporates a Notebook computer which controls the instrument and stores the data. The standard test heads cover the range of rope sizes between ø6 mm and ø63.5 mm, with specialist heads available outside this range.

3.20 SHANGHAI MARITIME UNIVERSITY, CHINA

No information available.

3.21 TECHNICAL UNIVERSITY STUTTGART, GERMANY

The Department of Rope Technology of the Institute of Mechanical Handling (Institute für Fördertechnik - IFT) was found in 1927, and has a history of research and teaching on the subject of rope applications and inspection. The IFT has nine different NDT test heads which cover a range of diameters ø8 mm to ø140 mm. Typical installations which are inspected using these heads are: aerial ropeways, bridge suspension cables, ship-lifts, cranes and lifts. Two sets of NDT equipment are marketed under license, which have operational diameters ø16 mm - ø40 mm or ø35 mm - ø60 mm. Recent developments include a system mentioned in section 2, of test head which has an annular array of two sets of 30 Hall effect sensors (Nussabaum, 1999). This, in combination with computerised processing of the data can provide a graphical representation of stray field around and along the rope which can separate closely spaced wire breaks. These instruments do not provide LMA measurements.

3.22 TÜV UK LTD., GERMANY

No information available.

3.23 VVUU, CZECH REPUBLIC

No information available.

3.24 WIRE ROPE TESTERS INC., USA

No information available.

3.25 ZAWADA NDT (REPRESENTING AGH, LRM AND MERASTER), POLAND

The company has close links with the University of Mining and Metallurgy at Kraków (AGH), where magnetic testing technology was developed from 1946. Since 1979, the technology has been marketed first as Meraster and now as Zawada NDT, and a series of testing heads have been developed. The standard product line covers rope diameters from ø8 mm - ø90 mm. A range designed for testing flat ropes is also available. The company also manufactures the MD120, which is a dedicated data acquisition and recording device (see figure 3.7).

More recently, Zawada NDT has started to represent all Polish manufacturers of NDT related equipment. Basing on MERASTER brand name products, Zawada NDT integrates into one system, various sensing heads, i.e. GP-series (Meraster) (see figure 3.7), GM-series (AGH), and LRM-MH-series (Laboratory Roman Martyna).

Meraster SA as a company is no longer a manufacturer (the company was finally liquidated in January 2000). At present, products named Meraster are supplied by both Zawada NDT and JTT Silesia, which is also represented by Zawada NDT.

Figure 3.7
GP-2S magnetic sensor head and MD120 digital recorder

3.26 ZEG - TYCHY, POLAND

No information available.

4. SURVEY OF SELECTED NDT EQUIPMENT MANUFACTURERS

Table 4.1
Generic parameters of NDT equipment surveyed

Equipment Manufacturer	Equipment	Rope sizes covered by product range (ø mm, hxw mm)	Technical paper (Y/N)	Method of magnetisation	Magnet type	Type & position of sensors	Parameters measured
AATS		UP to ø73 mm	N	Permanent magnets mounted axially around the rope, steel pole pieces at head ends to provide flux path	Nd-Fe-B	Coils - around pole pieces Saddle coils at centre of head Hall sensors - around circumference of the rope at the centre of head	Distance LF LMA
Health & Sherwood (Noranda/ CANMET)	Magnograph	Ø12 - ø65	Y	Permanent rare earth	Samarium cobalt	Individually temperature compensated Hall devices measuring magnetic flux passed through the rope (8 sensors) and in a differential magnetic circuit measuring flux leakage (4 sensors)	Rope travel mass/length LMA, LF head temp.
Intron	MH-24, MH-40, MH-64, MH-F/124 & 233	Ø6 - ø64 72-233x 11-38	Y	Permanent rare earth	Nd-Fe-B	Hall sensors, location commercially confidential.	Distance LF, LMA
Lloyds Beal	Ropescan	???	N	Permanent rare earth		DC main flux sensor coil with ferrous concentrator	LF, LMA
NDT Technologies	LMA series	Up to Ø150 mm	Y	Permanent rare earth	-	Coils - cum - integrators	Distance, LF LMA
Rotesco	R300-3 R225-3 R1125-2	Ø22.5 - Ø63.5 Ø13 - Ø44.5 Ø6 - Ø22.5	N	Permanent magnets	Nd-Fe-B	2 flux gate sensors in the magnetic assembly for LMA measurement, 2 inductive saddle coils for LF detection.	Distance, LF, LMA
Zawada NDT	GP - series GM - series LRM- MH - series	Ø8 - Ø85 Ø10 - Ø90 up to Ø165	Y	Permanent Permanent rare earth Permanent rare earth	Ferrite ND-Fe-B Nd-Fe-B	Coils for LF sensors, Hall generators for LMA sensing. Placed centrally with concentrators.	Various from Distance, LF, LMA, speed

Table 4.2
Physical dimensions, size and weight

Equipment Manufacturer	Equipment designation	Range of rope sizes (mm)	Rope speed (m/s)	Dimensions (mm)	Total mass (kg)
AATS	40 mm Inner Dia. 60 mm Inner Dia. 80 mm Inner Dia.	- ø38 - ø73 _	0-2.5	- 400x300x150 -	- 60(2x30) -
Heath & Sherwood Noranda/ CANMET	Magnograph ® II	ø12 - ø65	0 - 3.5	600x270x270	29
Intron	MH-6-24 MH-20-40 MH-40-64 MH-24-64 MH-F/124 (flat) MH-F/233 (flat)	ø6 - ø24 ø20 - ø40 ø40 - ø64 ø24 - ø64 (72-124)x38 (124-233)x38	0 - 1 0 - 2 0 - 2 0 - 2 0 - 1 0 - 1	235x230x64 330x205x190 330x235x190 330x235x190 285x220x225 325x300x152	3 8 15 15 9 23
Lloyds Beal	Ropescan	???	???	~600x300x300	~30
NDT Technologies	LMA-75 LMA-125 LMA-275 L LMA-250 LMA-300 LMA-350/325 LMA-400 larger sizes on request	up to ø19 up to ø32 up to ø45 up to ø64 up to ø76 up to ø89/83 up to ø102 up to ø150	0.003 - 3 0.003 - 3 0.003 - 3 - 0.003 - 3 - - -	203x114x38 254x152x76 508x76x203 - 330x127x254 - - -	2.7 8 16 - 36 - - -
Rotesco	R300-3 R225-3 R1125-2	ø22.5 - ø63.5 ø13 - ø44.5 ø6 -ø22.5	0.05 - 4	530x240x240 480x110x270 250x60x230	32 22.7 5.4
Zawada NDT	GP - 3Arh GP - 2Sh GM - 60h GP - 1h LRM-MH - 120 LRM-MH - 180	ø10 - ø30 ø20 - ø60 ø20 - ø60 ø30 - ø85 ø50 - ø100 ø100 - ø165	0.05 - 10	400x88x150 600x192x192 350x250x250 630x224x224 - 1100x470x470	18 55 35 66 - 120

Table 4.3
Recording technology

Equipment Manufacturer	Recorder including (Y/N)	Model of recorder	Type of recorder	Weight (kg)	Chart axis (Rope position or time)
AATS	Y	_	computer/chart		rope distance
Heath & Sherwood Noranda/ CANMET	Y		computer	9	rope distance
Intron	N	Graphtec WR7300/7400 (optional)	Strip chart recorder	7.4/6.3	rope distance
Lloyds Beal	N	-	Gould strip chart	-	time and rope distance markers
NDT Technologies	Y	CC-03, Rev. A	Digital recording onto PCMCIA type card, thermal strip recorder built in	9	time and rope distance markers
Rotesco	Y	2C-TAG88M-AstroMed AG400 2D - computer hard drive and AstroMed AG400	AG400 - dual channel thermal digital chart recorder Computer hard drive standard	chart recorder and hard drive built in total 22	Synchronous speed-rope position Asynchronous speed-time
Zawada NDT	Y	MD120B	Digital recording onto PCMCIA memory card, and thermal digital recorder built in	13	rope distance

Table 4.4
Computing requirements

Equipment Manufacturer	Computing requirements	Power supply required
AATS	Computer with data acquisition card and custom written software	Built in batteries (lasting 3+hours.)
Heath & Sherwood Noranda/CANMET	Dedicated computer and custom made software included	90 - 240 V AC 50/60 Hz, 100 VA max.
Intron	IBM PC, 16 MB, Pentium 100, Windows 95/98NT, RS-232, Original software WINTROS	3 AA rechargeable batteries, 220 V/50 Hz adapter
Lloyds Beal	No output for data acquisition	???
NDS Technologies	Notebook computer, MS Excel, A to D converter and data acquisition software, (NDS_Care™ Computer-Aided Rope Evaluation)	Batteries, battery charger
Rotesco	2D - Minimum requirements CPU - Pentium 233MHz RAM-64 MB Operating system - DOS v5.0 plus Windows95 Data Acquisition Hardware - National Instruments DAQPAD-1200	85 - 250 V AC, 47-63 Hz 250 VA max. Internal battery optional Connections for 12 V DC external battery
Zawada NDT	486 or Pentium, Windows 95/98 or DOS options Interfacing hardware: PCMCIA/PC card slot Software supplied, depending on hardware	

Table 4.5
Accuracy/Sensitivity

Equipment Manufacturer	Equipment	Range of rope sizes (mm)	LF (% rope CSA)	LMA (% rope CSA)	LMA threshold* length (mm)
AATS	40 mm Inner Dia. 60 mm Inner Dia. 80 mm Inner Dia.	- ø38 - ø73			Claimed to be 5
Heath & Sherwood (Noranda/CANMET)	Magnograph ®II	ø12 - ø65			25 - 50
Intron	MH-6-24 MH-20-40 MH-40-64 MH-24-64 MH-F/124 (flat) MH-F/233 (flat)	ø6 - ø24 ø20 - ø40 ø40 - ø64 ø24 - ø64 (72-124)x38 (124-233)x38	1 1 0.5 1 - -	2 2 1 1 2 2	250 500 500 500 500 500
Lloyds Beal	Ropescan	???	???	???	~10
NDS Technologies	LMA-75 LMA-125 LMA-175 L LMA-250 LMA-300 LMA-350/325 LMA-400	up to ø19 up to ø32 up to ø45 up to ø64 up to ø76 up to 89/83 up to 102			20 - 50
Rotesco	R300-3 R225-3 R1125-2	ø22.5 - ø63.5 ø13 - ø44.5 ø6 - ø22.5	0.05	0.1	530* 480* 250*
Zawada NDT	GP - 2Sh GM - 60h GP - 1h LRM-MH - 120 LMR-MH - 180 GP - 3Arh	ø20 - ø60 ø20 - ø60 ø30 - ø85 ø50 - ø100 ø100 - ø165 ø10 - ø30	0.2	0.05 0.05 0.05	30 - 50

*Minimum consistent defect length to give accurate results.

** Rotesco employ an algorithm to compensate for the LMA threshold length

Table 4.6
Calibration and interpretation of the output signal

Equipment Manufacturer	
AATS	A rod of known area is inserted as close to the rope surface as possible. The instrument is calibrated in "calibration mode" in the software package, which requires the user to enter values for deflection measured on the screen and the actual area gain.
Heath & Sherwood (Noranda/CANMET)	Calibration and data analysis features of the software is claimed to be extremely versatile. For detailed description refer to document by Geller & Kitzinger (1996).
Intron	Three calibration methods are suggested, all are based on ASTM E1571, and conducted on the rope to be examined. Software (WINTROS - based on Windows 95/98NT) is available to download test data to a PC from the data logger, process the test data, print LMA and LF traces and prepare reports containing compressed LMA and LF data.
Lloyds Beal	"Rod" calibration used on site.
NDT Technologies	Calibration should be performed in accordance with ASTEM E1571. The process of calibration may be aided by use of NDT_Care™ software. A signal enhancement algorithm is described by Weischedel (no date). NDT_Care™ software can make the trace independent of the rope speed.
Rotesco	The appropriate calibrated value for the LMA sensitivity control for a particular rope diameter and construction is obtained from the "calibration table" in the Operating manual provided with the instrument (the instrument is fully calibrated before it is shipped). The amplitude of the LF channel would be set by the operator, so that in a good section of rope, the LF trace would be 2 - 3 mm in width. A trial run using the rope to be tested will help determine appropriate settings. The computerised model (2D) includes software that calibrates the instrument.
Zawada NDT	Calibration of the LF channels is performed by the manufacturer. Calibration of the LMA channel may be performed with a reference specimen (supplied with the test head - a steel rod) and should be performed just before the rope test when the rope is in the sensing head. Real time chart recording on paper is a basic operation of the MD120. Additionally, (or instead of this) digital data acquisition may be used by employing a PCMCIA memory card. Data thus obtained may be copied to a computer hard disc for processing. Browsing software is available, which also includes a data export facility, allowing data to be exported to software such as Microsoft Excel or Matlab.

Table 4.7
After sales service and support

Equipment Manufacturer	
AATS	Currently no agents are in place, as no units have been sold to the UK. Previous models sold outside the borders of South Africa were returned for re-calibration and/or servicing.
Heath & Sherwood (Noranda/CANMET)	Contact the manufacturer in Canada for service.
Intron	It is possible to arrange for a distributor of Intron products in the UK, as well as in other countries. In these instances, "Intron Plus" will provide prompt support, personnel training, spare parts, etc. Currently there is no support outside the URS.
Lloyds Beal	Not applicable
NDT Technologies	Unlimited telephone and email support after purchase. Return to USA for service/repair.
Rotesco	A training course is offered in the use of the equipment. It is recommended that this takes place on site. There is a warranty with the Rotescograph, the length of which depends upon the failed component and cause of failure.
Zawada NDT	Service is available: Return to Poland for repair within two weeks including express shipping period; or, service is available on site within one week if urgent. Customer support available: Training at AGH University, Kraków (typically 5 days) on site tutoring; and, life time free email or fax guidance (answer within one or two days) One year guarantee on equipment

5. DISCUSSION AND CONCLUSIONS

There is a limited range of wire rope NDT instruments which are likely to be used in the UK, but there are no agreed performance specifications for such instruments, and all have their own particular features, advantages and disadvantages. All these instruments have the capability to provide an effective enhancement to the reliability of rope inspection, but these benefits are conditional upon the operator's competence, experience and ability, rather than the performance of the instrument.

It is essential that the operator of the NDT device understands the principles of operation of that particular device and is familiar with the limitations of the equipment. This should include sensitivity to wire breaks (taking account of gap and location in cross section); rope construction (especially with regards to multi-strand ropes and internal damage); and, the geometrical implication of LMA measurements and threshold length for accurate LMA.

It is also important that inspectors are able to use visual observation of the type and distribution of damage in combination with NDT measurements to infer rope integrity with respect to future use. LMA signals must not be treated *per se* as discard criteria, particularly because of the difference between "normal" (= snapshot) area measurements and the "effective" (i.e. cumulative) loss to load bearing area.

Attention should also be paid to the comparison of NDT results with that obtained from the signature when the rope was new, and subsequent tests. This comparison will give an indication of trends regarding certain defects and could be useful in determining periods between NDT inspections, especially for ropes used in safety critical applications.

Calibration processes need to be understood especially in relation to whether "static" or "dynamic". NDT operators need to be aware of other influences (such as rope tension or external magnetic fields) which can affect calibration.

The level of understanding required for effective and reliable rope inspection assisted by NDT goes beyond the initial guidance given in instructions provided by the instrument manufacturers.

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