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TITLE: TEST AND EVALUATION OF THE MT 75  
ROPE TESTER - A HAND-HELD NDT WIRE-  
ROPE INSPECTION DEVICE

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AUTHOR: L. D. Underbakke

DATE: March 1983

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PROGRAM NO: YO995-01-004-620

# NOTE

NAVAL CIVIL ENGINEERING LABORATORY  
PORT HUENEME, CALIFORNIA 93043

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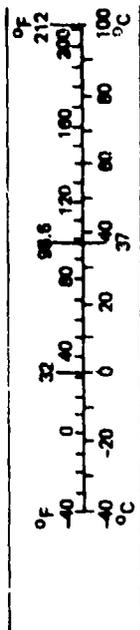
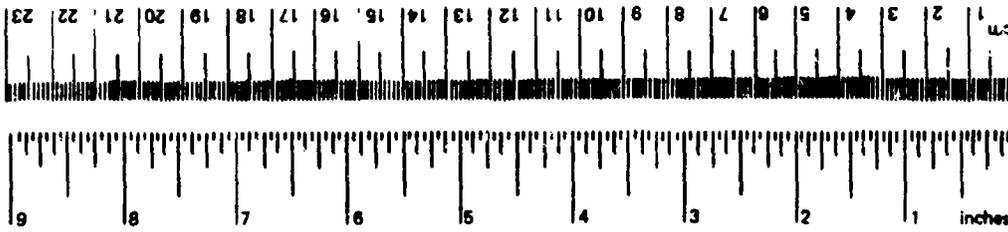
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		<b>LENGTH</b>		
in	inches	2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		<b>AREA</b>		
in <sup>2</sup>	square inches	6.5	square centimeters	cm <sup>2</sup>
ft <sup>2</sup>	square feet	0.09	square meters	m <sup>2</sup>
yd <sup>2</sup>	square yards	0.8	square meters	m <sup>2</sup>
mi <sup>2</sup>	square miles	2.6	square kilometers	km <sup>2</sup>
	acres	0.4	hectares	ha
		<b>MASS (weight)</b>		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2,000 lb)	0.9	tonnes	t
		<b>VOLUME</b>		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft <sup>3</sup>	cubic feet	0.03	cubic meters	m <sup>3</sup>
yd <sup>3</sup>	cubic yards	0.76	cubic meters	m <sup>3</sup>
		<b>TEMPERATURE (exact)</b>		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

Approximate Conversions from Metric Measures

When You Know	Multiply by	To Find	Symbol
	<b>LENGTH</b>		
millimeters	0.04	inches	in
centimeters	0.4	inches	in
meters	3.3	feet	ft
meters	1.1	yards	yd
kilometers	0.6	miles	mi
	<b>AREA</b>		
square centimeters	0.16	square inches	in <sup>2</sup>
square meters	1.2	square yards	yd <sup>2</sup>
square kilometers	0.4	square miles	mi <sup>2</sup>
hectares (10,000 m <sup>2</sup> )	2.5	acres	
	<b>MASS (weight)</b>		
grams	0.035	ounces	oz
kilograms	2.2	pounds	lb
tonnes (1,000 kg)	1.1	short tons	
	<b>VOLUME</b>		
milliliters	0.03	fluid ounces	fl oz
liters	2.1	pints	pt
liters	1.06	quarts	qt
liters	0.26	gallons	gal
cubic meters	35	cubic feet	ft <sup>3</sup>
cubic meters	1.3	cubic yards	yd <sup>3</sup>
	<b>TEMPERATURE (exact)</b>		
Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



\* 1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price \$2.25, SD Catalog No. C13.10:286.

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L. D. Underbakke  
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## INTRODUCTION

The Naval Civil Engineering Laboratory (NCEL) under Naval Facilities Engineering Command (NAVFAC) and Bureau of Mines joint sponsorship has investigated nondestructive test (NDT) equipment for the inspection of wire rope. Conventional NDT equipment utilizes separate AC and DC units to detect loss of metallic area (LMA) and local faults (LF), respectively. A representative device was tested and compared to a newly developed type of NDT equipment that is a unitized AC/DC device. The two devices were compared considering operational capabilities and ease of use. The Magnograph<sup>TM</sup> equipment, the unitized AC/DC device, was recommended for use by the Navy. It is more versatile than the separate AC and DC units, as both LF and LMA data are recorded simultaneously on a 2-channel, brush-chart recorder and on a cassette tape. The Magnograph<sup>TM</sup> uses Hall effect sensors, which permit the wire rope speeds to vary from 0 fpm to over 800 fpm without any change in the reliability of the recorded LF and LMA data\*. Figure 1 shows the Magnograph<sup>TM</sup> in operation.

As a result of extensive field testing of these NDT devices, inspectors stated that a need existed for a small, lightweight, and inexpensive NDT wire rope inspection device. This inspection device would be used to replace the "rag and visual" method for interim or preliminary inspections when there is a question of broken wires.

NCEL, under NAVFAC sponsorship, conducted a survey to find a NDT wire rope inspection device that met these criteria. As a result of this survey, the MT 75 Rope Tester was selected for test and evaluation (Figure 2). This report presents the results of the test and the evaluation program conducted on the MT 75 to determine its characteristics before Navy field activities acquire the units and start NDT wire rope inspection programs.

## MT 75 ROPE TESTER

The MT 75 is a hand-held NDT wire rope inspection device that uses the DC method of detection. The MT 75 is 6 inches long, 8-1/2 inches wide, 1-1/2 inches deep, and weighs about 5 pounds.

The DC method of detection is a well-established method for detecting local faults such as broken wires. The DC NDT wire rope inspection equipment uses strong permanent magnets to magnetically saturate the wire rope to be inspected; this causes a magnetic flux field to radiate from the wire rope into the surrounding air. Search coils are positioned close to the wire rope inside this flux field. As the wire rope is

\*Naval Civil Engineering Laboratory. Technical Note N-1639: Test and evaluation of the Magnograph<sup>TM</sup> unit - a nondestructive wire rope tester, by L. D. Underbakke. Port Hueneme, Calif., July 1982.

moved, the flux leakage intersects the search coils and if there is an anomaly in the wire rope, such as a broken wire, corrosion, pitting, etc., the flux field is distorted. This induces a signal in the search coils which is then conditioned and displayed. In the case of the MT 75 the data are transmitted to headphones as "clicks" and "crackles". The data can also be recorded on a 1-channel, brush-type recorder for a permanent record. The recorder, however, does not come with the MT 75 and must be obtained elsewhere.

## LABORATORY TESTING

### Test Procedures

New wire ropes, of 6x25 right-regular-lay-fiber-core construction, with diameters of 1/2 and 3/4 inch were used for the laboratory testing. They were modified with simulated broken wires. The gaps in the crown wires were made with a special chisel that produced clean square breaks. Gap spacings were initially less than 1/128th of an inch and were increased, by filing, in 1/16-inch increments to a maximum of 3/8 inch.

NCEL's wire rope test track was used to move the test wire rope through the MT 75. The test track was designed to accommodate 100-foot loops of wire rope from 1/8 to 2-1/2 inches in diameter. The speed of the wire rope was changed by a variable speed transmission powered by a 1-3/4 horsepower electric motor. The wire rope speeds were varied from 0 to over 800 fpm. Each end support consisted of three 1-foot diameter sheaves that simulated a 4-foot diameter sheave. The larger sheave diameters were needed for wire rope with larger diameters to provide adequate bend radius.

### Gap Configuration

A broken wire can, depending on the cause, have various end configurations. For example, a fatigue break produces square ends, a tensile break produces necked down ends, and a shear break produces angular ends. The various types of gap configurations are shown in Figure 3. A series of tests were conducted to determine the effective gap size for all four types of configurations. The results indicate that the signal loudness depended on the clear gap space size in the longitudinal direction.

### Gap Orientation

Gap orientation is the location of a broken wire or any other abnormality in relation to the two halves of the search coils located 180 degrees apart in the MT 75. In these tests a wire break could be directly under a search coil or up to 90 degrees from the coil. To determine the effect of gap orientation on signal size, a 1/2-inch wire rope, with two simulated wire breaks about 3 yards apart, was run on the wire rope test track. The broken wires maintained the same orientation after each completed loop. Break A was a broken crown wire and break B was a broken filler wire. The MT 75 was then rotated from 0 to 90 degrees in 22.5-degree increments. The signals were compared to observe any

changes in the signal size. Figure 4 shows that the signal size changed from a strong signal to a weak signal. The signal size for breaks A and B differ because of their orientation. The amplitude of the spike in the signal trace is related to the loudness of the click. The higher the amplitude of the spike the louder the click.

### Gap Space

A series of tests were conducted on new wire rope in order to determine broken wire signal size, as a function of longitudinal air-gap space.

These tests were conducted on 1/2- and 3/4-inch diameter wire ropes. A rope speed of about 200 fpm was maintained for all the tests. Results showed that gaps of 1/128th inch or less do not always produce clicks. Gap spaces of greater than 1/128 have a detection rate that is much higher. Test data are shown in Figure 5.

Results for gap spaces greater than 1/4 inch are not given because the signal size did not increase after the 1/4-inch gap space was reached. It must be realized that the only signal output from the MT 75 Rope Tester, as provided by the manufacturer, is clicks and crackles in the headphones. The signal size in Figure 6 represents the loudness of the click, although some clicks in the headphones did not produce a signal on the brush-chart recorder.

New wire rope is usually clear of background noise. However, it tends to increase when surface corrosion, internal and external wear, peening, etc. begin to develop. As wire ropes approach the end of their useful life this background noise tends to mask the broken wire signals, making detection much harder. If the background noise becomes great it can completely mask the broken wire signal. However, based on field test results using several NDT devices and data supplied by the manufacturers, background noise is a good indication of the overall condition of the wire rope. When it becomes loud (continuous "thundering") enough to mask the broken wire signals, the wire rope has degraded to a point where it should be considered for replacement.

### Rope Speed

The signal generated by the search coils, when the broken wires create a magnetic flux leakage field, is normally proportional to rope speed in DC devices. However, the MT 75 rope tester has a preamplifier and speed compensation circuit, which amplifies the search coil signal and equalizes its strength allowing the wire rope to move as slow as 5 fpm or as fast as 500 fpm with no significant change in signal strength (Figure 7).

Wire rope speeds greater than 200 fpm, while allowing good quality signal pickup, are hazardous because the hand-held unit can be pulled from the inspector's hands, or the inspector could be pulled with the rope if it snags the MT 75. The MT 75 can be removed from the moving wire rope by pulling perpendicular to the axis of the wire rope. If the MT 75 is moved to an angle which is not perpendicular from the wire rope, it is difficult to pull free. A lanyard attachment from the equipment to the MT 75 is recommended for the inspector's safety if rope speeds exceed 200 fpm.

## Rope Guides

The MT 75 is designed for use on wire ropes from 3/8- to 3/4-inch in diameter by using different size rope guides. The rope guides perform a two-fold function: (1) they concentrate, in the wire rope, the magnetic field generated by the strong permanent magnets, and (2) they guide the rope through the search coils. A test was conducted on 1/2-inch wire rope to observe the effects of tight and loose fit on each of the search coil sizes. The search coil is available in four sizes: 3/8, 1/2, 5/8, and 3/4 inch. The test results showed that the best signals occurred when the search coil's fit was as snug as possible without it touching the wire rope. Figure 8 shows that the closer fitting coil (1/2-inch diam) produces the best signal-to-background noise ratio.

## FIELD TESTING

Tests were performed to evaluate the MT 75's field inspection capabilities. The first test was on a load line of a 35-ton truck crane which was recently inspected by the visual-rag technique shown in Figure 9. The MT 75 shown in (Figure 10) detected broken wires and an area of corrosion which were missed on the earlier inspection. Several other small capacity cranes were also inspected with similar findings. Inspection time was on the order of one sixth that required using the "visual and rag" method. Some of this time was used for a close inspection of those areas which were in the worst condition. Wire ropes on overhead cranes, lift slings, winch wires and elevators were also tested.

The MT 75 was loaned to a Public Works inspection division for two months. The inspectors were given several hours of training on its use and signal interpretation. After the two months, the inspectors provided a brief evaluation of the device. The consensus was that the device was much faster than the standard method. About 8 hours were required for a "visual and rag" inspection of truck crane and only 1.5 hours for the MT 75. Because of the MT 75's light weight, it is easy to handle and the inspectors were inclined to carry it with them and use it in their daily inspections.

## CONCLUSIONS

1. The MT 75 provides useful information than cannot be obtained from rag and visual inspection methods, e.g., internal broken wires, corrosion pitting, peening, and nicking.
2. Field tests have shown that the time required for wire rope inspections may be reduced by as much as 80% over that required by the visual and rag method
3. The wire rope can be inspected at higher rope speeds and only those areas that "sound" bad need to be inspected closely.

4. The MT 75 is an effective "electronic rag" which complements the larger, more sophisticated NDT wire rope inspection devices on the market.

#### RECOMMENDATIONS

1. The MT 75 is recommended for use with the Magnograph<sup>TM</sup>. Its value lies in its ability to inspect small diameter short length wire ropes rapidly, while providing information not acquired by the visual and rag method.

2. The MT 75 should be modified to have an easily detachable sensor head. It then could be used either (a) as a hand-held unit or (b) as a unit attached to the equipment on which the wire rope is being inspected.

3. The electronic section (connected to the sensor head by an instrument wire) could be carried by a strap over the inspector's shoulder. This would reduce the danger of the inspector being in close proximity with the moving wire rope and reduce the strain on the inspector during a long inspection.

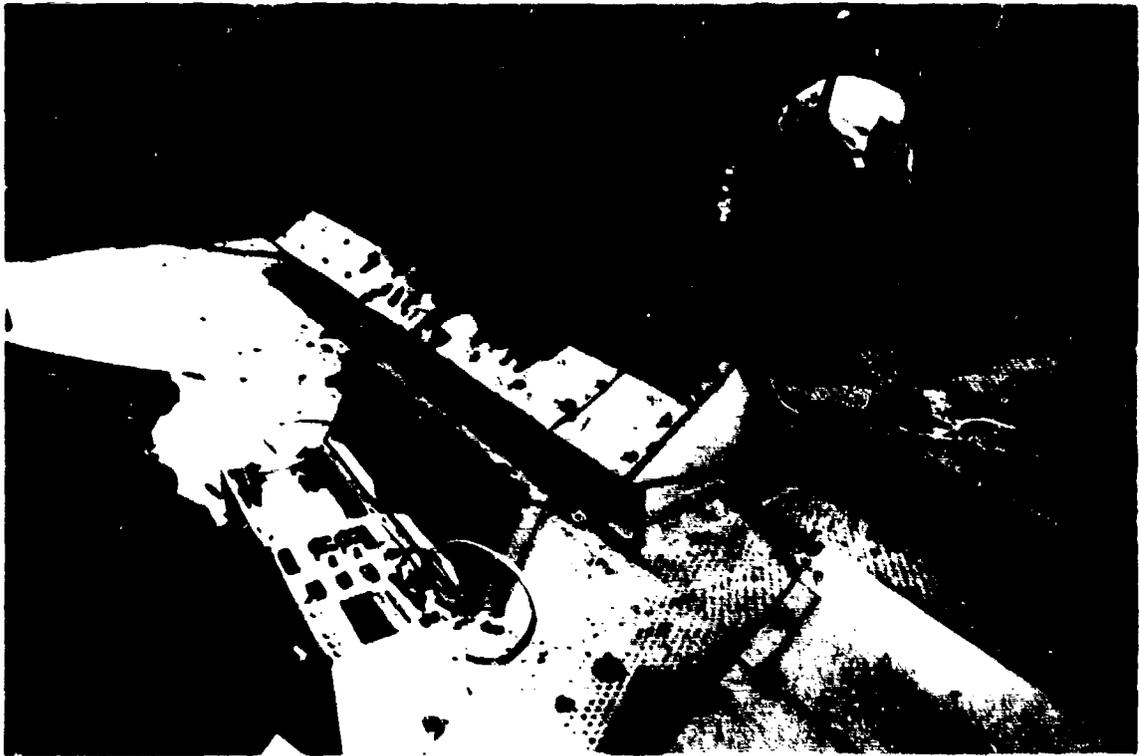


Figure 1. Wire rope being inspected using the Magnograph™.

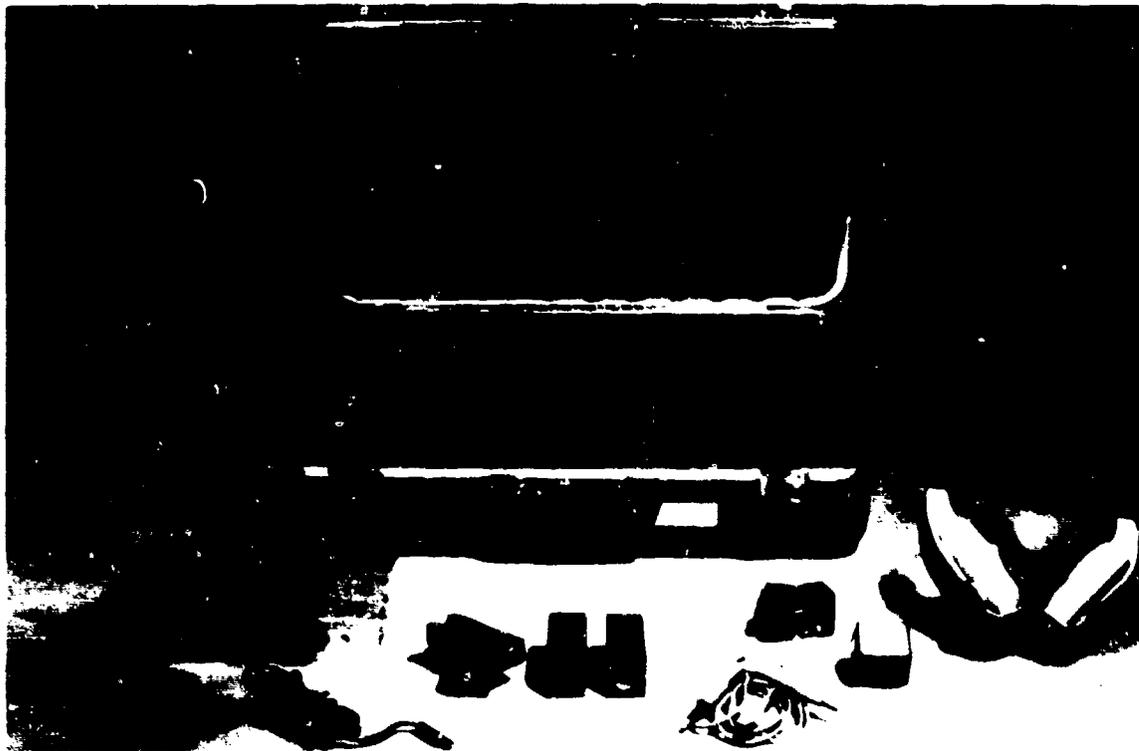
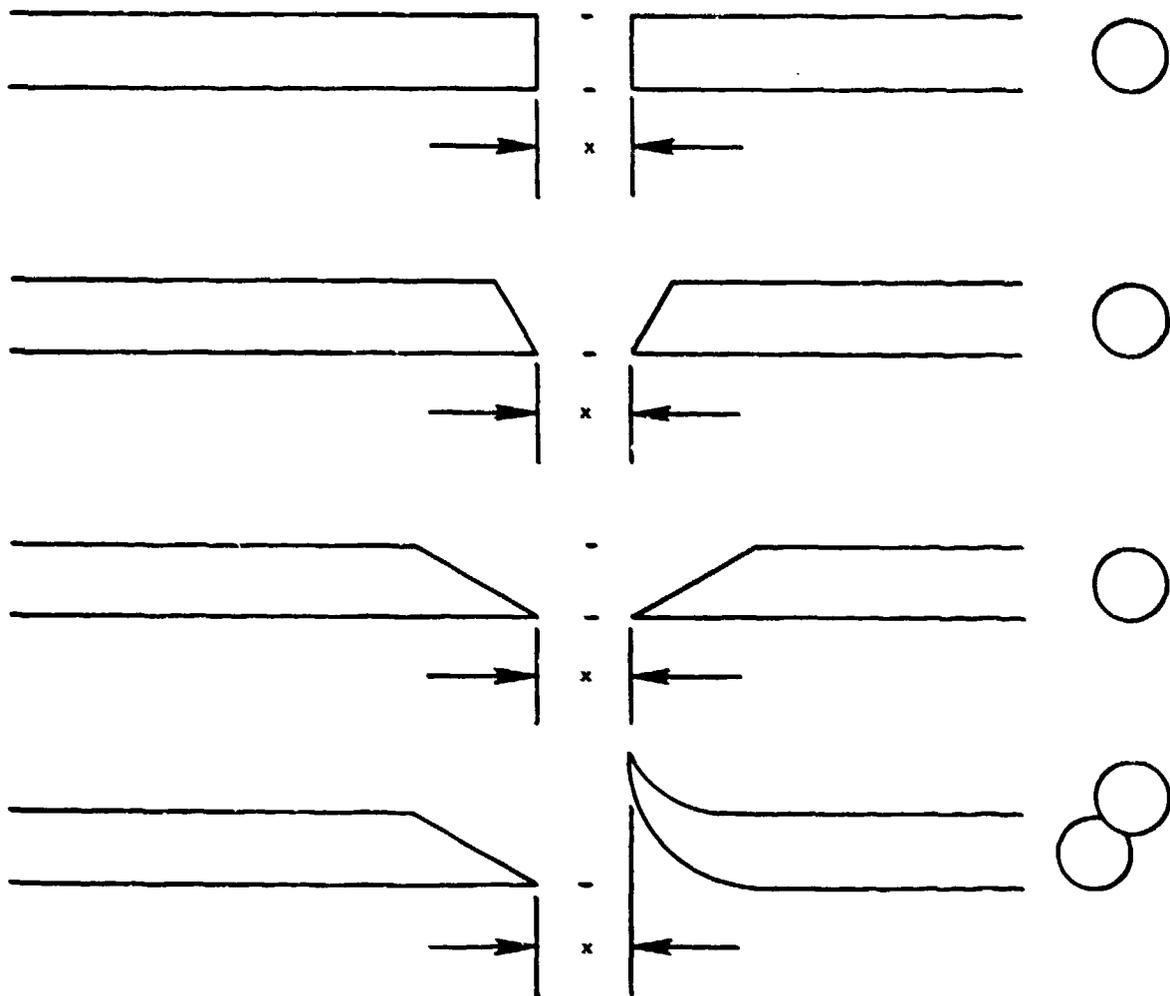


Figure 2. MT 75 wire rope inspection device.



x = clear air gap space in longitudinal direction of wire rope

Figure 3. Gap configuration for wire rope.

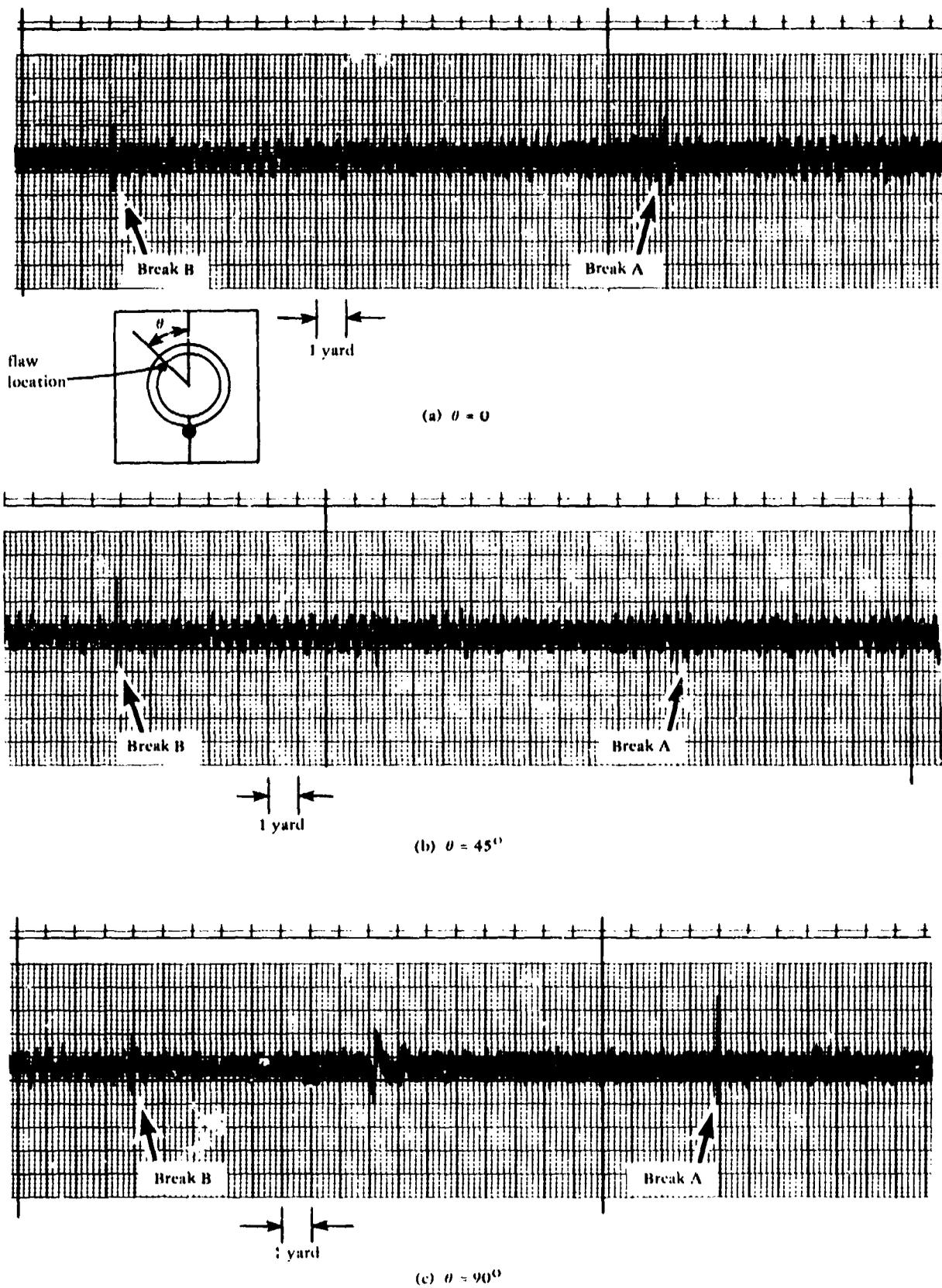
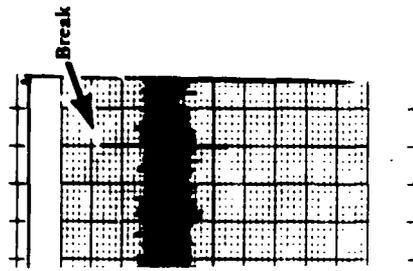
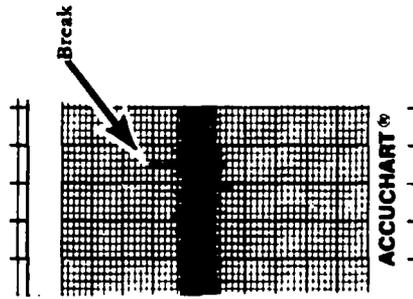


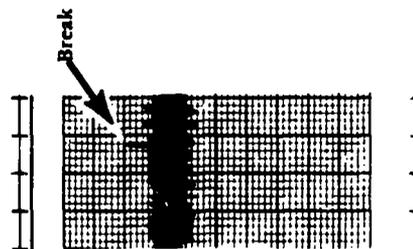
Figure 4. The effect of sensor head rotated on signal strength using a 1/2-inch diameter wire rope.



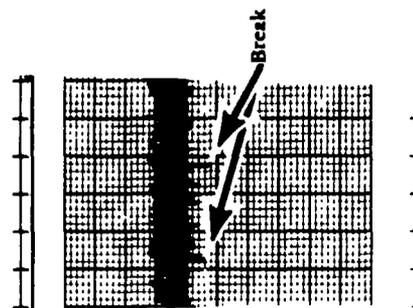
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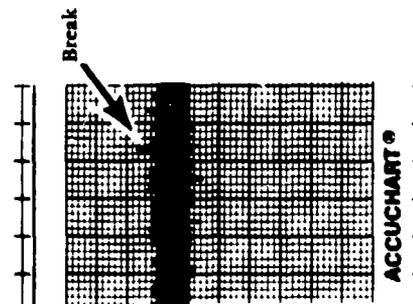
3/16 in.



1/8 in.

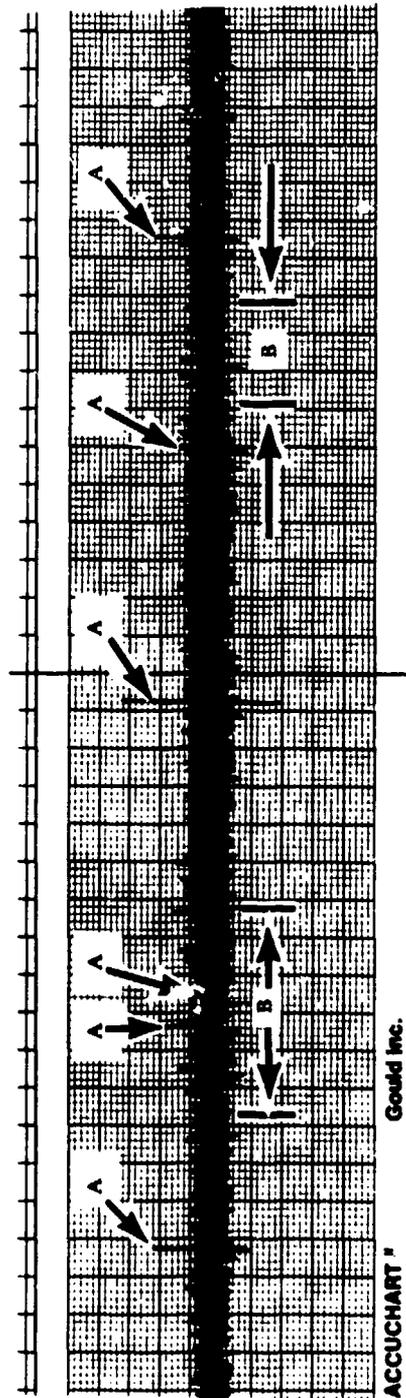


1/16 in.



1/128 in.

Figure 5. Broken wire signal size as a function of gap size for 1/2-inch diameter wire rope. Tests at equal rope speeds.



A = Broken wires

B = Areas of corrosion pitting

Figure 6. Data from a field inspection of a 1/2-inch diameter wire rope.

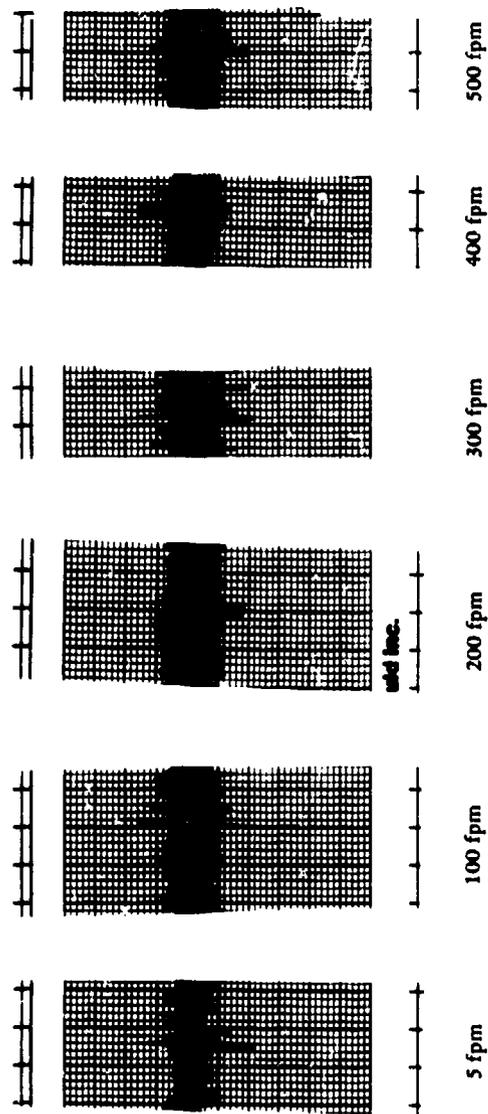
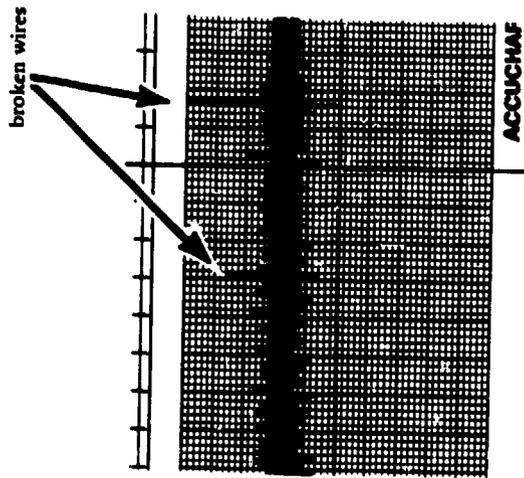
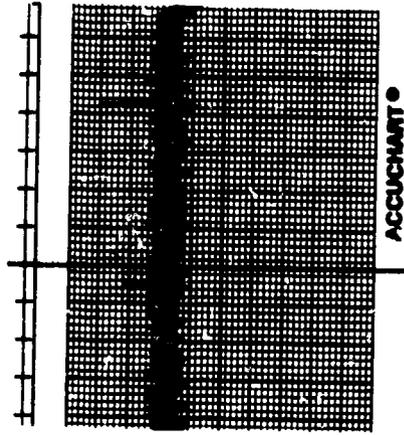


Figure 7. Signal amplitude remains constant as line speed increases. (Recorded at a constant chart speed.)



signal amplitude with 1/2 inch diameter search coil



signal amplitude with 3/4 inch diameter search coil

Figure 8. An oversized search coil reduces the signal amplitude (1/2-inch diameter wire rope).

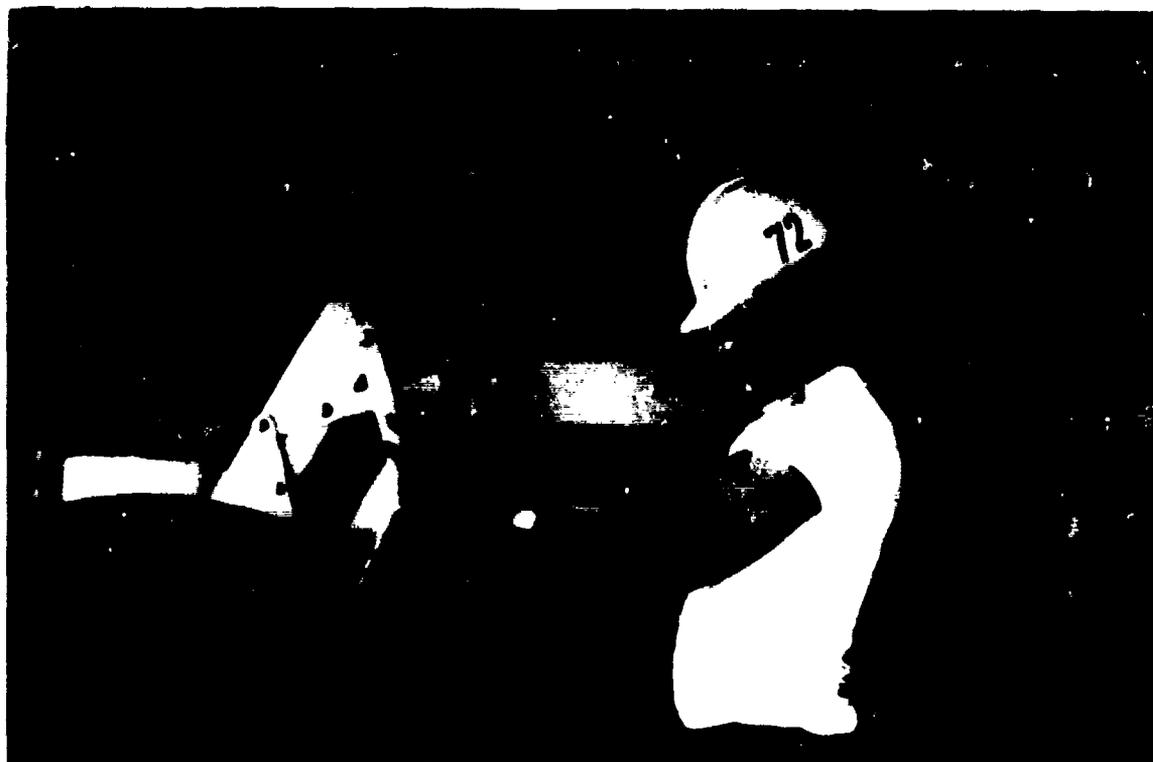
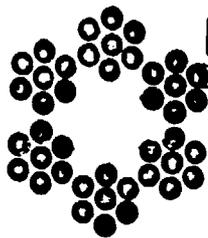


Figure 9. Inspector using the "rag and visual" inspection method.



Figure 10. Inspector using the MT 75 rope tester.



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Appendix

**MT 75**

**ROPE TESTER**

**Operation and Maintenance  
Manual**

DESCRIPTION

APPLICATION

The DC Rope Tester MT-75 is used in the field to test for and detect external and internal broken wires, broken cores, deformations, abrasion and corrosion in steel wire ropes. It was developed particularly for routine testing of wire ropes in mining, industrial and military applications where safety and hence the detection of anomalies is of paramount importance.

OPERATION

A section of the steel rope is magnetically saturated in the longitudinal direction by a strong permanent magnet. Where there is an inhomogeneity in the rope such as a broken wire, a broken core, corrosion or abrasion, the magnetic flux is distorted and leakage flux radiates from the rope into the surrounding air space. Test coils are positioned close to the rope to sense the leakage flux. The rope is moved which causes the leakage flux to intersect the coils. The changing intersecting flux induces signals in the coils. The signals are conditioned by electronic circuitry and aurally and/or visually displayed by headphones or a recorder.

The Rope Tester MT-75 consists of the following items:

- 1 ea. Tester Assembly comprising
  - 1 ea. Magnet Assembly
  - 1 ea. Signal Conditioning Circuitry
  - 1 ea. Instrument Case
  
- 2 ea. Hinged Sensors
- 8 ea. Rope Guides
- 1 ea. Headphone Set
- 1 ea. Carrying Case
- 1 ea. Operation and Maintenance Manual

## DESCRIPTION

Fig.1 shows the MT-75 DC Rope Tester with Headphones attached. The tester assembly including headphones is stored in a compact Carrying Case (not shown).

In operation, the Tester Assembly attaches to the rope by means of guide shoes to detect flaws as the rope moves at rates from 5 fpm to high speeds of 500 fpm. Rope flaws are indicated by clicking sounds in the Headphones. The fault signal can also be recorded by a strip chart recorder or a cassette recorder. Different rope flaws can then be identified from their characteristic chart patterns.

The Rope Tester operates from replaceable or rechargeable 9 V batteries.

### FUNCTION OF SIGNAL CONDITIONING CIRCUITS

Fig.2 shows a Functional Block Diagram of the instrument. The signal conditioning circuitry comprises the following components:

1. PREAMPLIFIER AND SPEED COMPENSATION CIRCUIT - This circuit amplifies the sense coil signal. At the same time, it equalizes the signal to make its amplitude independent of rope test speed (at speeds greater than 5 fpm).
2. DETECTION LEVEL CIRCUIT - This circuit controls the threshold level at which fault signals are detected.
3. SIGNAL ENHANCER CIRCUIT - This circuit controls the extent to which that part of the test signal above the detection level is enhanced and that part below the detection level is suppressed.

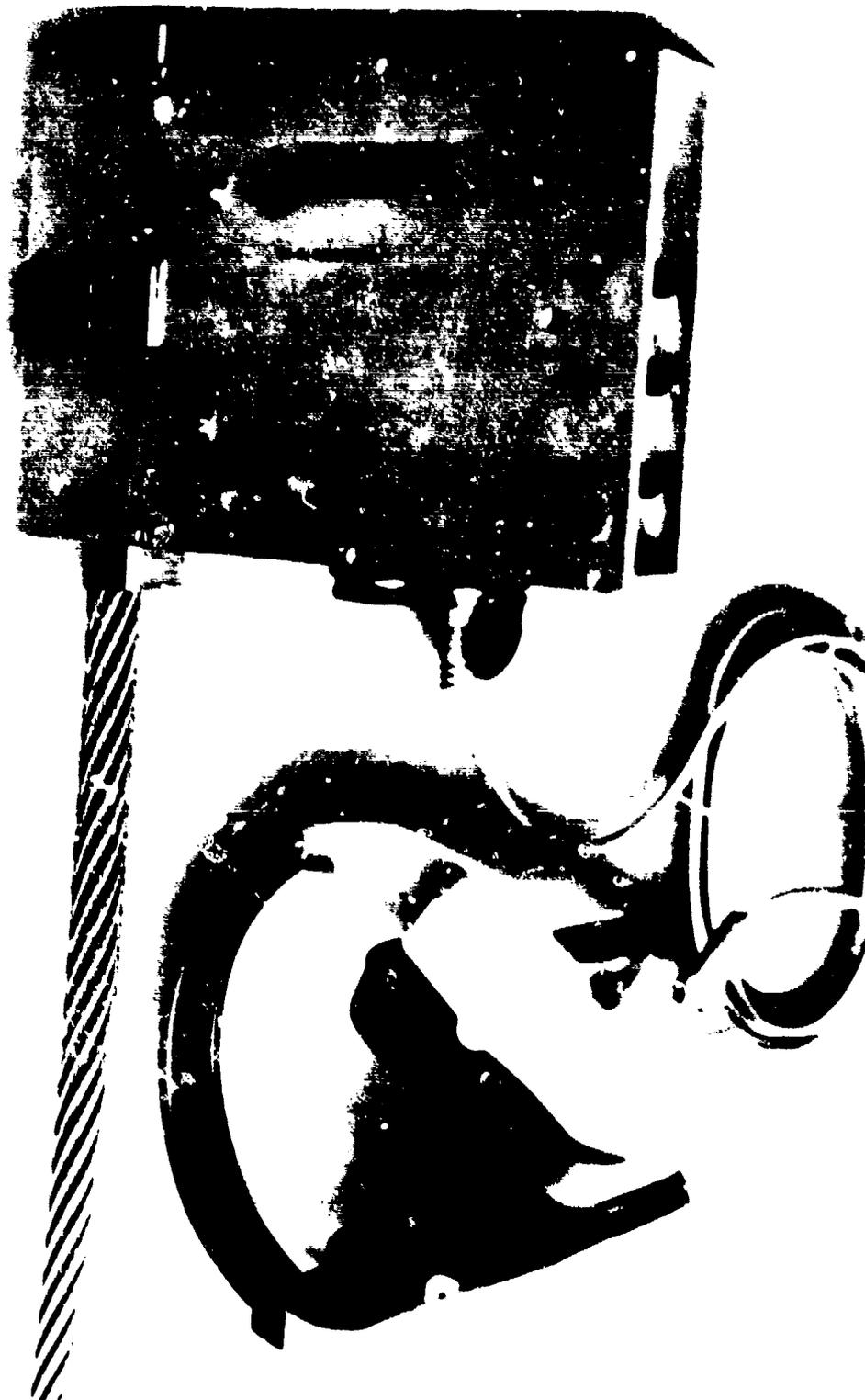


Figure 1. MT-75 rope tester.

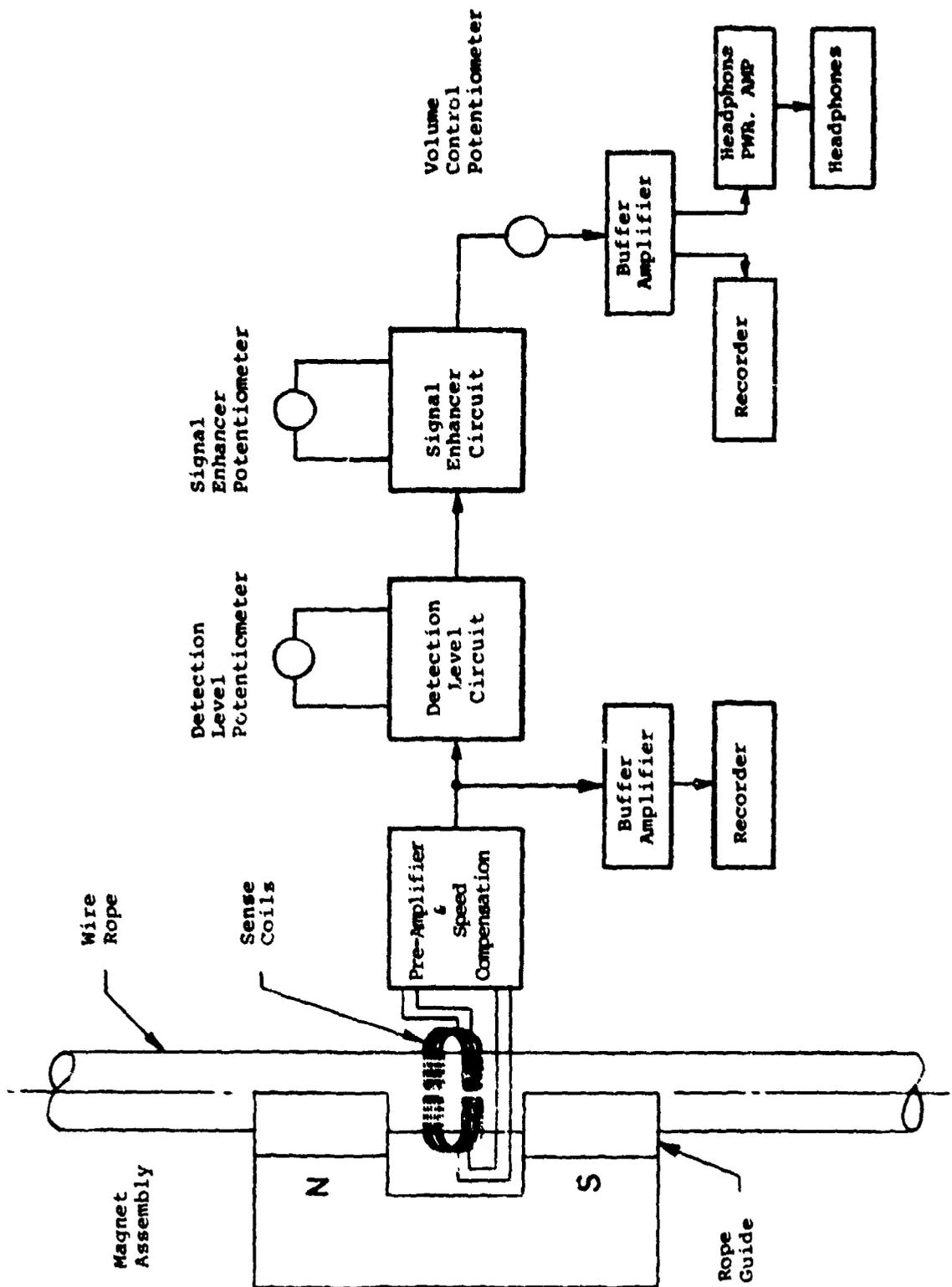


Figure 2. Functional block diagram.

DESCRIPTION

4. BUFFER AMPLIFIERS - The buffer amplifiers amplify the test signals to a level necessary for driving headphones or a recorder.
  
5. HEADPHONE POWER AMPLIFIER - This amplifier, built into the headphones, amplifies the test signal to a power level necessary for driving the headphone speakers.

S P E C I F I C A T I O N S

Input Limits

Rope Speed: 5 to 500 fpm

Faults Sensed: External and internal broken wires.  
Broken core. Corrosion. Abrasion.  
Various changes in rope structure.

Wire Ropes: Up to 0.75 inch diameter

Power

Batteries: 9 V Rectangular Batteries  
(replaceable or rechargeable)  
Eveready CH22 or equivalent.

Low Voltage Indicator: LED indicator turns on at end  
of battery life.

Battery Life: 4-5 hours of continuous operation.

Readout and Recording

Headphones: Built-in power amplifier including  
battery. Broken wires indicated by  
clicking sounds. Other rope deterio-  
rations indicated by "thundering" or  
"crackling" sounds. Indication inde-  
pendent of speed.

S P E C I F I C A T I O N S

Strip Chart Recorder: One or two channel recorder. Rope flaws indicated by characteristic chart patterns. Signal amplitudes independent of rope speed.

Dimensions

Length: 6 inches  
Width: 1.5 inches  
Depth: 8.5 inches  
Weight: 5 lb. (Test instrument including electronics and battery)

Environmental Conditions

Dust proof, splash proof (oil and water)  
Humidity to 95%

Operating temperature: 0° to 55° C  
Storage temperature: -40° to 55° C

O P E R A T I O N

FUNCTION OF CONTROLS AND CONNECTORS

1. ON-Off Switch - The ON-OFF Switch turns on battery power.
2. BATTERY INDICATOR - Turn-on of the red LED indicator light indicates the end of useful battery life. No light indicates adequate battery voltage for operation of the instrument.
3. BATTERY CHARGE CONNECTOR - This connector allows charging of the rechargeable batteries from the battery charger.
4. AUDIO PLUG - A modified test signal is available at this jack intended for audio detection by headphones. The modified signal can also be recorded by a strip chart recorder or a cassette recorder.
5. RECORD PLUG - The unmodified test signal is available at this jack. It can be recorded by a strip chart recorder or a cassette recorder. The unmodified signal can also be monitored by earphones.
6. VOLUME POTENTIOMETER - This potentiometer controls the volume at the Audio Plug.
7. Detection Level Potentiometer - This potentiometer controls the signal level at the Audio Plug at which fault signals are detected.
8. SIGNAL ENHANCE POTENTIOMETER - This potentiometer controls the degree to which that part of the signal at the Audio Plug above the detection level is enhanced, and that part of the signal below the detection level is suppressed.

O P E R A T I O N

CALIBRATION

1. Mount proper size Guide Shoes and Pick-up Head on the instrument (see page 11 of this manual).
2. Plug Headphones into Audio Plug.
3. Turn Detection Level Potentiometer to the "0" setting (Extreme counterclockwise position).
4. Turn the Signal Enhance Potentiometer to the "10.0" setting (Extreme clockwise position).
5. Turn the Volume Potentiometer to the "10.0" setting (Extreme clockwise position).
6. Turn on Power Switch.
7. LED indicator above power switch should not turn on. (A turned on LED indicates weak batteries. Charge or replace batteries. See page 11 of this manual.)
8. Find a rope section without flaws to be tested.
9. Open Sense Head. Attach instrument to the rope. The instrument is held against the rope by magnetic attraction. Close Sense Head.
10. Put on Headphones. Turn on Headphones.
11. Move instrument by hand up and down along the flawless part of the rope. Crackling or clicking sounds are usually audible.
12. Keep moving the instrument. Increase the detection level by turning the Detection Level Potentiometer in the clockwise direction until crackling or clicking sounds disappear.

OPERATION

13. Make a note of all potentiometer settings for later reference. Lock potentiometers. The instrument is now ready for testing.
14. Note: If during testing, clicking or crackling sounds are audible for rope sections which have definitely no flaws that warrant attention, the detection level can be raised even further. Ideally, the detection level should be set such that for marginally acceptable ropes no sounds are audible.

TESTING INSTALLED ROPES

Audio Inspection

1. Mount proper size Guide shoes ( $3/8"$ ,  $1/2"$ ,  $5/8"$  or  $3/4"$ ) on instrument. (Refer to page 11)
2. Mount proper sized Pick-Up Head on instrument. (Refer to page 11)
3. Set all potentiometers to calibrated setting. (Refer to page 7 for calibration procedure.) Lock potentiometers.
4. Plug Headphones into Audio Plug.
5. Open Sense Head. Attach instrument to the rope. The instrument is held against the rope by magnetic attraction. Close Sense Head.
6. Turn on Power Switch.
7. A turned on LED indicates weak batteries. In that case, charge or replace batteries. (Refer to page 11)

OPERATION

8. Put on Headphones. Turn on Headphones.
9. Holding instrument so that it cannot move, run rope at inspection speed.
10. If crackling or clicking sounds are audible, stop rope and visually search for flaws. Flaws can be located by moving instrument manually up and down along the rope and listening to sounds in the headphones.
11. Mark position of flaw for later reference.

Permanent Record:

If a permanent record of the rope condition is desired, a two channel strip chart recorder can be used as follows:

1. Connect first channel of Strip Chart Recorder to Audio Jack.
2. Connect second channel of Strip Chart Recorder to Record Jack.
3. Turn Detection Level Potentiometer to calibrated setting.
4. Turn Volume Potentiometer to 10.0 setting.
5. Turn Signal Enhance Potentiometer to 10.0 setting.
6. Lock Potentiometers.
7. Turn on Instrument Power Switch.
8. Open Sense Head. Attach instrument to rope. Close Sense Head.

O P E R A T I O N

9. Signals will be in the 0.1 to 5V range. Adjust Strip Chart Recorder sensitivity accordingly.
10. Start Strip Chart Recorder.
11. Holding instrument so that it cannot move, run rope at inspection speed and record signals.
12. The amplitude and shape of the "Audio" signal can be adjusted by the Volume and Enhancement controls.
13. Inspect strip chart recording. In general, flaws will be indicated by pronounced pulses in the "Audio" recording. The nature of the flaw can usually be better identified from the "Record" recording.
13. Reinspect rope visually making use of the headphones to precisely locate the flaw and compare results with strip chart recording.

S E R V I C E

BATTERY CHARGING

1. Plug Battery Charger into wall outlet. Turn off instrument Power Switch.
2. Plug Charger Cord into "Battery Charge" connector of instrument.
3. Charge for approximately 14 hours.

CAUTION: Charge Nickel-Cadmium batteries only!

Other types of batteries may rupture causing severe damage to instrument.

BATTERY REPLACEMENT

If battery recharging is not feasible, used batteries can be replaced by charged Nickel-Cadmium batteries or by replaceable batteries.

1. Remove 9 screws from instrument lid.
2. Lift off instrument lid.
3. Remove old batteries from battery holders.
4. Install new batteries (9V Rectangular replaceable or rechargeable batteries).
5. Replace instrument lid.

EXCHANGE OF GUIDE SHOES AND SENSE HEAD

1. Loosen two brass screws on bottom of instrument.
2. Remove sense head by gently pulling it in a forward direction.

S E R V I C E

3. Lift guide shoes and slide them out of the instrument in opposite longitudinal directions. The guide shoes are magnetically retained and moderate force is required.  
Note: Guide Shoes cannot be removed with sense head in place.
4. Insert new guide shoes by reversing the above procedure.
5. Insert sense head by gently pushing it into the magnet assembly.
6. Secure sense head by tightening two brass screws on bottom of instrument.

CAUTION: Keep connectors absolutely clean!

Sense head, guide shoes and magnet assembly can be cleaned with most cleaning compounds. Iron filings can be removed from magnet assembly by using self-adhesive tape.

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