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# An Electronic Inclinometer Design for the Measurement of Wire Cable Angles During Bongo Plankton Tows

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January 1982

**Canadian Technical Report of  
Fisheries and Aquatic Sciences  
No. 1085**



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MEASUREMENT OF WIRE CABLE ANGLES DURING  
BONGO PLANKTON TOWS

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PREFACE

We would like to thank the machinists and electronics technicians in the Metrology section at Bedford Institute of Oceanography whose helpful suggestions during the developmental prototype stages contributed to the success of this project.

Minister of Supply and Services Canada 1982

Cat. No. FS 97-6/1085E ISSN 0706-6457

Correct citation for this publication:

Reid, J.G.G. and E. Larsen. 1982. An Electronic Inclinometer Design for the Measurement of Wire Cable Angles During Bongo Plankton Tows. Can. Tech. Rept. Fish. Aquat. Sci.

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## ABSTRACT

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The depth of towed plankton gear such as the 61 cm bongo net may be calculated, from the angle of the towing cable and the amount of wire cable deployed. This angle (and subsequently gear depth) is dependent on a combination of ship's velocity and currents. Traditionally these wire angles have been measured using hand held inclinometers, of the mechanical pendulum or liquid filled glass tube variety. This electronic design uses a pendulum pot within a waterproof case, that is mounted on a frame fixed directly onto the towing cable. Angles are transmitted via an electrical cable to a remote readout where they are observed and recorded. A second remote unit may be installed on the ship's bridge. The desired tow cable angle and thus the desired gear depth can thereby be maintained throughout the tow by altering the ship's velocity according to the angles observed on the readout.

Key words: Inclinometer, Electronic, Plankton Tows, Pendulum Pot

## RESUME

La profondeur de remorquage d'engins à plancton tel un filet bongo de 61 cm peut être calculée à partir de l'inclinaison du câble de remorque et de la quantité de câble déployée. Cette inclinaison (et par conséquent la profondeur de l'engin) dépend à la fois de la vitesse du navire et des courants. Jusqu'à présent, les angles d'inclinaison ont été mesurés à l'aide de clinomètres manuels consistant soit en un pendule mécanique, soit en un tube de verre rempli de liquide. Notre dispositif électronique utilise un potentiomètre encastré dans un boîtier imperméable fixé à un support attaché au câble de remorque. La valeur des angles est transmise par câble électrique à un système d'affichage pour observation et enregistrement. Un système semblable peut également être installé sur la passerelle du navire. Ceci permet d'ajuster la vitesse de celui-ci de façon à maintenir le câble de remorque à l'inclinaison désirée, contrôlant ainsi la profondeur de l'engin pendant toute la durée du trait.

Mots-clés: Clinomètre, Electronique, Traits à Plancton, Potentiomètre

## INTRODUCTION

This paper presents a design for an electronic inclinometer which continuously monitors the cable angles of towed plankton gear and displays this data on a remote readout. The design has evolved from the experiences gained during fifteen Scotian Shelf Ichthyoplankton Program cruises over the past three years. The long-term year round nature of the sampling program has provided a wide variety of operating conditions (temperatures of -20°C, freezing spray, 35 kt winds) underwhich the unit could be tested, as well as adequate time for modifications, and retesting. The advantages of this device to a sampling program are:

- (1) it provides accurate angle measurements that do not vary due to observer error as in the case of visual mechanical units,
- (2) the remote readout improves the quality of the data collected by removing the observer-recorder from the effects of the elements, especially during winter sampling operations, and
- (3) it reduces manpower requirements.

## DESCRIPTION

### GENERAL DETAILS

The frame of the inclinometer is 0.6 cm stainless steel "T-Bar" approximately 80 cm long to which are welded three pulley supports, an anchoring arm and an offset, mounting support for a waterproof aluminum housing (see Photos 1 and 2). The stainless steel supports contain a squeeze-proof brass pulley system that maintains the frame of the inclinometer parallel to the towed cable being measured (see Photos 3 and 4). The position of the inclinometer on the warp is maintained by the attachment of a short length of rod (with shackles) from the towing crane to the anchoring arm on the inclinometer (see Photo 5). The metal rod attachment prevents the ramming of the inclinometer into the towing block if the pulley system should momentarily jam. On the lower extreme end of the inclinometer T-Bar, two, two kg weights bolted to the T-Bar frame help to give the inclinometer additional stability. To the offset electronic housing support is bolted the waterproof housing that contains and protects the potentiometer used to measure the wire angles. The pendulum pot (potentiometer) itself is bolted in a fixed position to the circular cover plate of the housing (see Photo 6). The circular cover plate can be rotated to fine tune the position of the pendulum pot relative to the stationary housing and then tightened in a fixed position. A machined groove on the circumference of the cover plate carries an "o ring" which makes the housing waterproof. The electrical leads from the potentiometer are connected to a two pin, four contact bulkhead EO connector which conducts data through a cable to the remote readout (see Photos 7 & 8). As well, a slave

readout can be installed on the bridge so that ship's speed can be modified to maintain the consistency of desired wire angles.

Figure 1 illustrates a towing arrangement for one towed gear using one inclinometer. The proximity of winch and Hiab Crane controls to the readout enables one man to deploy the gear and also to record wire angle data. As well, but not shown in Figure 1, an instrumented block and readout can centralize the sampling operation to the point that 2 men are all that are required on deck and then only when the gear is being deployed or recovered. The instrumented block and readout are manufactured by General Oceanics, models CB4041NS and 4046 respectively. This block system displays the amount of cable out at anytime and the rate at which it is being deployed or hauled back.

## ELECTRONIC CIRCUIT

The electronic circuit for the inclinometer system layout in Figure 1 is presented in Figure 2. The voltage source applies 9V across the potentiometer in the pendulum pot between points 1 and 3. The voltmeter reads the potential across points 2 and 3, which is directly proportional to the distance swept by the wiper. When the wiper is in position 3 there is no potential and therefore the meter reads 0. When the wiper is in position 1, the potential is maximized and the voltmeter readout reaches a maximum. The formula below describes the angles measured.

$$\frac{\text{Voltage } (2, 3)}{\text{Voltage } (1, 3)} \times 90^\circ = \text{angle}^\circ$$

therefore when the wiper is at position 3:

$$\frac{\text{Voltage } (2, 3)}{\text{Voltage } (1, 3)} \times 90^\circ = \frac{0V}{9V} \times 90^\circ = 0^\circ$$

therefore when the wiper is at position 1:

$$\frac{\text{Voltage } (2, 3)}{\text{Voltage } (1, 3)} \times 90^\circ = \frac{9V}{9V} \times 90^\circ = 90^\circ$$

therefore when the wiper is half way between positions 1 and 3:

$$\frac{\text{Voltage } (2, 3)}{\text{Voltage } (1, 3)} \times 90^\circ = \frac{4.5V}{9.0V} \times 90^\circ = 45^\circ$$

Figure 4 represents the schematic wiring diagram for the system in Figure 3 that uses two inclinometers, a switching box, a master readout in the winch room and an additional slave readout on the bridge.

## INSTRUMENT CALIBRATION

With the circuit diagram in Figure 2, an inclinometer can be calibrated in the lab with a short lead to the readout. The system can then be installed on board ship without the usual errors due to cable resistance. This feature is useful when two (matched) inclinometers with different cable lengths share a common readout through a switching box as in Figure 3. The following procedure is used to calibrate each unit in the lab.

- (1) Set inclinometer T-bar in a fixed horizontal position and check with a carpenter's level.
- (2) Loosen the lock screws on the cover plates of the waterproof housing and rotate until readout reads 00.0.
- (3) Tighten lock screws and place inclinometer T-bar in a fixed vertical position and check with a carpenter's level.
- (4) Adjust variable resistor trim pot on the back of the readout until readout displays 90.0.
- (5) Lock position of trim pot.

#### SYSTEMS WITH TWO INCLINOMETERS

In Figure 3, two inclinometers are connected to a switching box, so that only one readout in the winch room is required. With the switching box two gears using two separate inclinometers may be monitored simply by switching over from one to the other. The schematic diagram for the two inclinometer system is illustrated in Figure 4.

#### SPECIFICATIONS

##### Inclinometer

###### Electrics

- Humphrey Pendulum Pot - Model No. CP17-0662-1. Overall system accuracy  $\pm 1\frac{1}{2}^{\circ}$
- EO Bulkhead Connector - 2 Pin, 4 Contact (male) P/N B53F4M-1

###### Mechanical

- T-Bar - stainless steel 5 cm x 5 cm
- Towing arm - stainless steel plate (10 cm x 3.75 cm x 0.5 cm)
- Pulley housing - stainless steel plate (10 cm x 3.75 cm x 0.5 cm)
- Pulleys - brass (3.8 cm dia. x 1.2 cm width)
- Bolts - stainless steel (0.9 cm x 4.0 cm coarse thread)
- Anti-lock pulley bearings - brass 1.3 cm OD x 1.3 cm)
- Electronics housing support - stainless steel
- Electronic housing - aluminum pipe OD 11.4 cm ID 10.0 cm

- Electronic housing cover - aluminum plate
- Waterproof seal - "O" ring

##### Cable

- Beldon - 4 conductor shielded - neoprene jacket (flexible at low temperatures)
- EO connector 2 pin, 4 contact (Female) P/N B51F4F-1
- Amphenol 5 pin connector (Female)

##### Main electronic readout (see photos 7 and 8)

- Power supply
- Digital voltmeter - Datel DM 3100L
- 10 K $\Omega$  variable resistor
- 17.8 K $\Omega$  resistor
- 2 Amphenol 5 pin connectors (Female)

#### SUMMARY

These units are simple to build and are highly reliable. They have been tested under a variety of adverse weather conditions and in temperatures from 25°C to -20°C in a marine environment. The cost of building an inclinometer system is less than \$1,500 and is certainly worthwhile in severe winter sampling conditions.

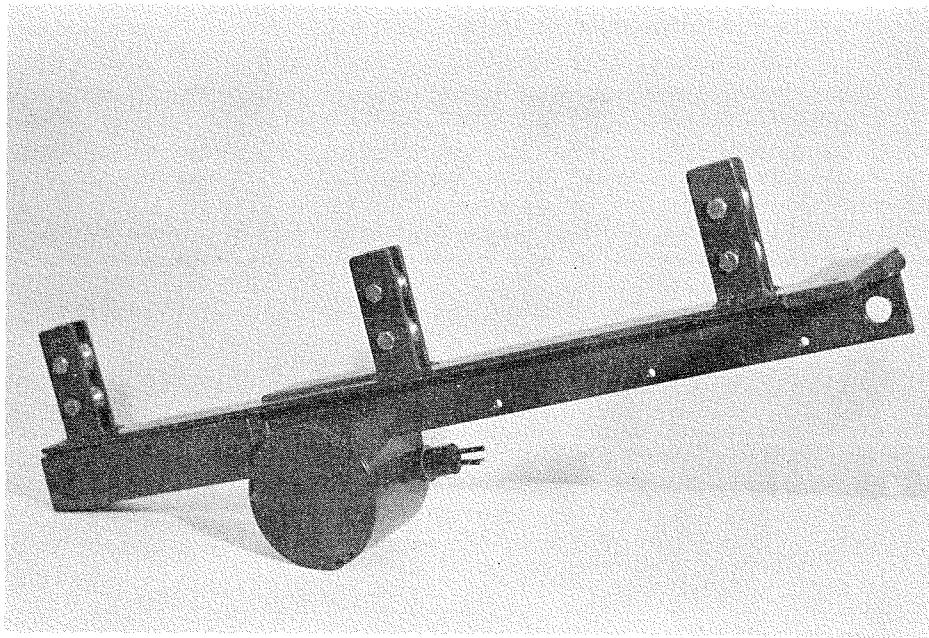


Photo 1. Electronic inclinometer (right profile).

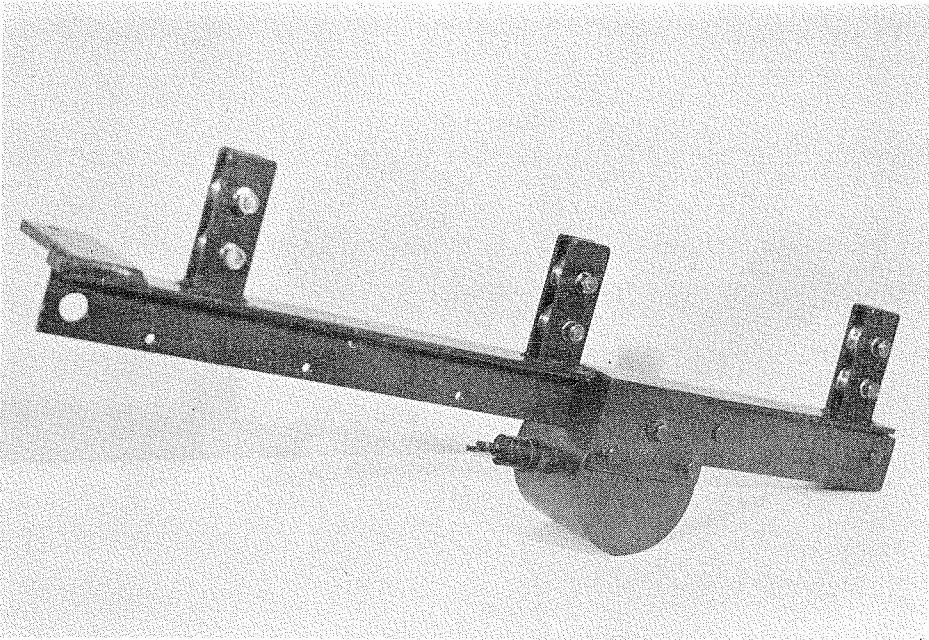


Photo 2. Electronic inclinometer (left profile).

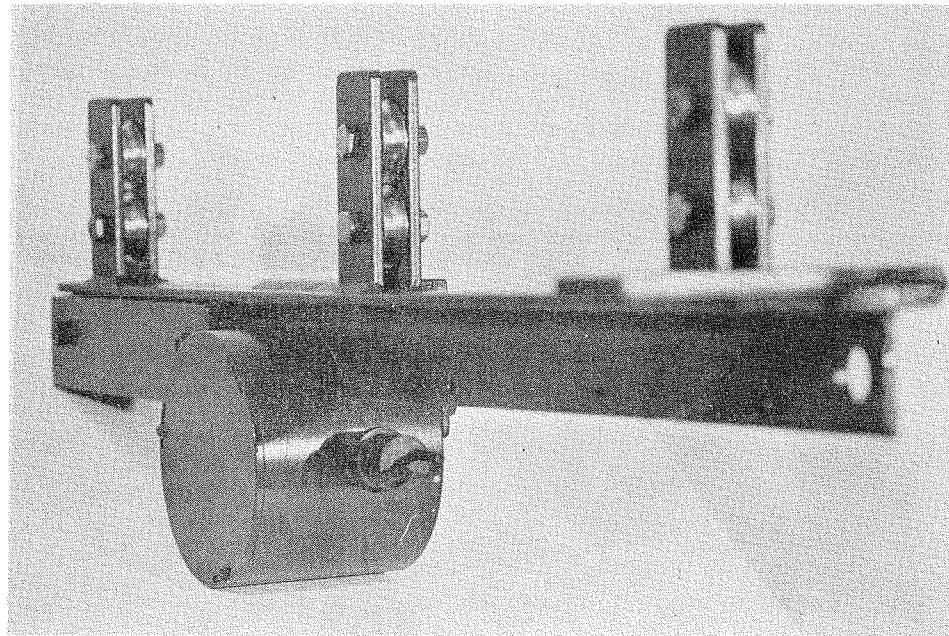


Photo 3. Squeeze-proof wire guide roller assembly.

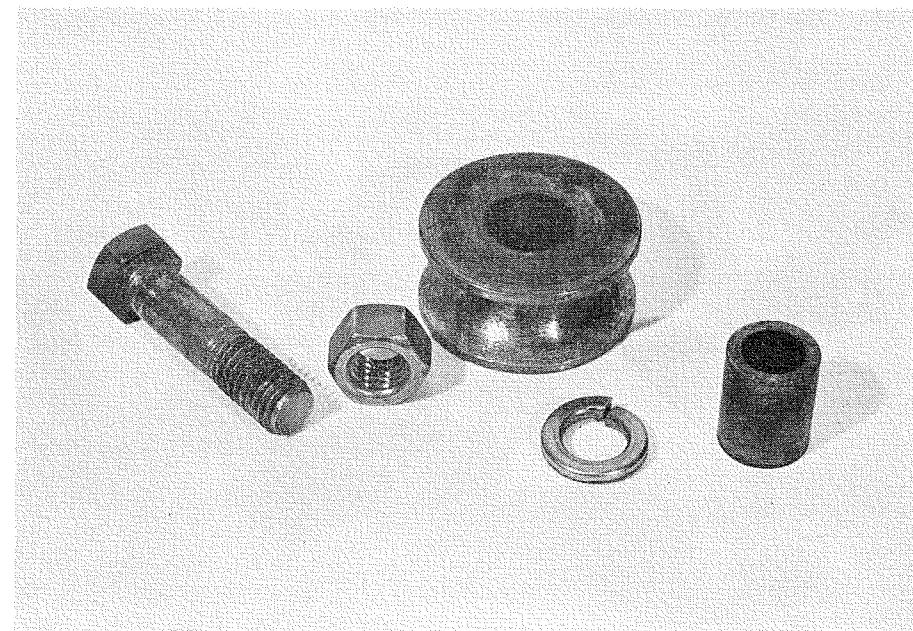


Photo 4. Wire guide assembly components.

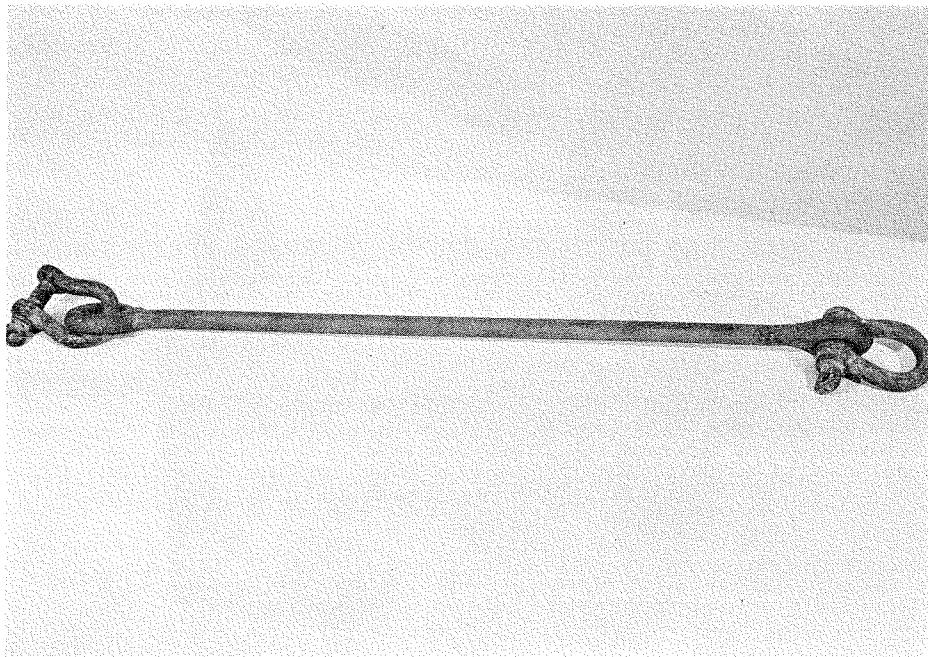


Photo 5. Anti-jamming bar.

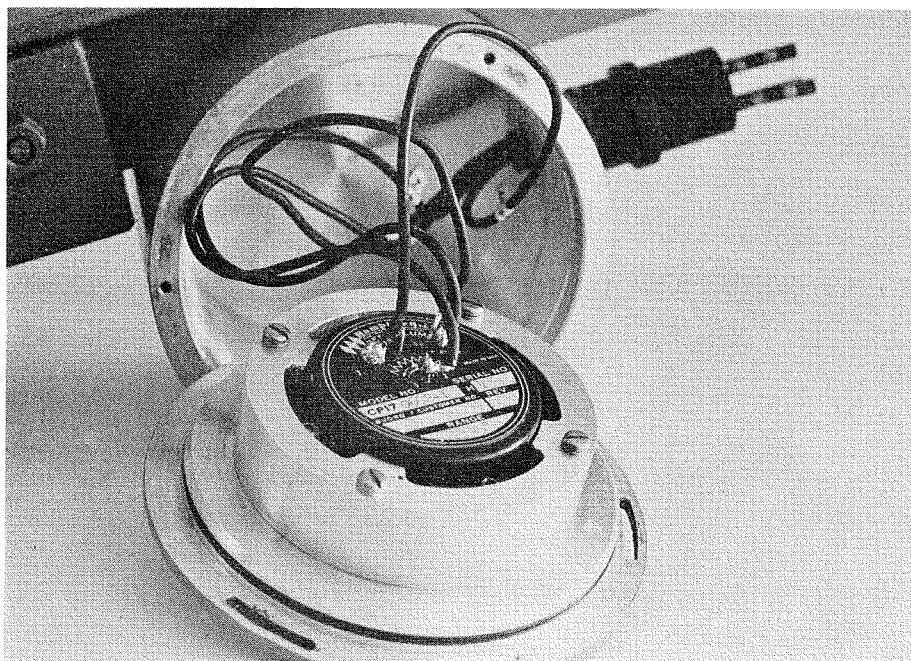


Photo 6. Potentiometer and water-proof electronic housing.

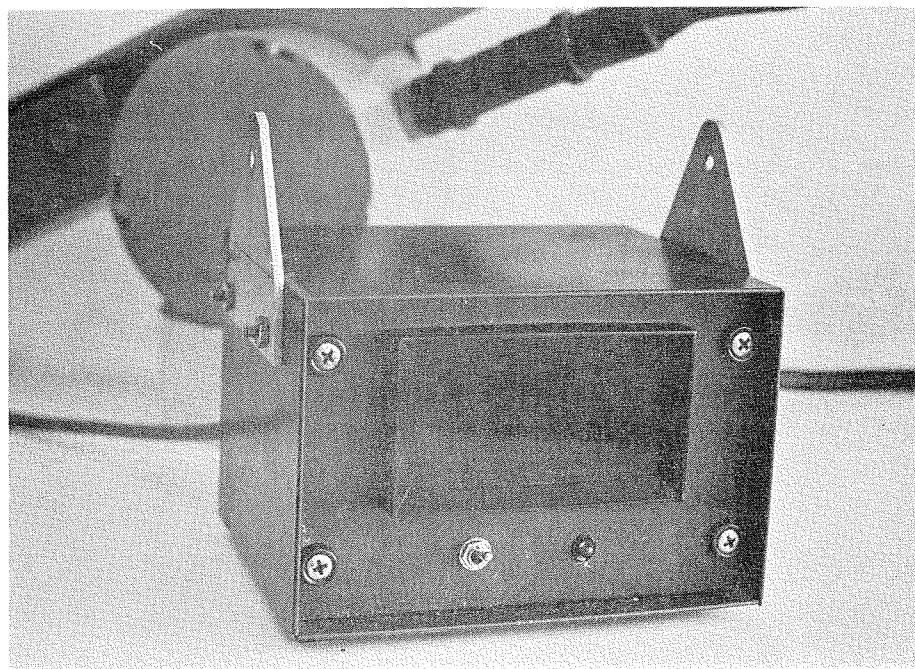


Photo 7. Main readout, front view.

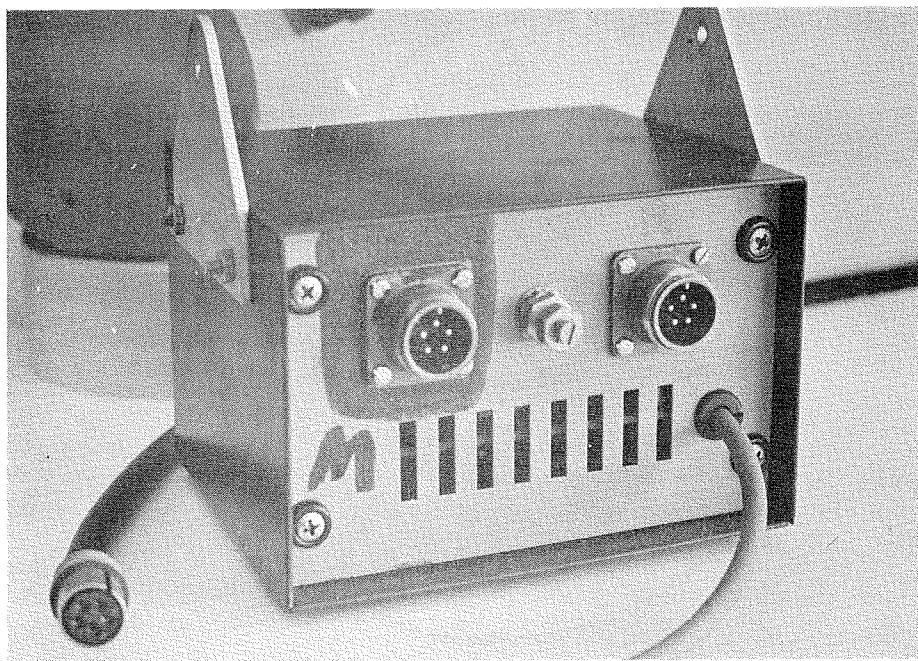


Photo 8. Main readout, rear view.

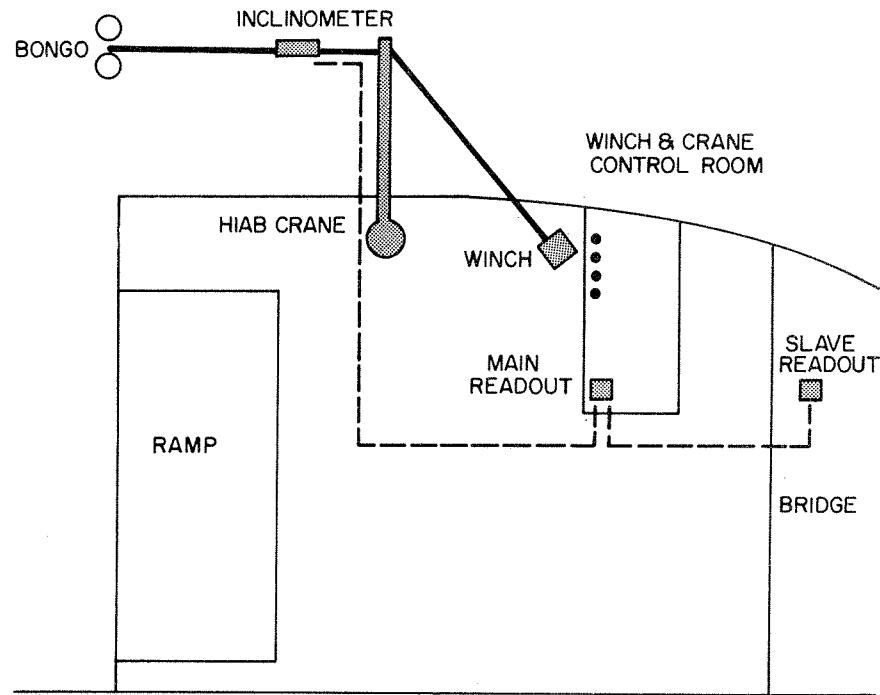


Figure 1. Inclinometer system for one towed gear.

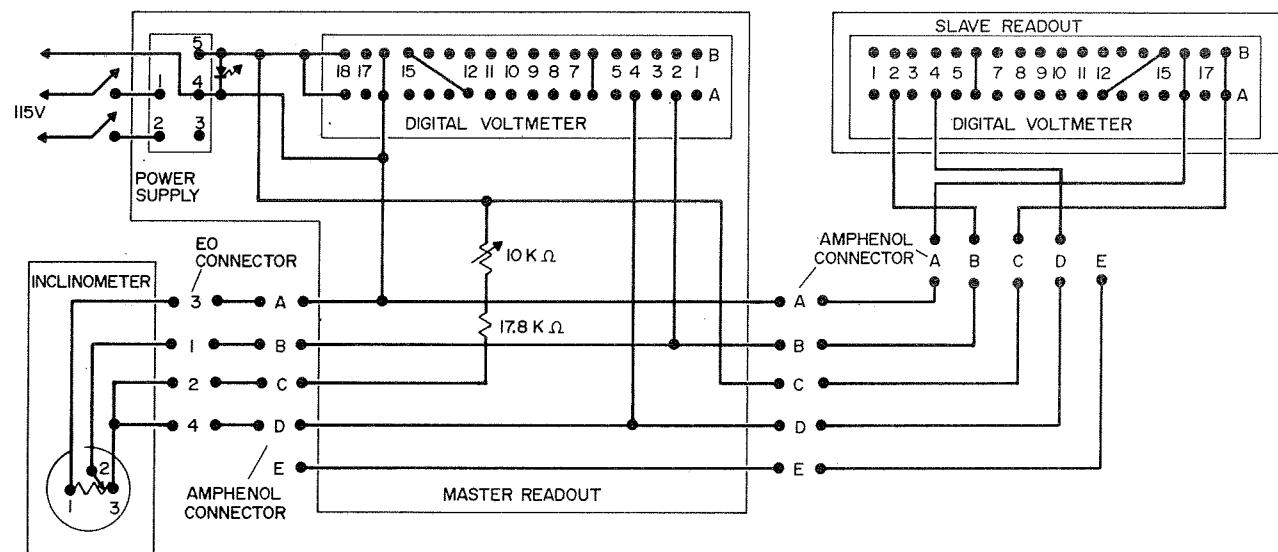


Figure 2. Circuit diagram for inclinometer system in Figure 1.

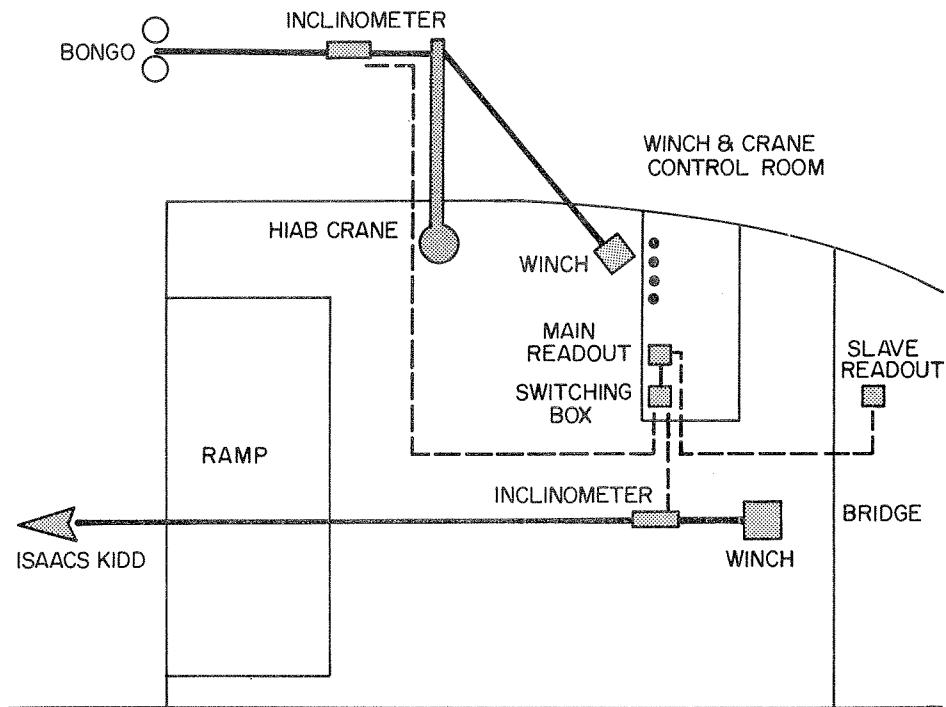


Figure 3. Inclinometer system layout for two towed gears.

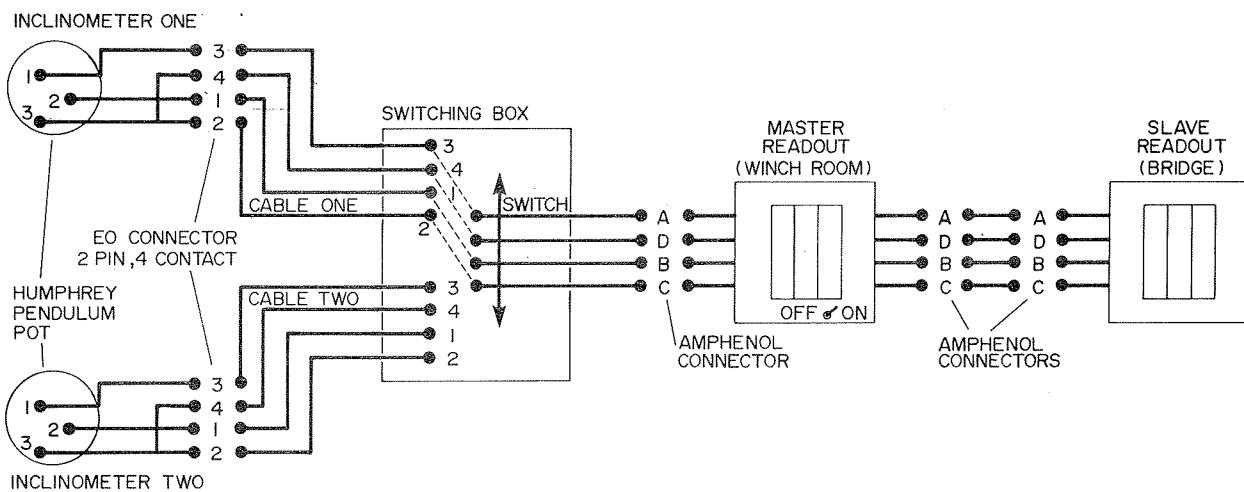


Figure 4. Schematic wiring diagram for inclinometer system in Figure 3.