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PRELIMINARY DEVELOPMENT AND TEST OF AN INFRARED WATER LEVEL PICKUP

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U. S. NAVAL CIVIL ENGINEERING LABORATORY
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PRELIMINARY DEVELOPMENT AND TEST OF AN INFRARED WATER LEVEL PICKUP

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by

F. E. Nelson

ABSTRACT

The pickup is designed to sense the motion of a distant light source. It consists of a wheel driven by a constant speed motor, a fixed visible light and two photo cells sensitive respectively to visible and infrared light.

Tests in the laboratory indicate that the pickup can measure with acceptable accuracy the change in the vertical position of a light at a distance of 3 feet when the rate of change of position is from 0.0 to 0.1 cycles per second. The observation distance is limited by the sensitivity of the photo cells used.

Future plans call for: reduction of wobble and variation in time of rotation of the wheel; the procurement of an infrared sensitive photo cell and of an electronic device to allow direct recording of movement of a distant light source (infrared); and the field testing of the pickup as a distance of at least 1500 feet from the light source.

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INTRODUCTION

Ocean water level variations are being measured and recorded at many locations for a variety of reasons. This normally requires that electrical cables and other components of the measuring device be submerged in the ocean water. These are frequently rendered inoperative by leaks or damage. If a water level measuring device is to provide reliable and continuous data, it must be designed so that the sensitive components are not subject to ocean water environment.

A measuring device should be reliable, accurate, inexpensive, re-usable and near free of maintenance. It should not be a dangerous obstruction to seagoing craft, nor should it require personnel to expose themselves to the danger of boarding piles from boats or working with high voltage in wet surroundings.

Inasmuch as a device meeting all of the desirable characteristics did not seem to be available, this Laboratory undertook the development of one, specifically: an infrared type water level pickup suggested by the author through the Navy Beneficial Suggestion program. This note reports on the work accomplished to date and on future plans.

DESCRIPTION OF PICKUP

The instruments under development is intended for measuring water level variations in the vicinity of a fixed structure in the open ocean or in coastal waters.

The pickup is in two sections. One section is a point source of infrared energy such as a lamp mounted on a raft which follows the water surface. The second section consists of a well balanced wheel driven by a constant speed electric motor, a fixed visible light, a photocell sensitive to visible

light, a photocell sensitive to infrared, all enclosed by a light-tight cover and mounted on a rigged base. The second section is mounted on a fixed structure based on land or on the sea bottom.

NCEL designed and fabricated both the wheel and the base which is of welded aluminum. The axle of the 18-inch diameter wheel is mounted in self-aligning precision ball bearings and is belt driven at a design speed of 240 revolutions per minute by a 1/8 H.P., synchronous, split-phase, 1800-RPM, 110-volt, AC motor.

THEORY OF OPERATION

Arrangement of the component parts of the pickup is shown in Figure 1.

The infrared sensitive photocell is positioned so that it receives reflected energy from the mirror when the mirror is in a position that cuts through a plane from the infrared source to the center of the wheel. Positioning of the infrared sensitive photocell is accomplished while the infrared source is in its mean position. This allows maximum linear measurements of movement of the infrared source.

As the wheel rotates, the infrared sensitive photocell receives a pulse of reflected energy from the mirror causing it to generate an electrical pulse. The electrical pulse starts the timer which measures time in micro-seconds. As the mirror sweeps past the fixed light, it reflects light onto the light-sensitive photocell which generates an electrical pulse which stops the timer. Thereby, the time required for the wheel to rotate through the arc subtended by the fixed light and the infrared source is measured.

The measure of time is converted to a voltage amplitude which is recorded. Vertical movement of the infrared source causes a change in time between electrical pulses from the photocells. The change in time is recorded as a change in voltage amplitude on a time base. This furnishes a record of water level variation with respect to time.

Figure 2 is a component arrangement using a lens in lieu

of a mirror. The operation of the system is basically the same as shown in Figure 1.

TEST PROCEDURE

Static Tests

The component arrangement shown in Figures 3 and 4 was used for laboratory tests. A rectangular duct, in lieu of the lens of Figure 2, was secured to the side of the wheel. Two visible light-sensitive photocells were mounted in hollow machine screws with the light-sensitive area of the cells exposed. The machine screws were positioned so that the light-sensitive portion of the photocells interrupted a stream of light that passed through the rectangular duct from the light source to the center of the wheel. A rim was attached to the wheel to prevent light from activating the photocells except when the light source was on a plane passing through the duct to the center of the wheel.

The fixed light was bolted to the pickup cover. A hole in the cover allowed light to pass through the duct and activate one photocell as the duct swept past the hole.

A visible light representing the infrared source of Figure 2 was mounted on a fixture which provided a means of changing the vertical position of the light. The fixture was positioned so that the light passed through the duct and activated one photocell as the duct swept past a hole in the pickup cover. A rule graduated in 1/50 inch steps was attached to the light fixture so that the change in vertical position of the light could be measured.

Two sets of measurements of the change in the vertical position of the movable light were made. During the first set of measurements the movable light was one foot from the center of the wheel. It was $1\frac{1}{2}$ feet from the center for the second set of measurements.

Dynamic Test

The component arrangement shown in Figures 3 and 5 was used for Laboratory tests. Since a digital to analog converter

of time measurement to voltage amplitude was not available, it was necessary to manually record each time measurement. To allow sufficient time to manually record the time measurements, it was assumed the recording of every sixth time measure over a period of one minute would yield the same result as the recording of every time measurement over a period of ten seconds. Ten seconds per cycle is a common period for ocean water waves.

An electric motor with a speed of one revolution per minute was mechanically connected to a light so that the light moved in a vertical plane in near a sinusoidal manner. Every sixth measurement of the time required for the wheel to rotate through the angle subtended by the movable and fixed light was manually recorded over a period of two minutes.

The movable light was held at each end of its travel and 100 time measurements were manually recorded. The average of these measurements were used for calibration.

TEST RESULTS

Static Tests

Measured and calculated results for each static test condition is shown in Table I and Figures 6 and 7.

As shown by Table I and Figures 6 and 7, the movement measured by the pickup agree closely with those measured by hand using a rule. The pickup results are considered more accurate than those obtained by hand measurement.

Dynamic Test

The average of the time measurements made with the light at the ends of its travel were used for the maximums, and the average of the time measurements made while the light moved in a vertical plane at near a sinusoidal rate were used for the zero axis of the sine wave plotted in Figure 8. The difference between the average time and the individual time measurements made while the light moved in a vertical plane is also plotted on Figure 8.

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The sine curve of Figure 8 is a close approximation of the position of the light at each instant of time, and also is an approximate average of the time deviations due to the mechanical deficiencies of the wheel. This average is readily obtainable by use of an electronic filter, and would be the recorded output from the digital to analog converter.

DISCUSSION

Each photocell generated one electrical pulse during one revolution of the wheel. Two hundred measurements were made of the time between electrical pulses from the photocell activated by the fixed light. The length of time between pulses varied from 238,351 to 238,736 micro-seconds. The average time between pulses was 238,543.36 micro-seconds which corresponded to a wheel speed of 251.53 revolutions per minute.

The variation in time of wheel rotation is likely due to the unbalanced condition of the wheel. Also, the wheel wobbled, probably because the wheel and its axle were machined separately.

The variation in time of wheel rotation due to unbalance, etc. is not considered significantly detrimental to the performance of the pickup. The variation in time caused by mechanical deficiencies of the wheel can readily be removed with a filter without affecting the change in voltage corresponding to the change in measured time caused by a change in position of the infrared source. The filter action gives the average value of the voltage deviation caused by the mechanical deficiencies of the wheel.

At present, the digital to analog converter which converts the measurement of time to a voltage amplitude is not available at NCEL. It is an off-the-shelf item available from the manufacturer of the timer.

The first measurements of time between pulses from the two photocells were made with both lights fixed in positions that required the wheel to rotate approximately 170° to align the duct with the lights and photocells. The deviation in the time required for the wheel to rotate the 170° was found to be up to 300 micro-seconds. The position of the fixed light and associated photocell were changed so that the wheel was

required to rotate approximately 20° to align the duct with lights and photocells. This change in angle of rotation reduced the deviation in time caused by the unbalance of the wheel, etc. to a maximum of 77 micro-seconds. The deviation in time measurements, can be further reduced by reducing the angle of rotation to a minimum.

The calculated curves of Figures ~~6~~⁶ and ~~7~~⁷ and the calculation of light movement by time measure shown in Table I is based on the average wheel speed of 251.53 revolutions per minute. Also, the time between pulses as listed in Table I is the average of 100 measurements for each position of the movable light. Use of the average time is considered proper for reasons previously stated.

FINDINGS

1. Tests in the laboratory using the full scale development pickup indicate that:

a. It can measure a change in the vertical position of a light of:

(1) 0.02 inch (as measured by a rule) with a maximum error of .005 inch over the range of 0.0 to 0.08 inch at a distance of 1 foot when the rate of change is very slow.

(2) 0.06 inch (as measured by a rule) with a maximum error of 0.008 inch over the range of 0.0 to 0.3 inch at a distance of 1 1/2 feet when the rate of change is very slow.

b. It can sense a continuous cyclical change in the vertical position of a light over the range of 0.0 to 0.3 inch at a distance of 3 feet when the rate of change is 0.1 cycle per second.

c. The wheel wobbles and varies in time of rotation; however, the effect of these mechanical deficiencies can be eliminated by use of an electronic filter.

d. The photocells used were adequate for tests in the laboratory but since they are sensitive to visible light

only they are not sufficiently versatile for use in field tests.

CONCLUSIONS

1. Accurate measurements of the movement of a point source of light energy by use of a rotating wheel is feasible.
2. The water level pickup described has proper potential but requires further development.

FUTURE WORK

To obtain a more conclusive evaluation of the water level pickup, the wobble and vibration of the wheel due to unbalance will be reduced as much as possible by machining and balancing procedures. The digital to analog converter necessary to convert time measure to voltage amplitude will be obtained and used in further static and dynamic tests. The infrared source and photocell will be procured and used in measurements of vertical movement from a distance of at least 1500 feet. The most effective physical arrangement of the components of the pickup will be determined experimentally.

To distinguish the infrared signal from background noise, it may be necessary to chop or modulate the infrared signal at its source. For this application, the chop or modulation frequency must be in the order of one megacycle.

The Lincoln Laboratory which M.I.T. operates for the U. S. Government, at its Lexington, Massachusetts, Research Center is using a gallium arsenide diode to generate pure infrared. They have successfully transmitted a television signal over a distance of thirty-four miles using an infrared beam that carried only .005 watts of energy.

Since the Lincoln Laboratory diode can be modulated by frequencies in the megacycle range, it will be the first source of infrared investigated for use in the NCEL water level pickup program.

TABLE I. Light movement and time change from static tests.

Movable Light Above Bench (Inches)	Light Movement (Inches)	Time Between Pulses (Avg. of 100) (10 ⁻⁶ Sec)	Maximum Deviation In Time Between Pulses (10 ⁻⁶ Sec)	Change In Average Time Between Pulses (10 ⁻⁶ Sec)	Light Movement From Time Measurement (Inches)
Movable Light 12 Inches From Center Of Wheel	8.90	11,734.4	61	0.0	0.0
	8.92	11,674.9	60	58.5	0.0195
	8.94	11,596.0	56	137.4	0.0449
	8.96	11,542.9	53	190.5	0.0635
	8.98	11,488.7	60	245.7	0.0785
Movable Light 18 Inches From Center Of Wheel	8.76	11,724.8	49	0.0	0.0
	8.82	11,604.3	61	120.5	0.0595
	8.86	11,535.8	62	189.0	0.0945
	8.94	11,374.4	63	350.0	0.1752
	9.00	11,260.8	59	464.0	0.2320
	9.06	11,121.9	77	602.9	0.3014

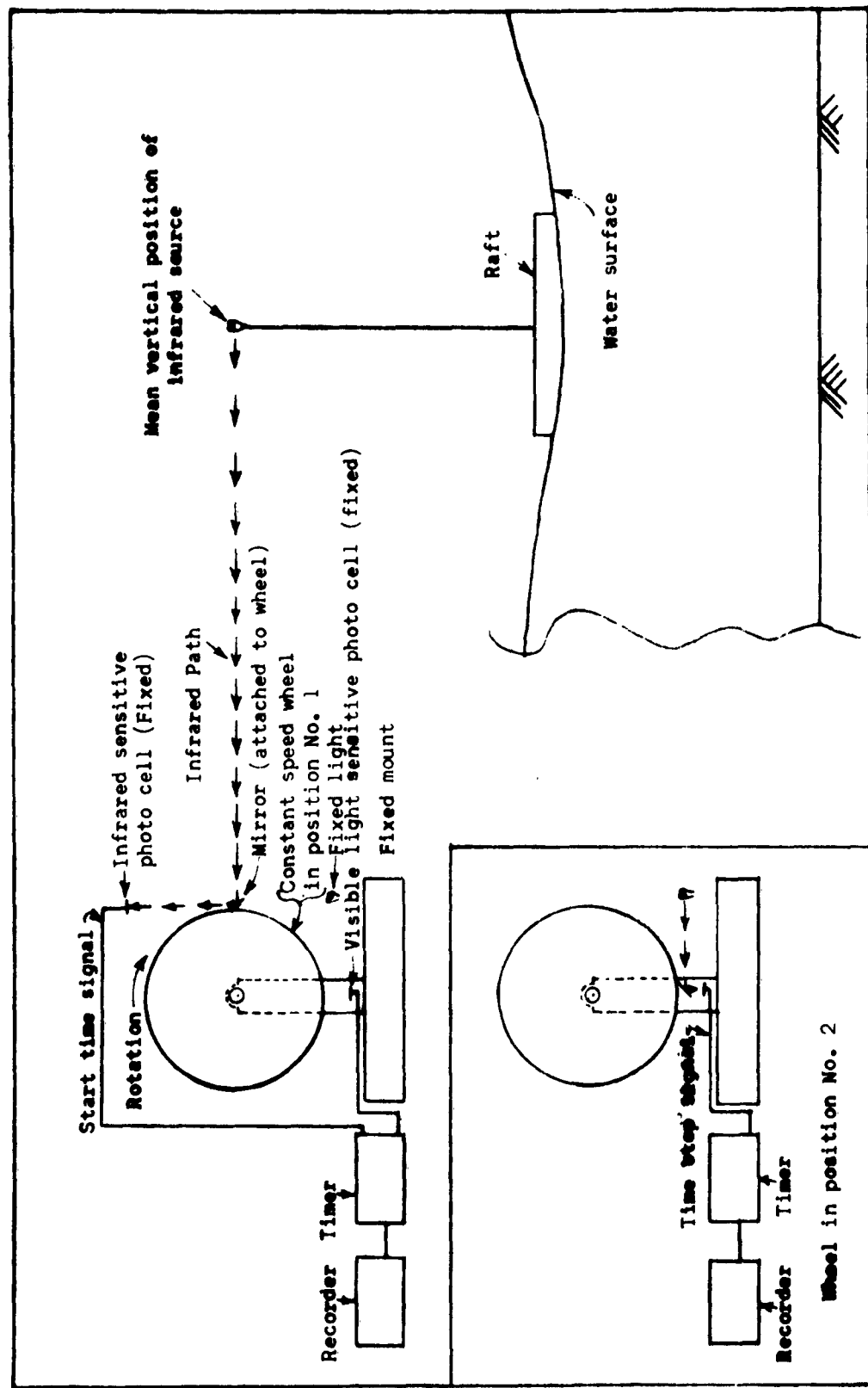


Figure 1 Basic component arrangement of water level pickup using a mirror

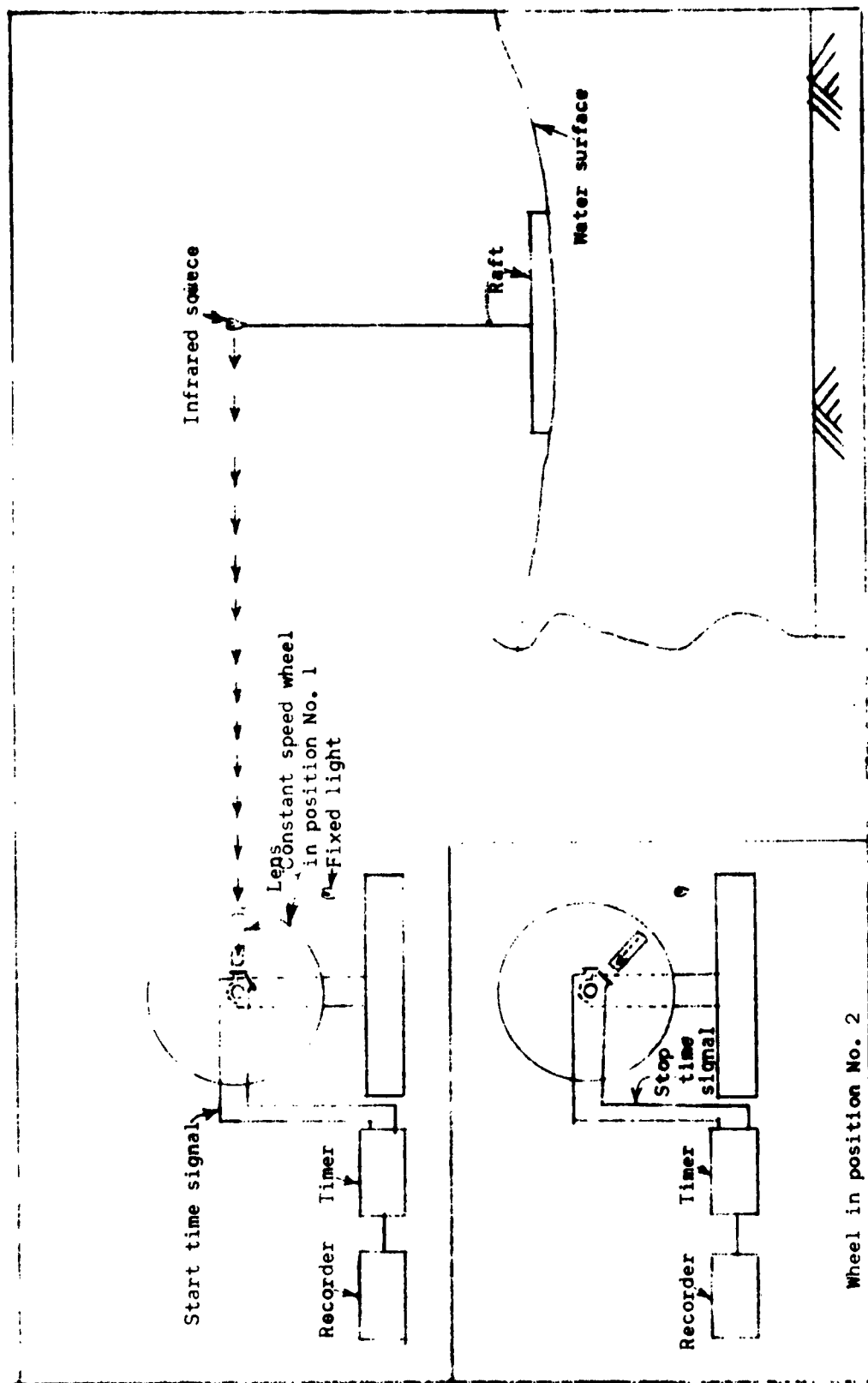


Figure 2 Basic component arrangement of water level pickup using a lens



Figure 3 Duct and Photo-cells as arranged during static and dynamic tests

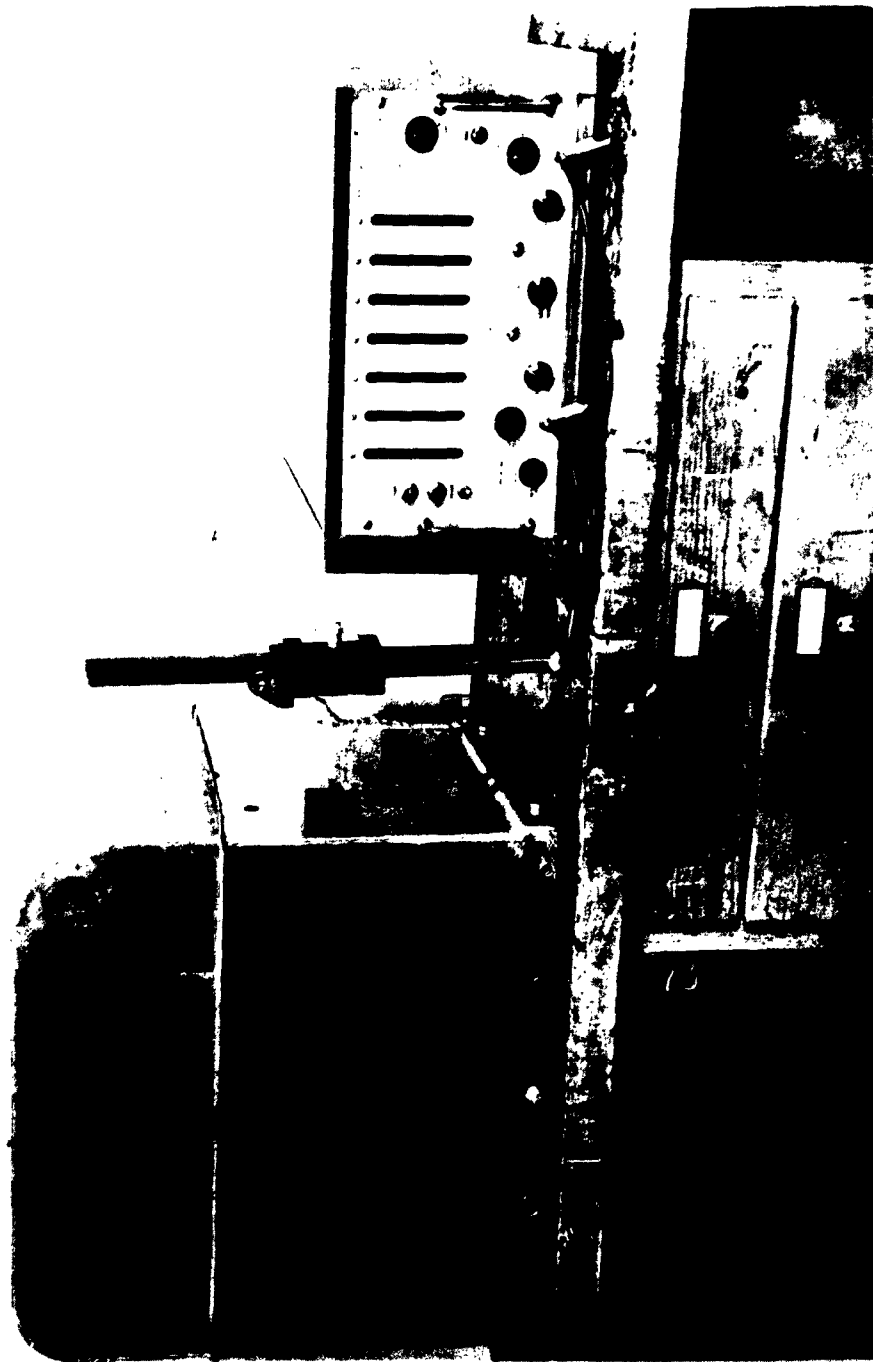


Figure 4 Pickup, movable light and timer as arranged during static tests

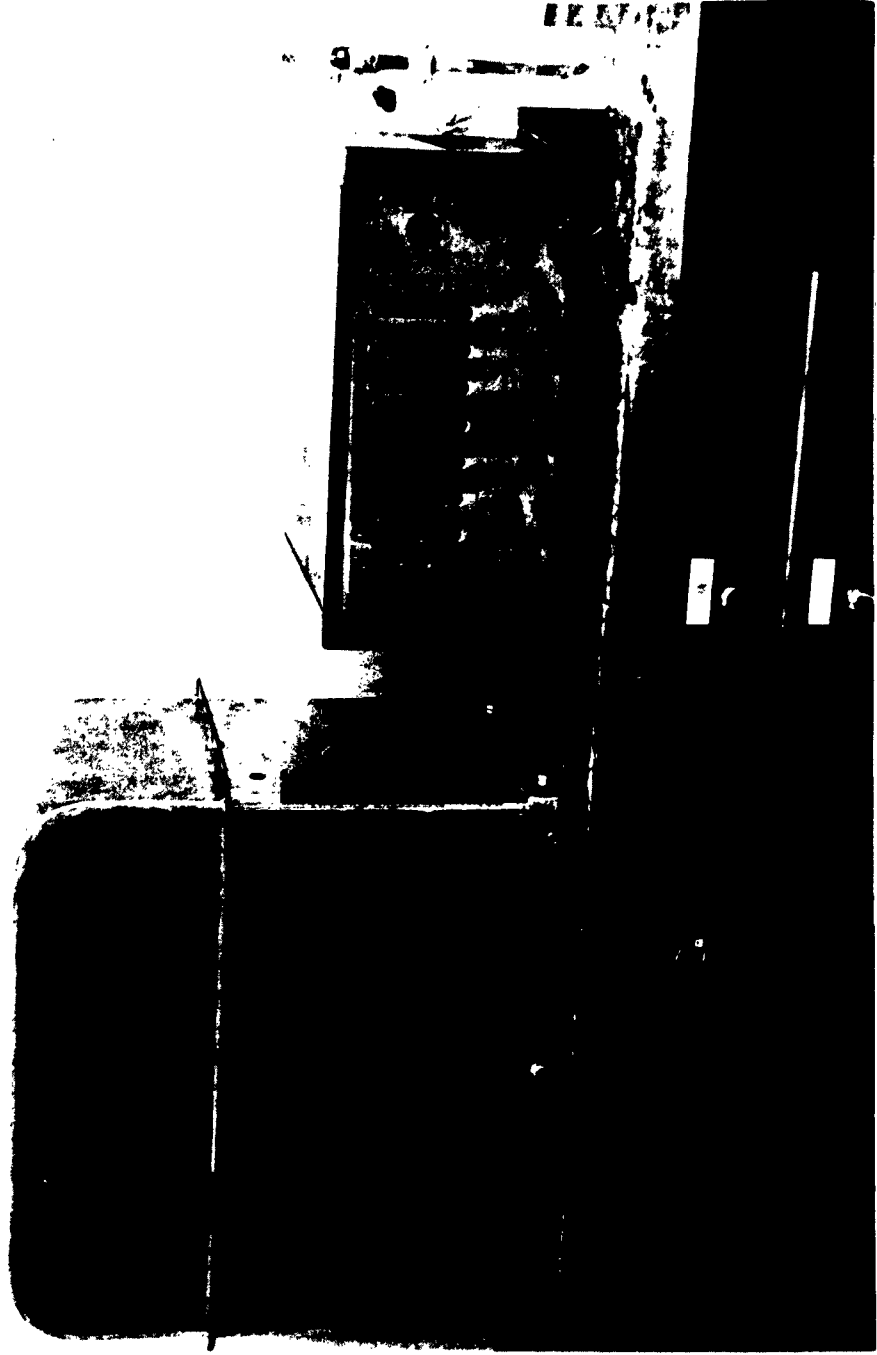


Figure 5 Pickup, motor driven movable light and timer as arranged during dynamic tests

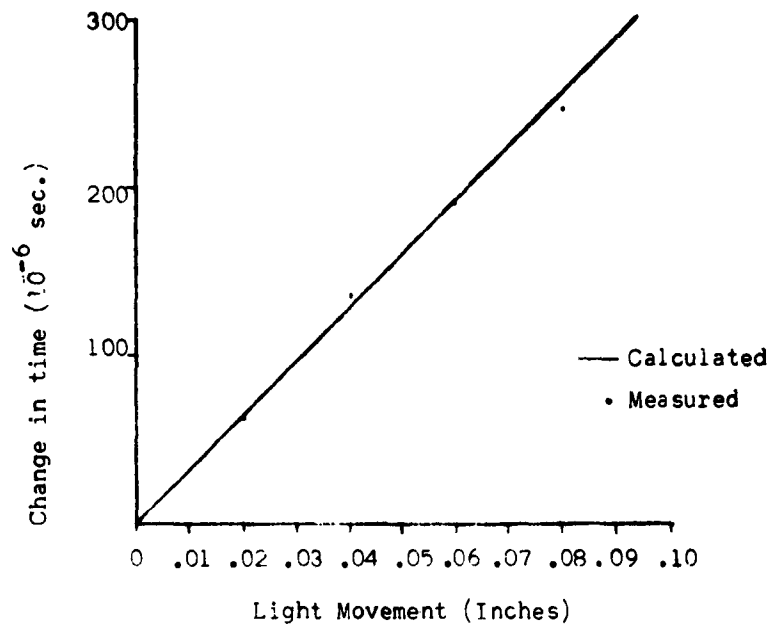


Figure 6 Change in time between pulses versus light movement with light twelve inches from center of wheel

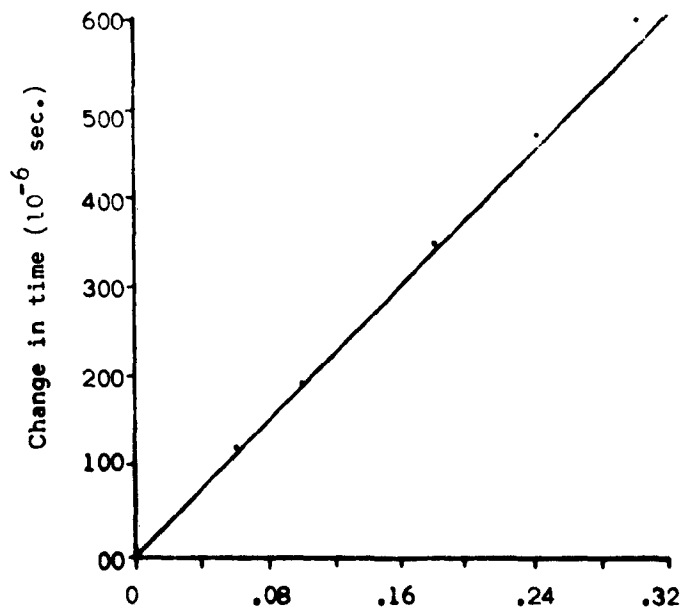


Figure 7 Light Movement (Inches)

Change in time between pulses versus light movement with light eighteen inches from center of wheel

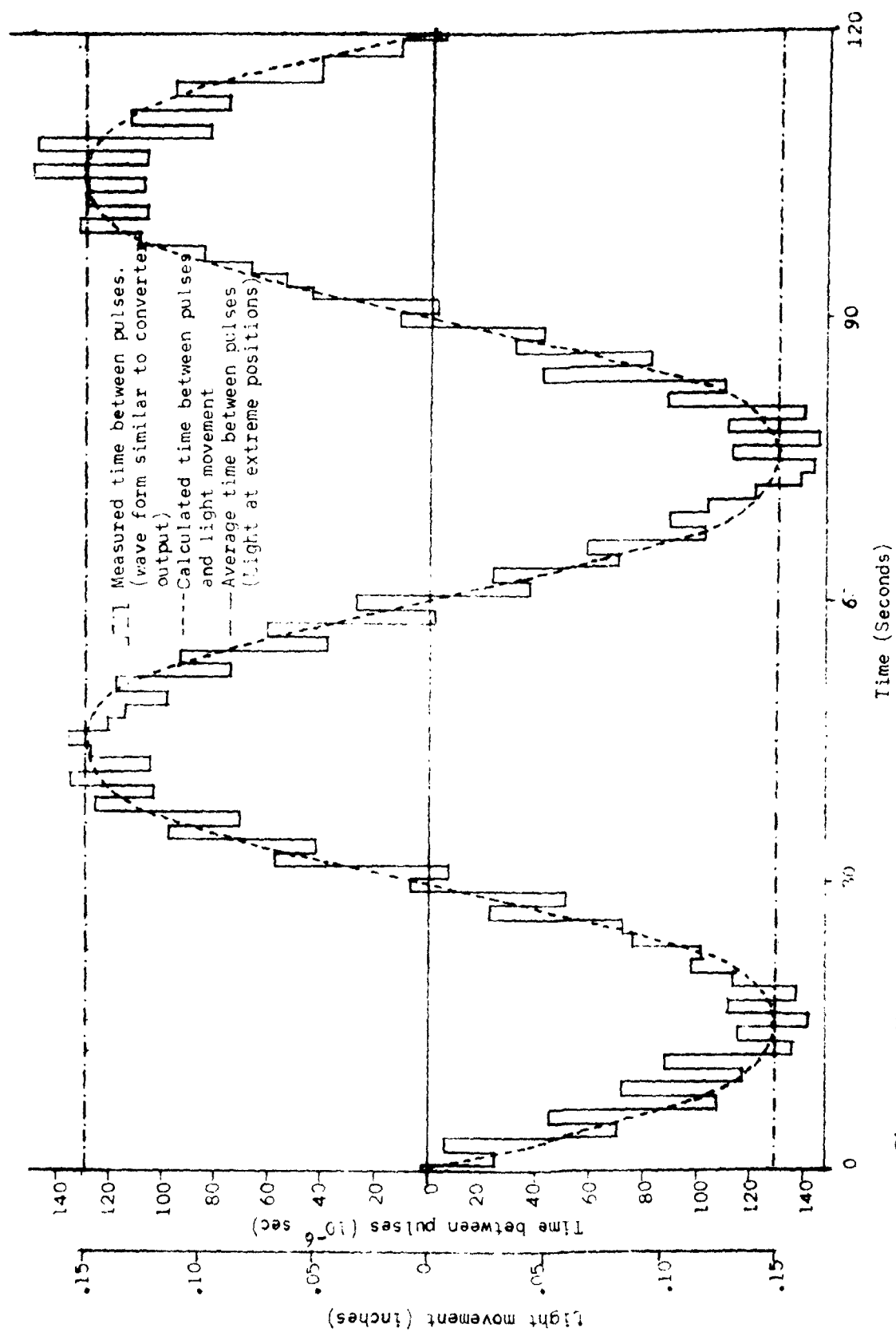


Figure 8 Time Between Pulses with Corresponding Light Movement Versus Period of Light Movement.

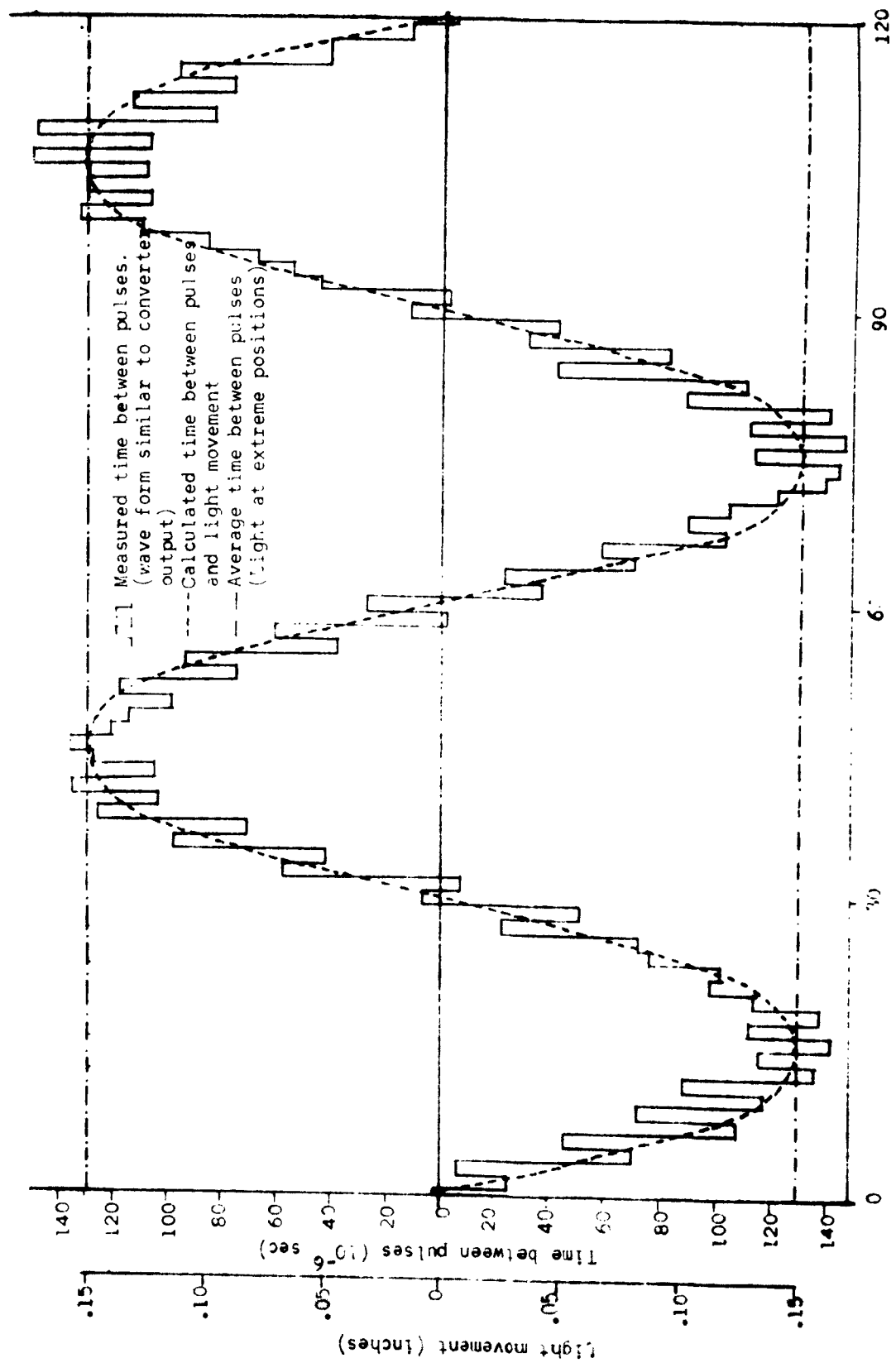


Figure 8 Time Between Pulses with Corresponding Light Movement Versus Period of Light Movement.