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DEVELOPMENT OF INSTRUMENTATION TECHNIQUES FOR MEASURING PERISCOPE VIBRATION

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NAVAL RESEARCH LABORATORY

COMMODORE H. A. SCHADE, USN, DIRECTOR

WASHINGTON, D.C.

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DEVELOPMENT OF INSTRUMENTATION TECHNIQUES FOR MEASURING PERISCOPE VIBRATION

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Approved by:

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Problem No. 40S06-02 November 4, 1947

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ABSTRACT

This report covers the work done to date on the development of instrumentation and techniques for measuring quantitatively the vibration occurring in submarine periscopes while proceeding at periscope depth. As a result of the work done, two methods have been developed, both of which give quantitative measurements with reasonable accuracy. One method gives the actual mechanical vibration at the tip of the periscope in terms of frequency and amplitude; the other gives the optical vibration of the whole system in terms of the angular displacement of the field of view. Each of these methods can be used independently or simultaneously. A correlation between the optical motion and mechanical motion can be obtained.

AUTHORIZATION

On March 28, 1947 the Bureau of Ships requested the Naval Research Laboratory to devise procedures and techniques whereby the vibration amplitudes and frequencies of submarine periscopes could be measured and evaluated.[1] The Laboratory accepted the problem on April 28, 1947 and assigned it to the Shock and Vibration Section of the Sound Division as problem 40S06-02.[2]

PROBLEM STATUS

This report concludes the work on the problem as originally assigned by the Bureau of Ships. However, at a conference conducted at the Navy Department, it was decided that the problem would be expanded and that the Laboratory would be requested to continue the work on additional investigations on another phase of the problem. This will attempt to:

1) correlate the optical and mechanical motion of the periscope,

2) perfect the optical measurements in order to achieve more accuracy at the lower amplitudes of vibration,

3) investigate the "higher" frequency vibrations suspected to be present, and

4) evaluate the vibration dampers currently used in periscopes.

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1 *BuShips ltr Serial 5815-330, SS/S24-9(5815-330) of 28 March 1947 to Director, NRL. Restricted Problem Assignment Request Number SRD 1094/47.*

2 *NRL ltr Number 115-46175 of 28 April 1947 to Chief of the Bureau of Ships. Restricted Acceptance of problem S06-02.*

DEVELOPMENT OF INSTRUMENTATION TECHNIQUES FOR MEASURING PERISCOPE VIBRATION

INTRODUCTION

Although it has long been known that excessive vibrations are present in the attack periscope at submerged speeds over six knots, no quantitative measurements of these vibrations had ever been made. It was realized that methods for accurately measuring in the field the frequencies and amplitudes of vibration should be developed prior to any attempted improvements in periscope design.

The immediate objective of the research undertaken at NRL on this problem was to provide a convenient means of obtaining vibrational frequencies and amplitudes of the periscope with the submarine operating at periscope depth. Ideally the instrumentation techniques should not involve any elaborate or time-consuming installation or involve dangerous operating maneuvers for the submarine.

The data obtained will ultimately be used to:

(1) provide the basis for the writing of specifications for improved models of periscopes,

(2) permit the evaluation of the performance of the present mechanical and fluid types of vibration dampers, and

(3) determine the efficiency of present periscopes at the higher submerged speeds of the GUPPY class submarine.

Performance evaluation of periscopes can be accomplished in the laboratory only with great difficulty due to the problems of providing water mass loading of the periscope tube, and providing hydrodynamic vibration excitation. All the work on this problem, therefore, was done in a series of two tests on two different fleet-type submarines. The first series was conducted on the USS QUILLBACK SS424, operating from the New London Submarine Base, during July 1 and 2, 1947; the second on the USS CHARR SS328, during August 28 and 29, 1947 at San Diego, California. In each case, the measurements were made on the 40-foot attack periscope mounted in the number two position. All data were taken with the number one periscope retracted, the attack scope fully extended and with the submarine submerged at normal periscope depth, that is, with the tip two to three feet above the surface of the water.

As suggested by the Bureau[3], two principal methods of instrumentation were tried:

(1) Mechanical - Recording the mechanical motion of the periscope from within the pressure hull in such a way as not to load the periscope.

(2) Optical - Projecting a steady beam of light into the optical system and recording the resulting vibrations on photographic film at the eyescope.

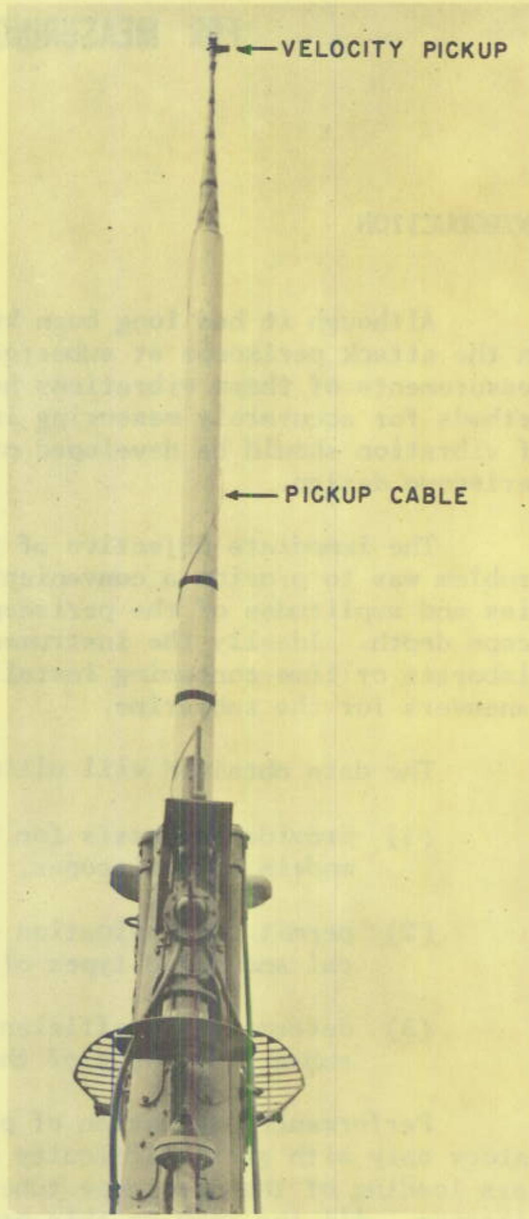

Figure 1

MECHANICAL VIBRATION MEASUREMENTS

To measure the actual mechanical vibration of the periscope at the tip while the submarine was operating at various submerged speeds the following method was evolved and tried on the USS QUILLBACK.

A velocity-type vibration pickup (Consolidated Engr. Corp. Type 4-102) was mounted at the tip of the periscope, just below the window, by means of a brass collar. (Figure 1). A lead-in cable, consisting of a 3/16-inch copper tube with an inner conductor, served to connect the pickup to a recording oscillograph located in the control room of the ship. The electrical circuit was completed through the pressure hull by connecting the

3 *Cf. footnote 1.*

[redacted]

Lead-in cable to the existing searchlight circuit terminating at the junction box located on the bridge. The electrical impulses from the pickup were picked up from the isolated searchlight circuit in the conning tower, amplified, and recorded by means of a Consolidated Recording Oscillograph. This instrument is able to record as many as 14 channels on a roll of photographic paper 9 inches wide. The oscillograph and its associated amplifiers and power supplies was set up on the plotting table in the control room of the ship. (Figure 2) A series of records was taken of the vibration in two axes, fore and aft and side to side, for different ship speeds from two to eight knots.

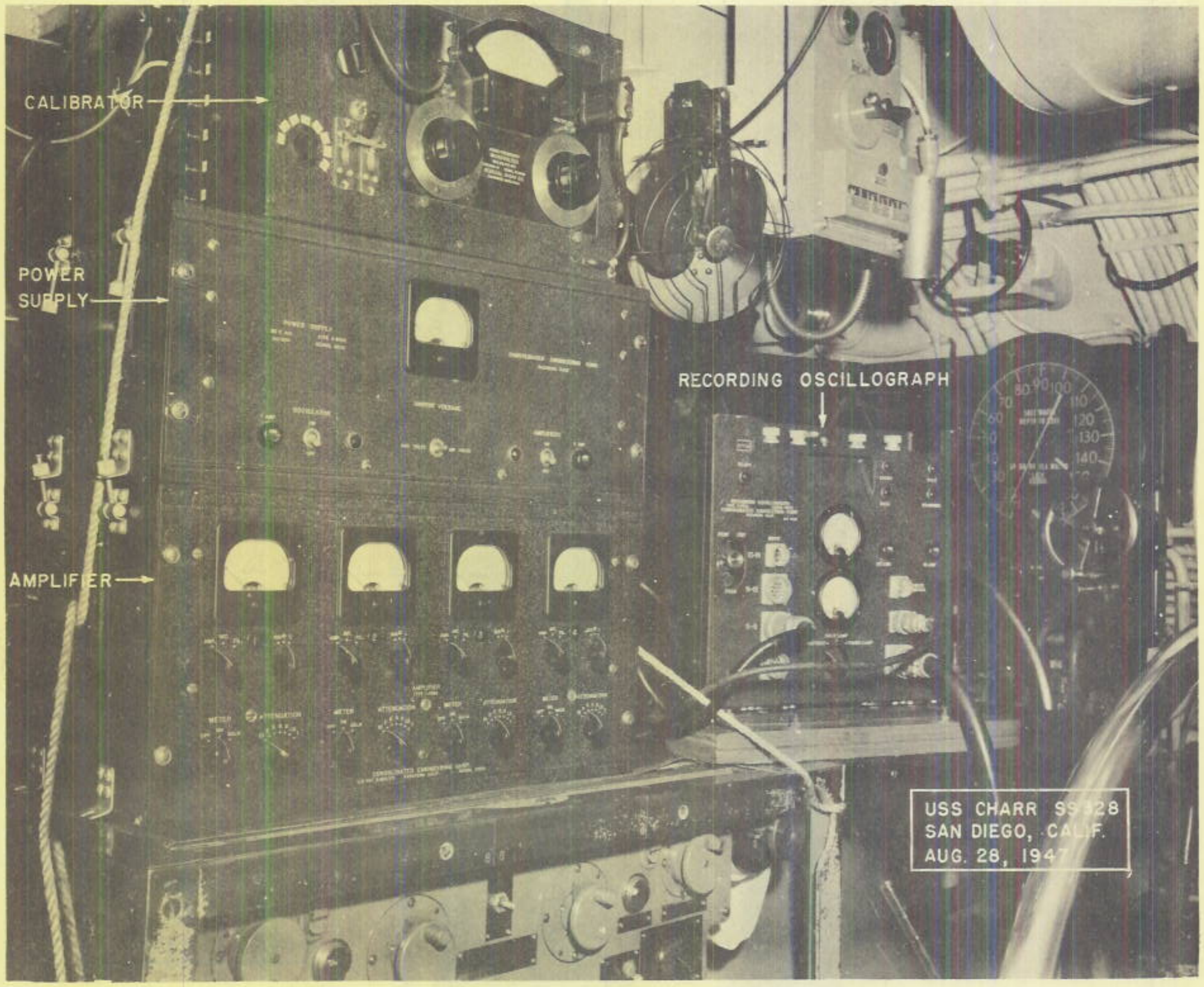

Figure 2

On the USS CHARR this method was repeated, with the exception that two pickups were used. (Figure 3) In this manner, simultaneous records were obtained of the vibration along the two principal axes, thereby permitting a correlation of the motion in the two planes. In both tests good, clear records were obtained and analyzed.

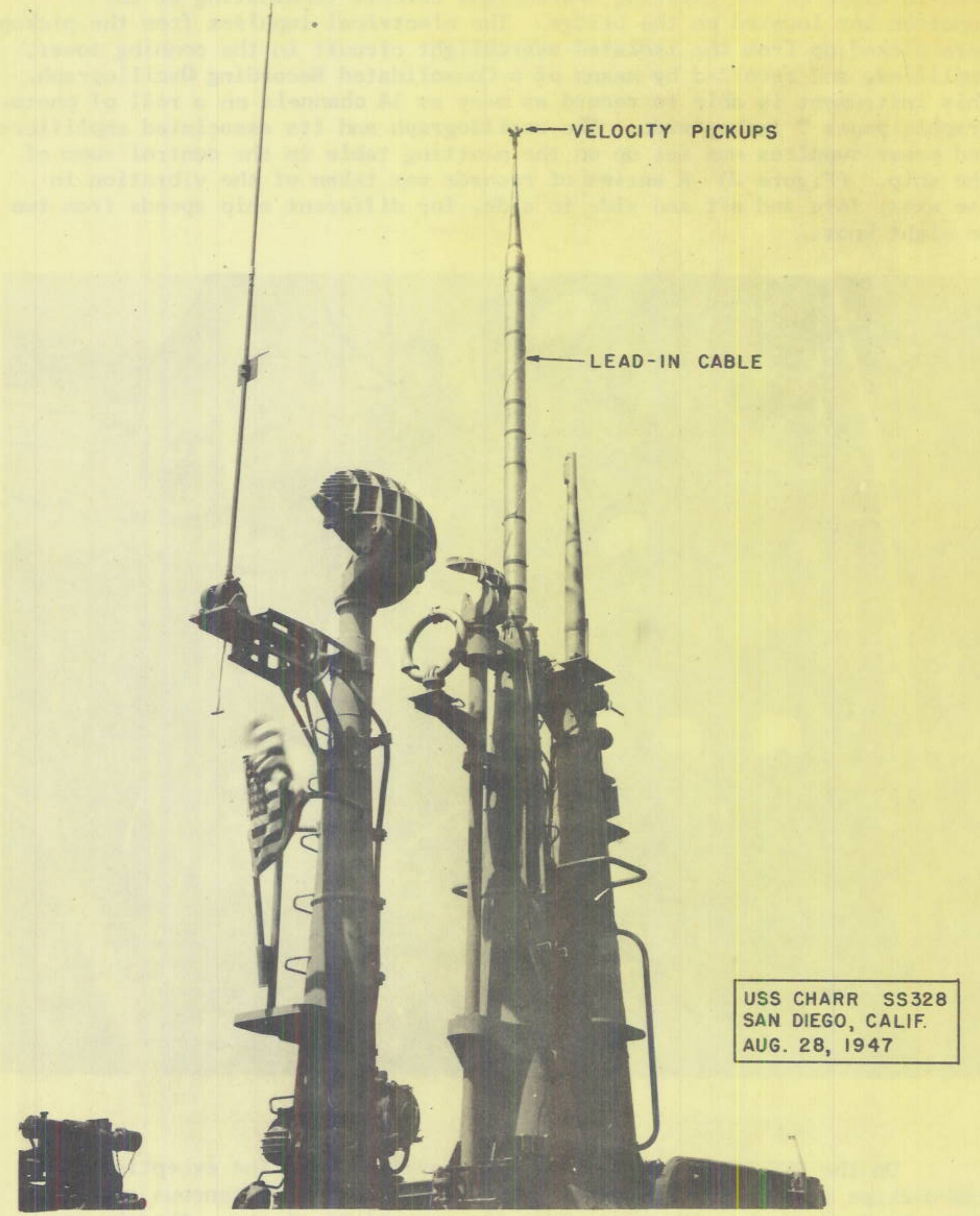
VELOCITY PICKUPS
LEAD-IN CABLE
USS CHARR SS328
SAN DIEGO, CALIF.
AUG. 28, 1947

Figure 3

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OPTICAL VIBRATION

Four different attempts were made to record on photographic film the apparent optical motion of a steady source of light in the field of view of the scope. In each case a 16-millimeter periscope movie camera mounted at the eyepiece served as the recorder (Figure 4). The camera was modified by removing the shutter and the intermittent mechanism to permit the film to move continuously in front of the lens and thus provide a time base for any apparent motion in the field of view of the scope. It was hoped to provide a steady point source of light external to the submarine, and to obtain a wavy track on the film as the periscope vibrated.

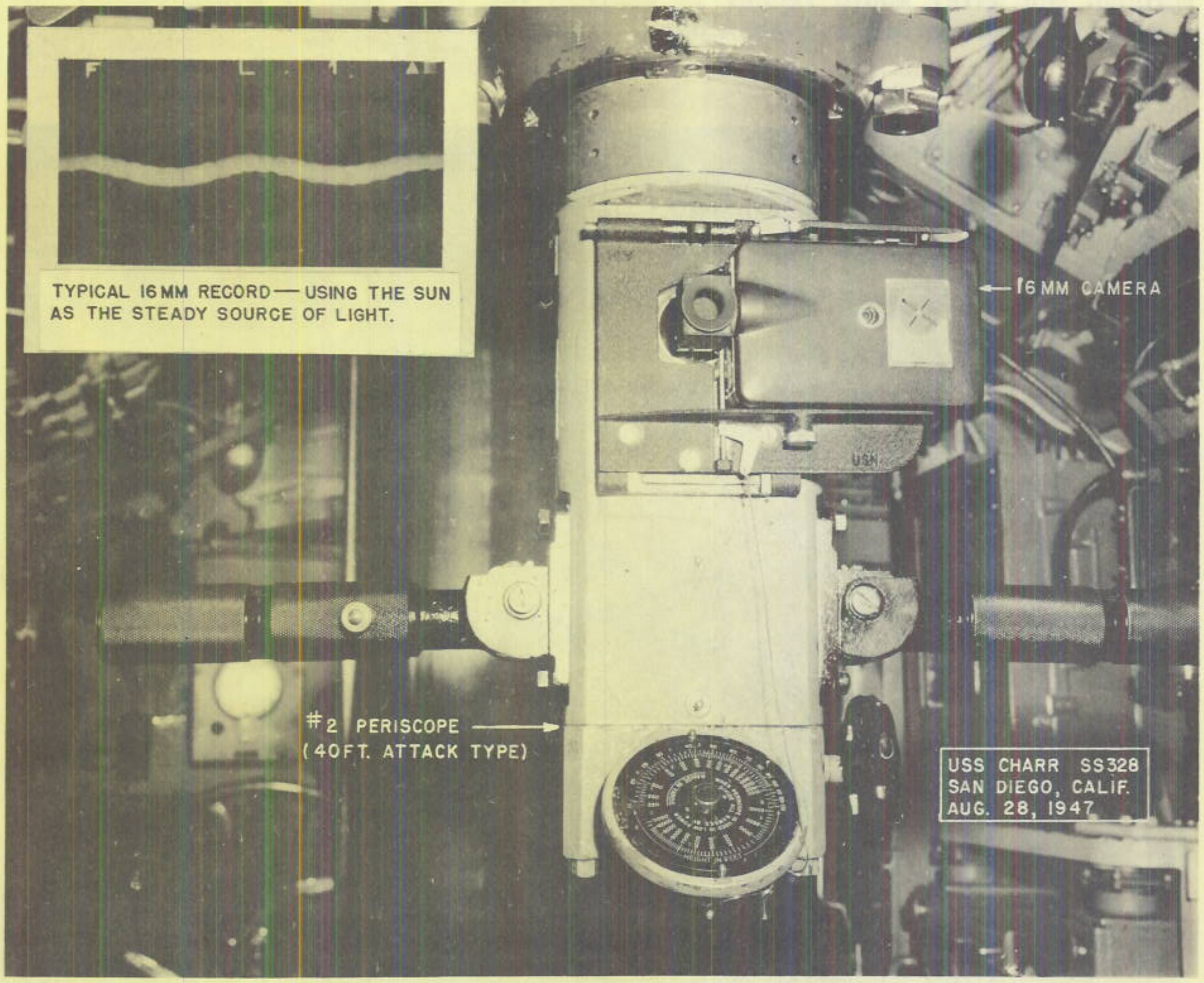

Figure 4

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Providing an efficient and practical source of light proved to be more difficult than anticipated. The following were tried in the order listed:

(1) A 1000-watt underwater diving lamp was mounted on the bow of the USS QUILLBACK and focused at the tip of the extended periscope (Figure 5). It was hoped that at night the light would be visible through the periscope while the ship was submerged.

On the actual trial it was found that the light was invisible at the eyepiece of the periscope due to its low intensity and the great dispersion of light through the murky water. It is believed that even if a more intense source of light were used, the scattering and distortion of the beam through the water would render it useless for this type of measurement. As a result, this method was abandoned.

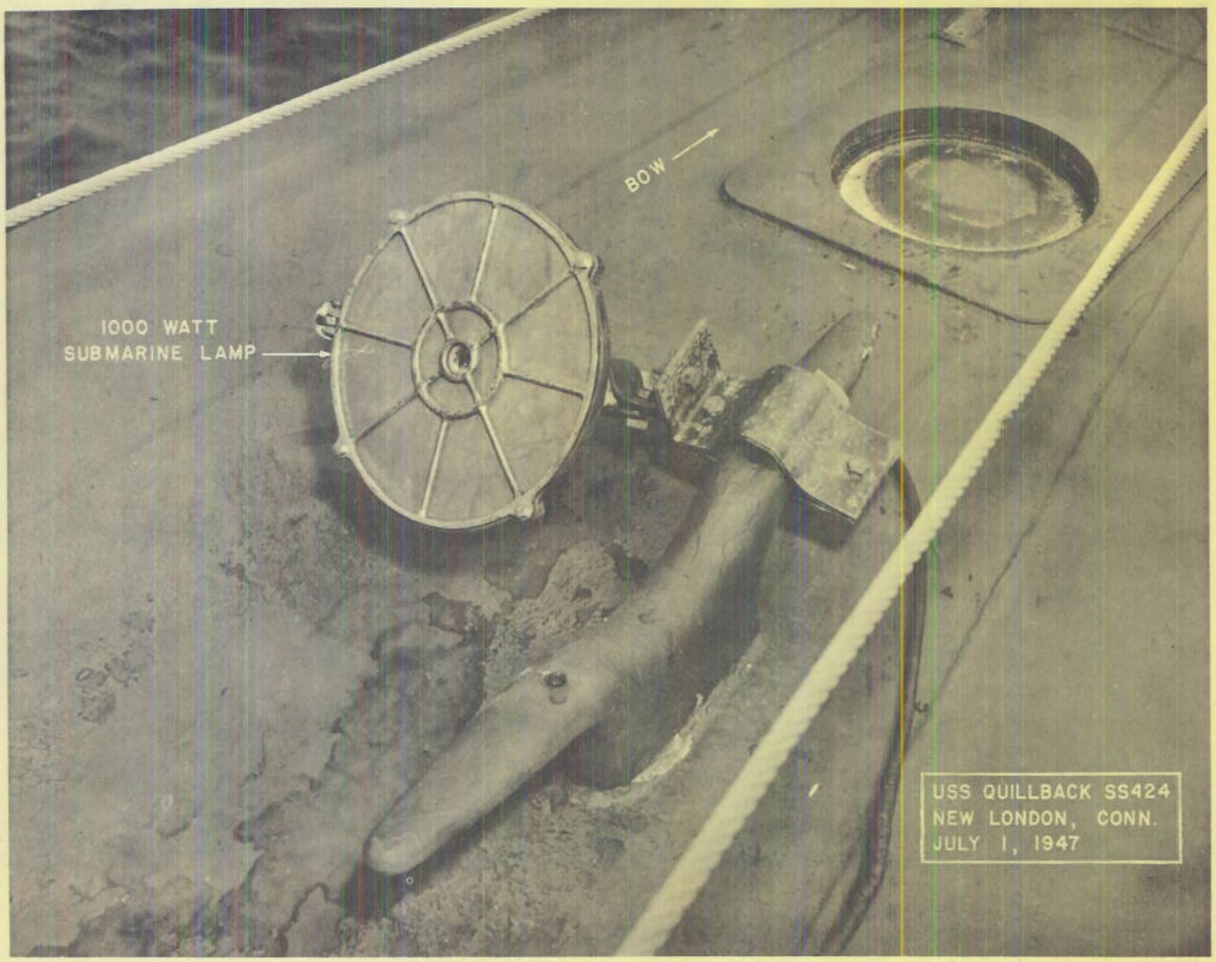


Figure 5

(2) A 12-inch Navy searchlight mounted on an auxiliary surface vessel was used as the light source. This test was conducted at night on Long Island Sound. The surface ship was ordered to remain in a fixed position and the submarine executed a series of head-on runs toward it at ranges of two to four thousand yards. The light was clearly visible to the human eye at the eyepiece of the periscope. However, on developing the film it was found that no record had been obtained due to the low intensity of the light. The film used was the fastest available - Eastman Super XX.

It was decided that a more intense source of light might yield some results.

(3) The next attempt to record the optical motion was made on the USS CHARR operating from the San Diego Naval Base. An operating area was selected along the coast north of San Diego harbor, in the La Jolla Canyon, which provided fairly deep water close to shore. A 5-foot diameter anti-aircraft searchlight was mounted on top of a cliff overlooking the ocean and served as the light source for this trial (Figure 6). The searchlight was manned by a shore party equipped with a radio transmitter and receiver for use in communicating with the submarine.

The test was conducted at night and the searchlight provided an intense point-source of light. A series of runs toward the light was attempted at

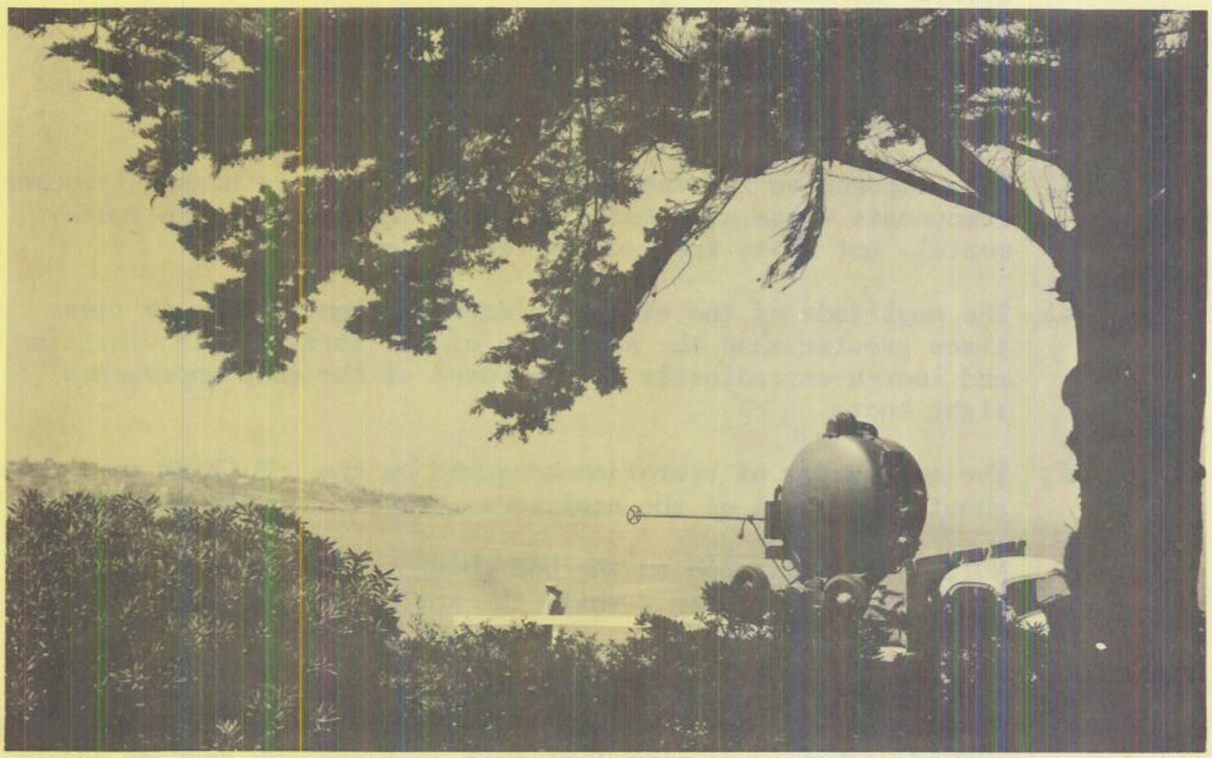


Figure 6

ranges of four to eight thousand yards.

Because of the difficulty encountered in keeping the ship's course directly into the narrow light beam, no measurable records were obtained. Owing to the necessity of frequently replacing the carbons in the searchlight, this method was abandoned as impracticable.

(4) In the last test the source of light used was the sun itself. A dark filter was inserted between the periscope eyepiece and the camera lens to cut down the intensity of the sun's rays and permit the recording of only the sun's disk. Measurements were made in the daytime with the sun near the horizon.

This method gave a good record of the apparent vibration of the sun as a wavy track on the film as shown in Figure 4.

RESULTS OF DATA TAKEN

The mechanical vibration as recorded on the oscillograph was analyzed and corrected for the reduced response of the pickup at the lower frequencies. The corrected data shows that:

(1) The vibration present in submarine periscopes is composed of several different frequencies.

(2) The main or fundamental frequency is low - five to six cycles per second - and remains constant through all ship speeds and amplitudes of vibration.

(3) Superimposed on the fundamental frequencies are higher frequency components whose amplitudes are small compared to the fundamental, but whose frequencies remain constant.

(4) The amplitude of the side-to-side vibration is four to five times greater than the amplitude of the fore-and-aft vibration and increases radically as the speed of the ship approaches eight knots.

(5) The amplitudes of vibration measured on the USS CHARR were only about 50 percent of the amplitudes measured on the USS QUILLBACK.

NOTE: The periscope on the USS CHARR was equipped with a vibration damper while the one on the USS QUILLBACK was not (Figure 7).

(6) The vibration records taken on the USS CHARR show that a definite "damping" action is occurring at irregular intervals. The records taken on the USS QUILLBACK show no such damping action (Figure 8).

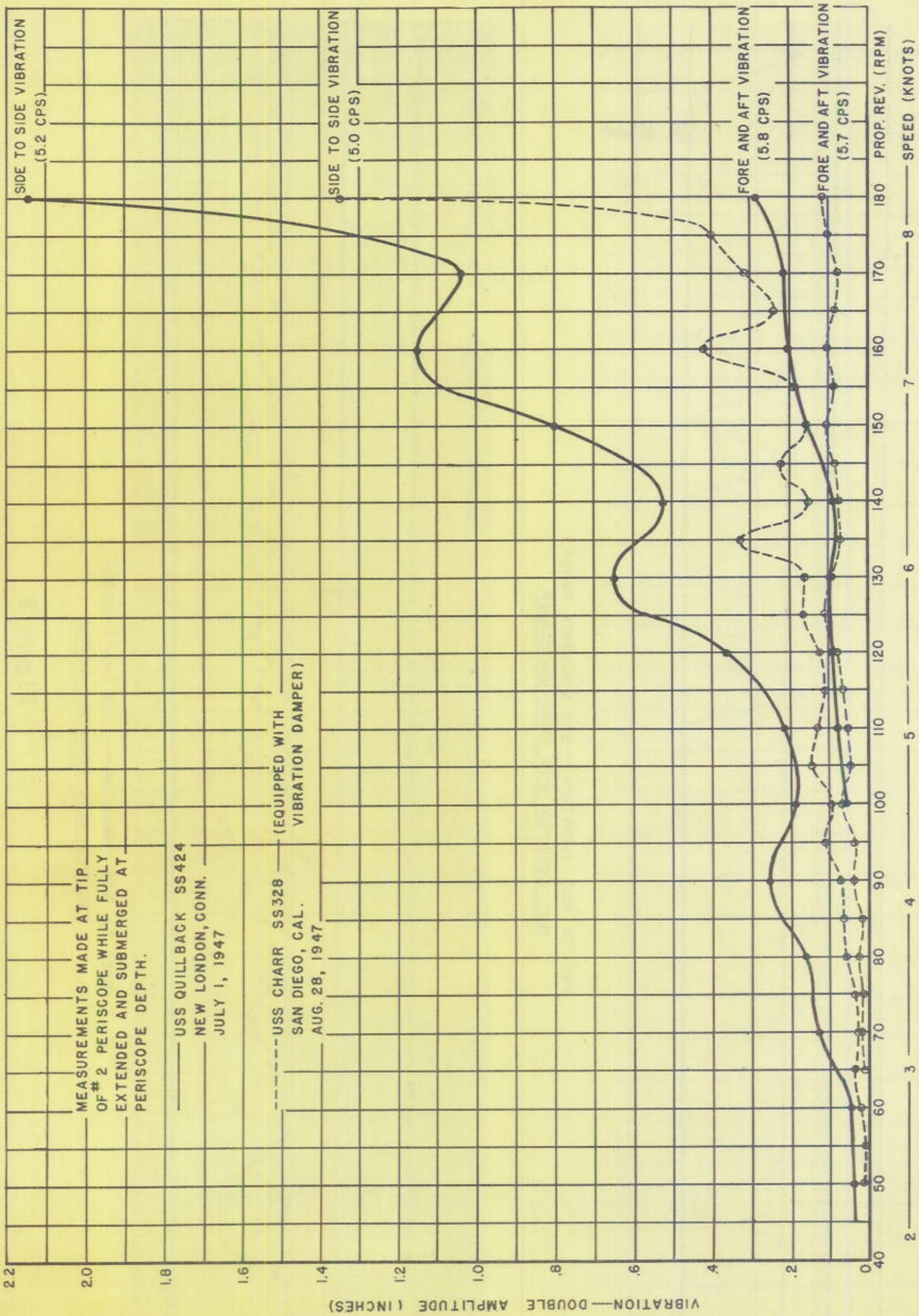
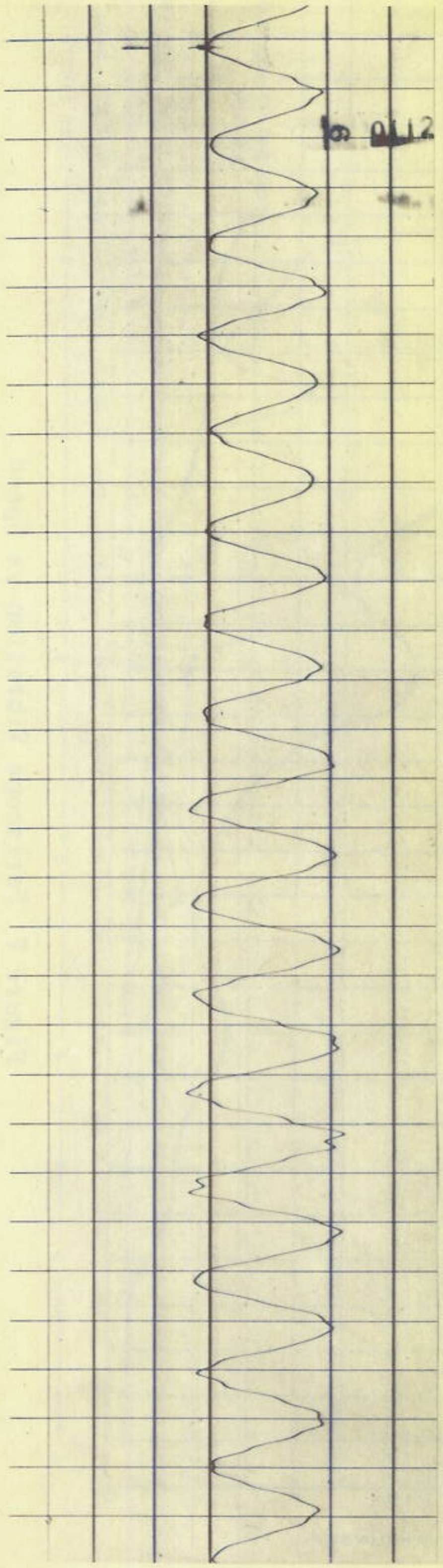
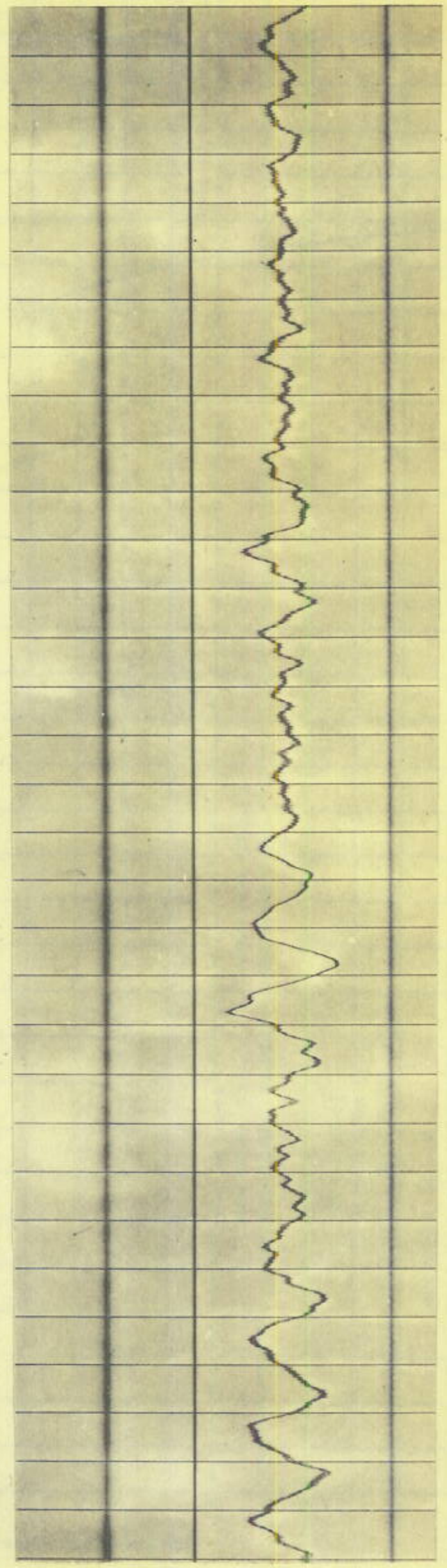


Figure 7 Periscope Vibration vs Speed



SIDE TO SIDE VIBRATION — USS QUILLBACK SS 424
NOT EQUIPPED WITH VIBRATION DAMPER



SIDE TO SIDE VIBRATION — USS CHARR SS 328
EQUIPPED WITH VIBRATION DAMPER

Figure 8

The accompanying table shows the amplitudes of the fundamental frequencies measured on the USS QUILLBACK and the relative amount of the higher frequency components.

TABLE I

Prop. Speed (RPM)	Side to Side Vibration			Fore and Aft Vibration	
	5.2 cps Max. Amplitude (inches)	27 cps Percentage of main freq.	42 cps Percentage of main freq.	5.8 cps Max. Amplitude (inches)	42 cps Percentage of main freq.
45	.039	4.1	---		
60	.043	4.4	---		
70	.125	1.5	---		
80	.162	1.5	---		
90	.249	1.3	---		
100	.184	1.3	---	.054	3.7
110	.227	1.1	---		
120	.357	---	2.0	.090	1.1
130	.656	---	1.6	.099	13.
140	.520	---	1.5	.082	18.
150	.800	---	1.6	.156	6.4
160	1.16	3.0	---	.197	4.0
170	1.03	5.3	---		
180	2.16	3.2	---	.287	3.5

The effect of the radically rising amplitudes of the side to side vibration at ship speeds close to eight knots can probably be explained by the fact that the "Von Karman" effect is beginning to have its maximum effect at this speed.

The optical motion as recorded on the 16 millimeter film record was resolved into angular motion in the following manner. As the diameter of the sun subtends an angle which is constant for any particular day, the total angular displacement was calculated as the ratio of the amplitude of the wavy track to the width of the track (diameter of the sun). This ratio multiplied by the angular width of the sun (31.74 minutes on the day of the test) gave the total apparent angular motion in the optical system.

The angular displacement was plotted against ship speed and the graph shows a marked resemblance to the graph of the mechanical motion (Figure 9). A graph was then plotted of the optical motion versus the mechanical motion for various ship speeds (Figure 10). This data, while very sketchy, seems to bear out the fact that an almost linear relation exists between these two quantities.

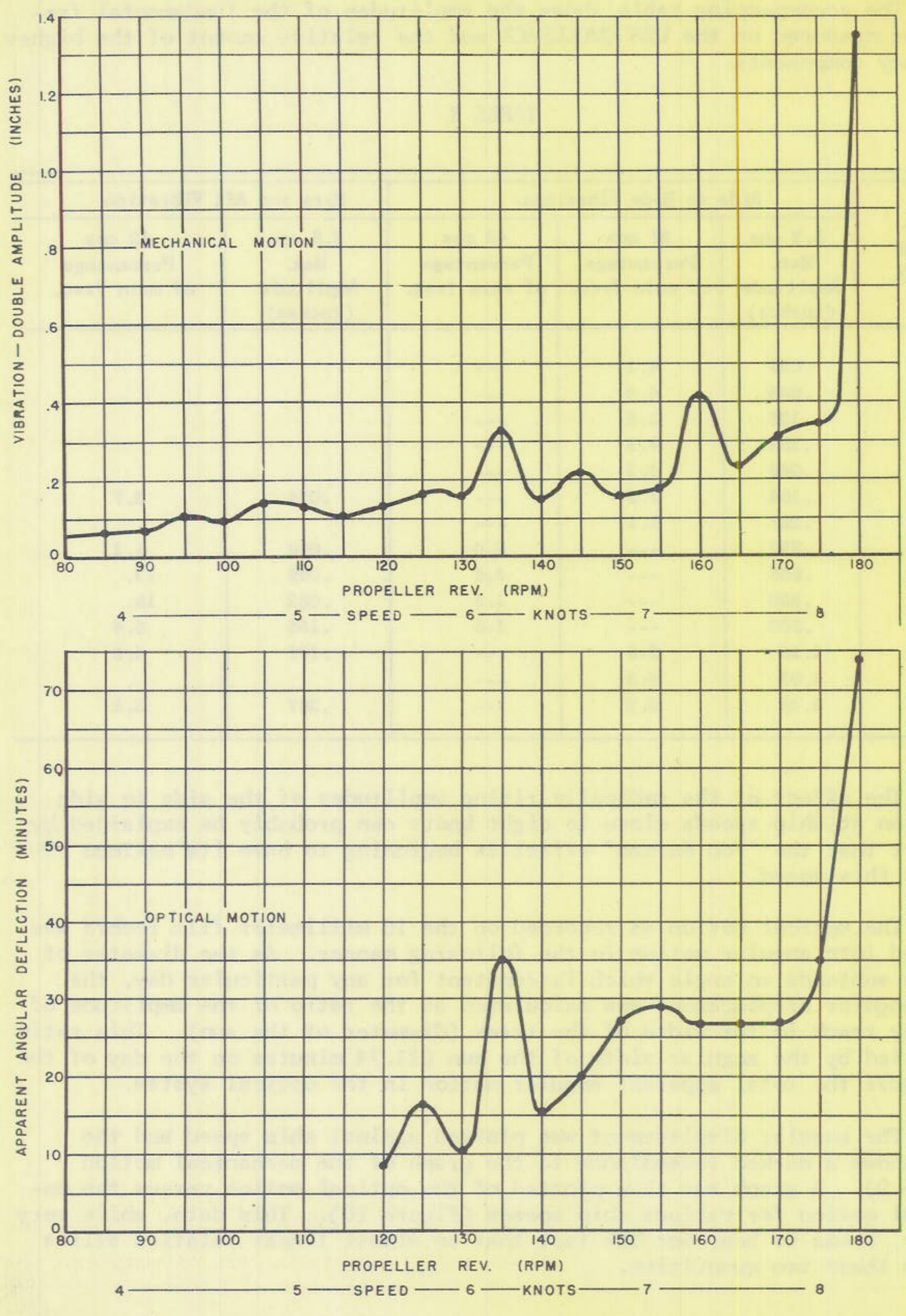


Figure 9 Periscope Vibration vs Speed

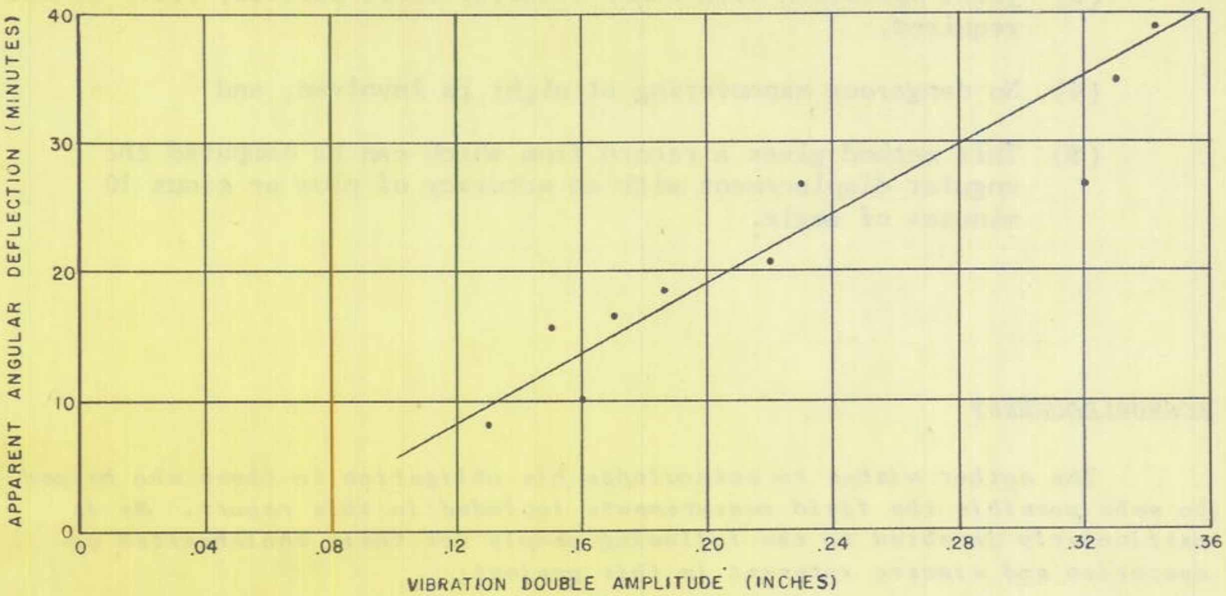


Figure 10 Optical Motion vs Mechanical Motion

RESULTS OF INSTRUMENTATION TECHNIQUES

As a result of the two series of tests conducted, it is believed that for the measurement of mechanical vibration on any part of the submerged periscope the procedure described above is entirely satisfactory and gives good results. This method of instrumentation has the following features:

(1) The recording equipment and vibration pickups are easily installed in a few hours.

(2) The equipment can be operated by one man.

(3) Records can be taken from as many as 14 pickups. (To study the flexing characteristics of the periscopes, this feature would be required).

(4) Good, clear records can be obtained from which the motion may be calculated to an overall accuracy of plus or minus 10 percent.

For the measurement of the optical vibration the most convenient and straight-forward method appears to be the method which uses the sun as the light source and the modified movie camera as the recorder. Its advantages over the other three methods tried to date are:

(1) No elaborate installation or preparation is required,

(2) Measurements may be made on any day that the sun is shining,

[redacted]

(3) Joint operation with other vessels, shore parties, etc., is not required,

(4) No dangerous maneuvering at night is involved, and

(5) This method gives a record from which can be computed the angular displacement with an accuracy of plus or minus 10 minutes of angle.

ACKNOWLEDGEMENT

The author wishes to acknowledge his obligation to those who helped to make possible the field measurements included in this report. He is particularly indebted to the following people for their wholehearted cooperation and sincere interest in this project:

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