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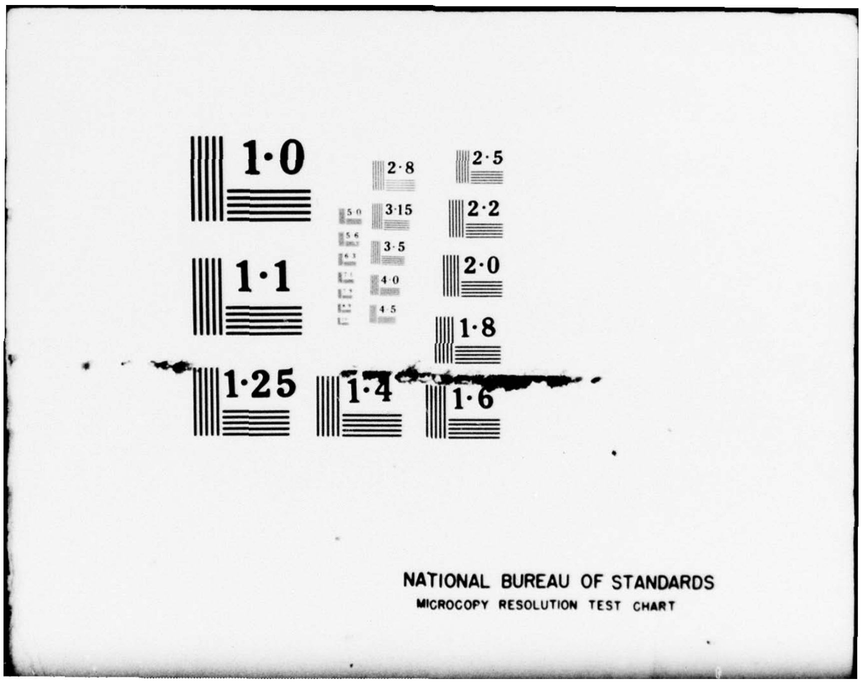
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DETERMINATION OF PERFORMANCE CHARACTERISTICS OF THE SUBMARINE TOWED COMMUNICATIONS ADVANCED BUOY MODEL

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DETERMINATION OF PERFORMANCE CHARACTERISTICS OF THE SUBMARINE TOWED COMMUNICATIONS ADVANCED BUOY MODEL

by

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September 1977

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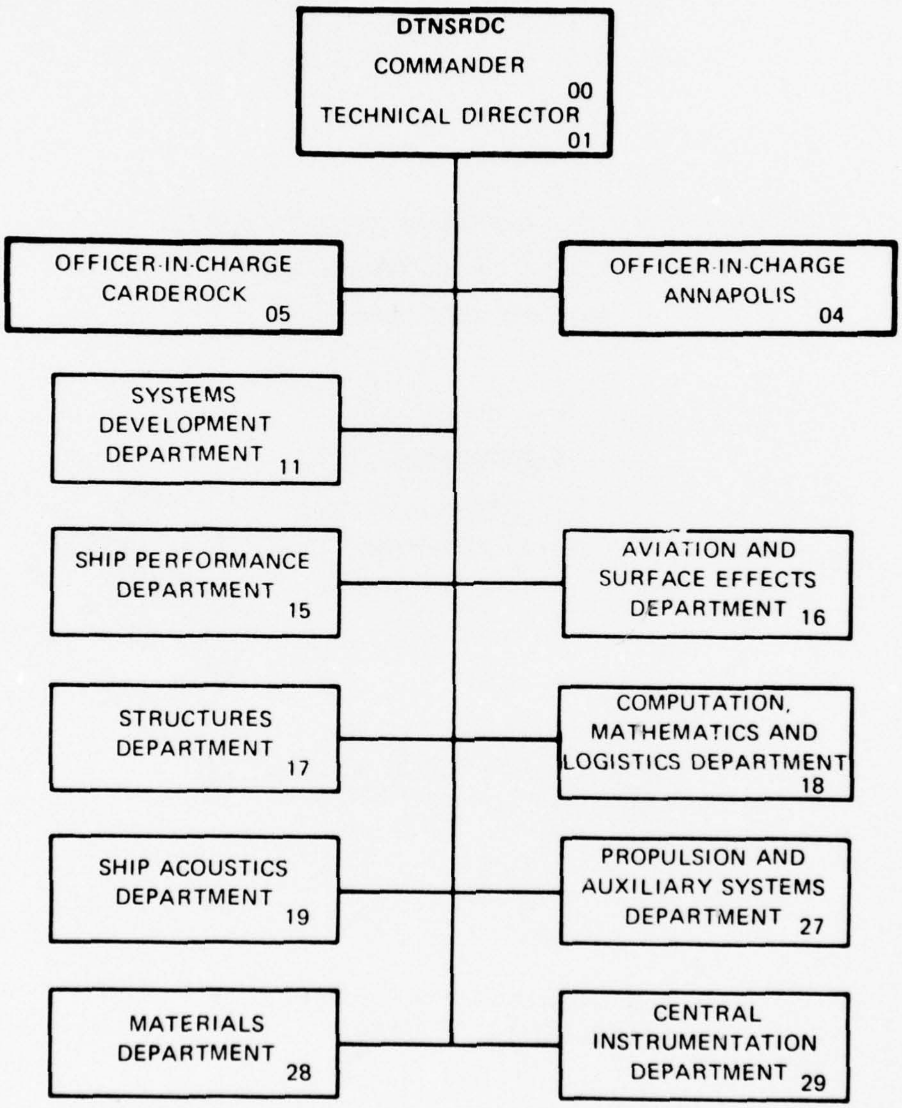

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REPORT DOCUMENTATION PAGE

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1. REPORT NUMBER: SPD-661-02
2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle): Determination of Performance Characteristics of the Submarine Towed Communications Advanced Buoy Model.
5. TYPE OF REPORT & PERIOD COVERED: Departmental rept.
6. PERFORMING ORG. REPORT NUMBER: ~~SPD-661-02~~
7. AUTHOR(s): Raymond Para [redacted] Corey Zimmerman
8. CONTRACT OR GRANT NUMBER(s): F21222
9. PERFORMING ORGANIZATION NAME AND ADDRESS: David W. Taylor Naval Ship R&D Center, Ship Performance Department, Bethesda, Maryland 20084
10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: Element 62721N, [redacted] XF21222-702, DTNSRDC W.U. 1548-214
11. CONTROLLING OFFICE NAME AND ADDRESS: Naval Electronic Systems Command (NAVELEX) Headquarters, Washington, D. C. 20362
12. REPORT DATE: Sep[redacted]1977
13. NUMBER OF PAGES: ~~21~~ 25p.
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)
15. SECURITY CLASS. (of this report): UNCLASSIFIED

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report): Approved for Public Release: Distribution Unlimited
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)
18. SUPPLEMENTARY NOTES
19. KEY WORDS (Continue on reverse side if necessary and identify by block number)
    - Submarine Communications
    - Buoy Model
    - Buoy Characteristics
    - Towed System
20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The SSN type submarines require a communications system for high-speed and deep depth operations. The performance of an existing towed communications system is not sufficient to meet new high-speed requirements. An Engineering Development Model (EDM) buoy was constructed and evaluated. The evaluation showed the buoy to perform satisfactorily over the speed range of 0 to 25 knots, and determined the best settings for the horizontal stabilizer to be zero degrees or less.

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ABSTRACT

The SSN type submarines require a communications system for high-speed and deep depth operations. The performance of an existing towed communications system is not sufficient to meet new high-speed requirements. An Engineering Development Model (EDM) buoy was constructed and evaluated. The evaluation showed the buoy to perform satisfactorily over the speed range of 0 to 25 knots, and determined the best settings for the horizontal stabilizer to be zero degrees or less.

ADMINISTRATIVE INFORMATION

The exploratory development program described in this report was funded by the Naval Electronic Systems Command under Program Element 62721N, Task Area XF 21.222.702, David W. Taylor Naval Ship Research and Development Center Work Unit 1-1548-214.

INTRODUCTION

In response to the need for a communications system for deeply submerged high-speed SSN-type submarines, the Naval Electronic Systems Command (NAVELEX) requested the David W. Taylor Naval Ship Research and Development Center (DTNSRDC) to explore the feasibility of towing a wingless, lifting buoy to act as a near-surface platform for communications antenna(s). The performance of an existing towed communications system (BIAS) is not sufficient to meet new high-speed requirements. To develop a significant improvement in system performance, efforts must be focused on: (1) improved buoy hydrodynamic performance and structural integrity for operation at high-speeds near the surface; and (2) improved hydromechanical and structural towline performance.

An earlier investigation of the hydrodynamic performance characteristics of two candidate shapes for an improved buoy was conducted from which one was selected for further evaluation.[1] A 1/2-scale, fiberglass - shell

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[1] Campbell, J. F., "Comparison of Hydrodynamic Performance of Two Candidate Shapes for use as Submarine Towed Communications Buoy," NSRDC SPD Report 562-H-01 (May 1974).

buoy model of the selected shape was constructed and evaluated through a simulated operational speed range for a full-scale buoy.[2] Based on the favorable results of that investigation, a full-scale Engineering Development Model (EDM) buoy was constructed and evaluated.

This report describes an experimental evaluation of the hydrodynamic performance of the full-scale EDM Advanced Buoy. Descriptions of the model, the instrumentation, and the experimental arrangement and procedure are presented. The results include towline tension, towline angle at the buoy, and buoy pitch angle as functions of speed.

MODEL DESCRIPTION

Three basic configurations were evaluated as shown in Figure 1; without the whip antenna and with the antenna in the extended and retracted positions. The buoy is photographically shown in Figure 2. The model consists of a fiberglass-reinforced plastic (FRP) buoy shell that has a NACA 4424 section for its basic shape, an FRP stabilizer assembly, and internally housed measurement systems. The stabilizer assembly, attached at the stern of the buoy, consists of one horizontal and two vertical FRP fins. The physical characteristics of the buoy shell and the stabilizer assembly are given in Table 1. The incidence angle of the horizontal stabilizer is adjustable to ±5 degrees relative to the bottom of the vertical fin. The sign conventions and reference planes for horizontal stabilizer angle, the buoy pitch angle and the towline angle at the buoy are defined in Figure 3.

Antenna extension and retraction is controlled by the operation of a small winch/motor unit located in the forward section of the buoy. Reeling a wire rope onto the winch folds the articulated antenna mast forward. Reversing the winch allows the spring mechanism in the antenna base to extend the antenna.

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[2] Webster, B. and Campbell, J. F., "Hydromechanical Performance Evaluation of a Submarine Towed Communications Buoy Model," DTNSRDC SPD Report SPD 661-01 (April 1976).

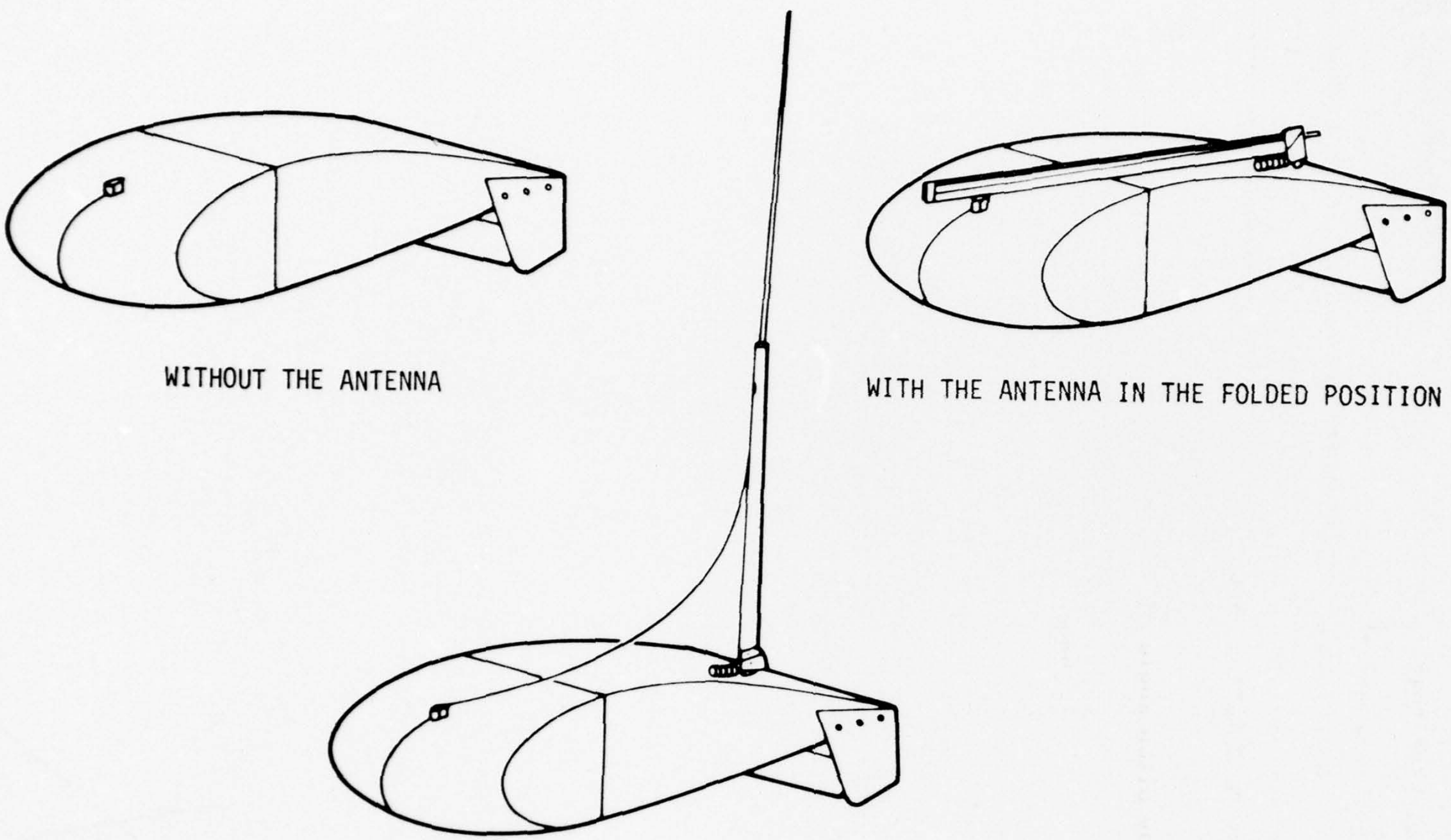

Figure 1 - Buoy Antenna Arrangements

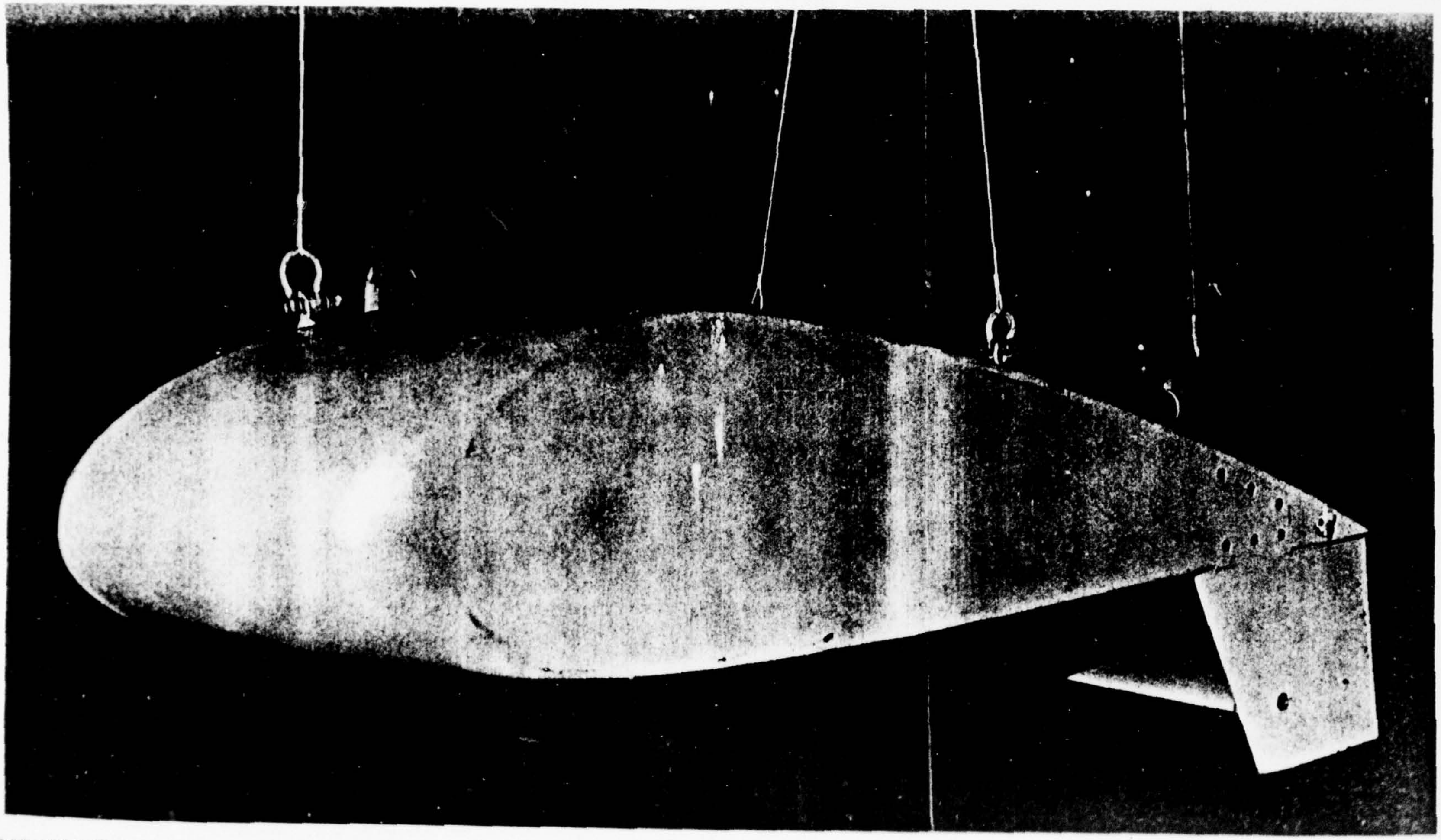

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Figure 2 - Photograph of Buoy Model

TABLE 1

Physical Characteristics of the High-Speed Buoy

Buoy Shell	
Section Shape	NACA 4424
Chord, feet (meters)	6 (1.83)
Span, feet (meters)	2.33 (.710)
Height, feet (meters)	1.44 (.439)
Nominal Wall Thickness, inches (millimeters)	3/8 (9.52)
Aspect Ratio	0.39
Volume Displacement, cubic feet (cubic meters)	12.4 (0.351)
Net Buoyancy without Antenna, pounds (Newtons)	290 (1290.0)
Net Buoyancy with Antenna, pounds (Newtons)	270 (1201.0)
Tail Assembly	
Vertical Fins (2)	
Section Shape	NACA 0012
Root Chord, inches (meters)	14.0 (.356)
Tip Chord, inches (meters)	10.0 (.254)
Span, inches (meters)	12.0 (.305)
Aspect Ratio	1.0
Taper Ratio	0.72
Sweep Angle of 1/4-chord, degrees (radians)	14 (.244)
Horizontal Fin	
Section Shape	NACA 0012
Chord, inches (meters)	11.25 (.286)
Span, inches (meters)	26.5 (.673)
Aspect Ratio	4.35
Taper Ratio	1
Sweep Angle, degrees	0

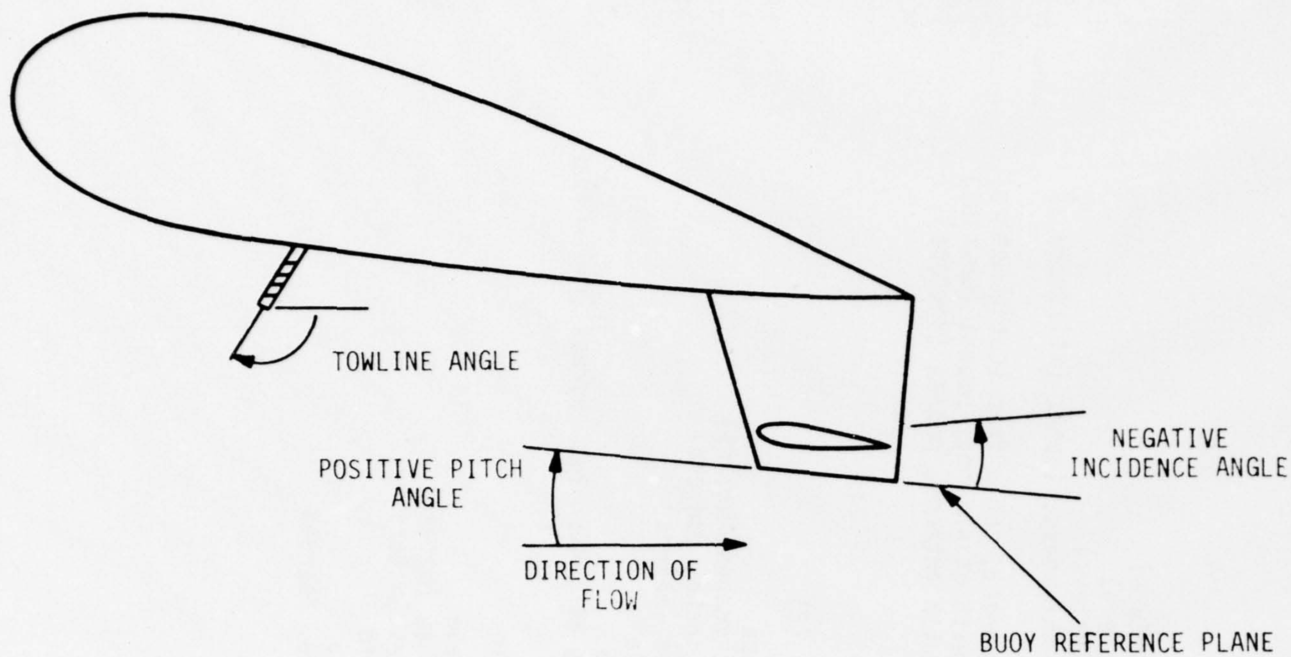


Figure 3 - Buoy Reference Planes and Sign Conventions

DATA ACQUISITION AND CONTROL SYSTEM

A schematic of the data acquisition and control system is shown in Figure 4. This system consists of transducers to measure towline tension, towline angle at the buoy, buoy pitch and roll angles, buoy depth, and stabilizer incidence angle. The type, range, and accuracy of these transducers are identified in Table 2. Signals from the transducers were processed through a frequency-division-multiplex (FDM) unit contained in the buoy which modulated and transmitted the signals through a nine conductor towline. The signal voltages were demodulated and recorded on a strip chart recorder on the towing carriage. Simultaneously, the demodulated signals were fed to an analog-to-digital converter (ADC) and used as inputs to an Interdata 70 computer system to average the measured data over 5-second periods.

EXPERIMENTAL ARRANGEMENT

The low-speed experimental evaluations of the Advanced Buoy were conducted in the deep-water towing basin at DTNSRDC. The general towing arrangement is illustrated in Figure 5. To represent towing from a submarine at depth, a depressor body was towed from the carriage and the buoy model was towed from the depressor body. The body towline was a variable length of ribbon-faired, 0.347-inch (8.81mm) diameter double-armored cable with nine inner-core electrical conductors. The variable length permitted towing the model at two depth conditions. The interference effects of the depressor body on the flow near the model was assumed negligible.

The high-speed experimental evaluations of the Advanced Buoy were conducted in the high-speed towing basin at DTNSRDC. The general towing arrangement is illustrated in Figure 6. The buoy was towed from a point on the Parachute Twin Strut Rig to maintain a constant depth below the surface.

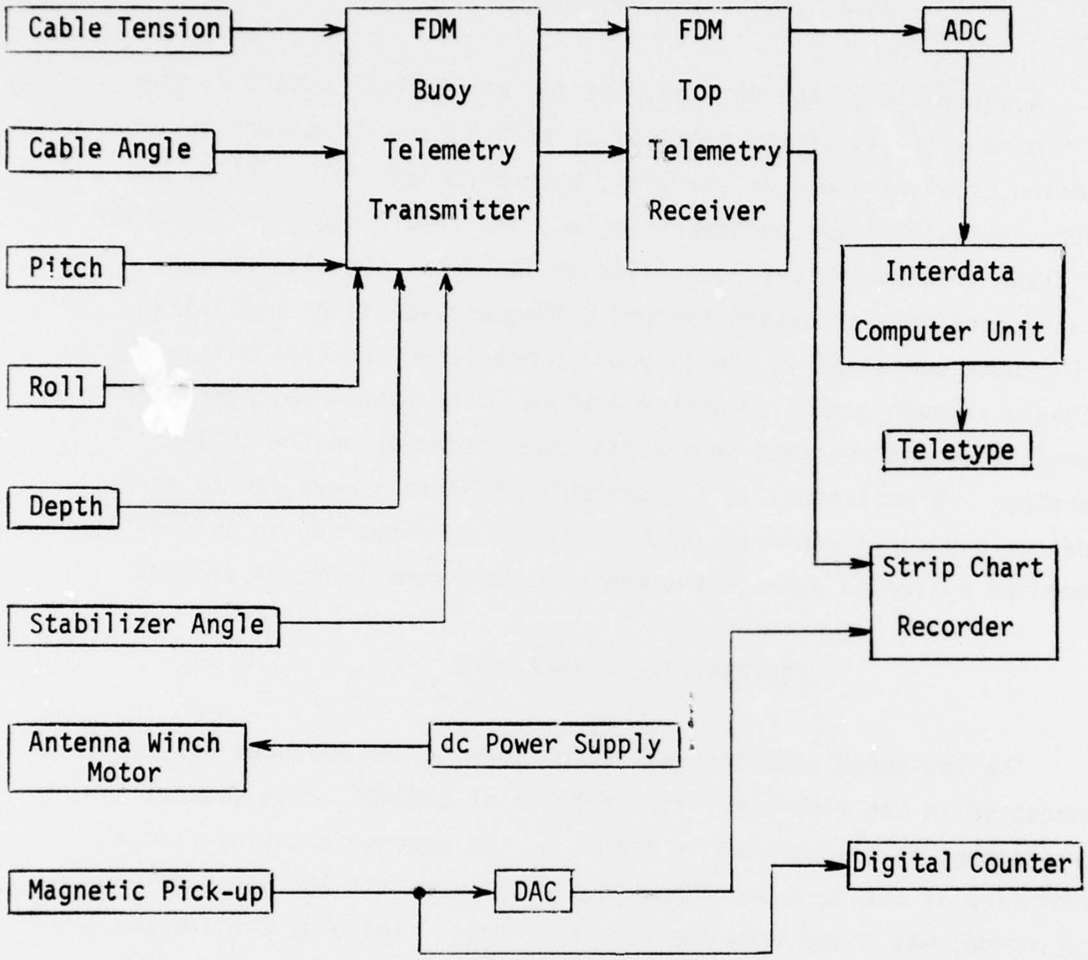


Figure 4 - Schematic of Data Acquisition and Control System.

TABLE 2

Measurement System Transducer Characteristics

Measurement	Transducer Type	Range	Accuracy
Tension	Ring Gage Dynamometer	12K pounds (53.38N)	±1/2%
Cable Angle	Pendulous Potentiometer	±20° (±.349 rad)	±1%
Pitch Angle	Pendulous Potentiometer	±20° (±.349 rad)	±1%
Roll Angle	Pendulous Potentiometer	±20° (±.349 rad)	±1%
Depth	Potentiometer	0-56 ft (0-17.1m)	±1%
Stabilizer Angle	Potentiometer	230° (4.01 rad)	±1%

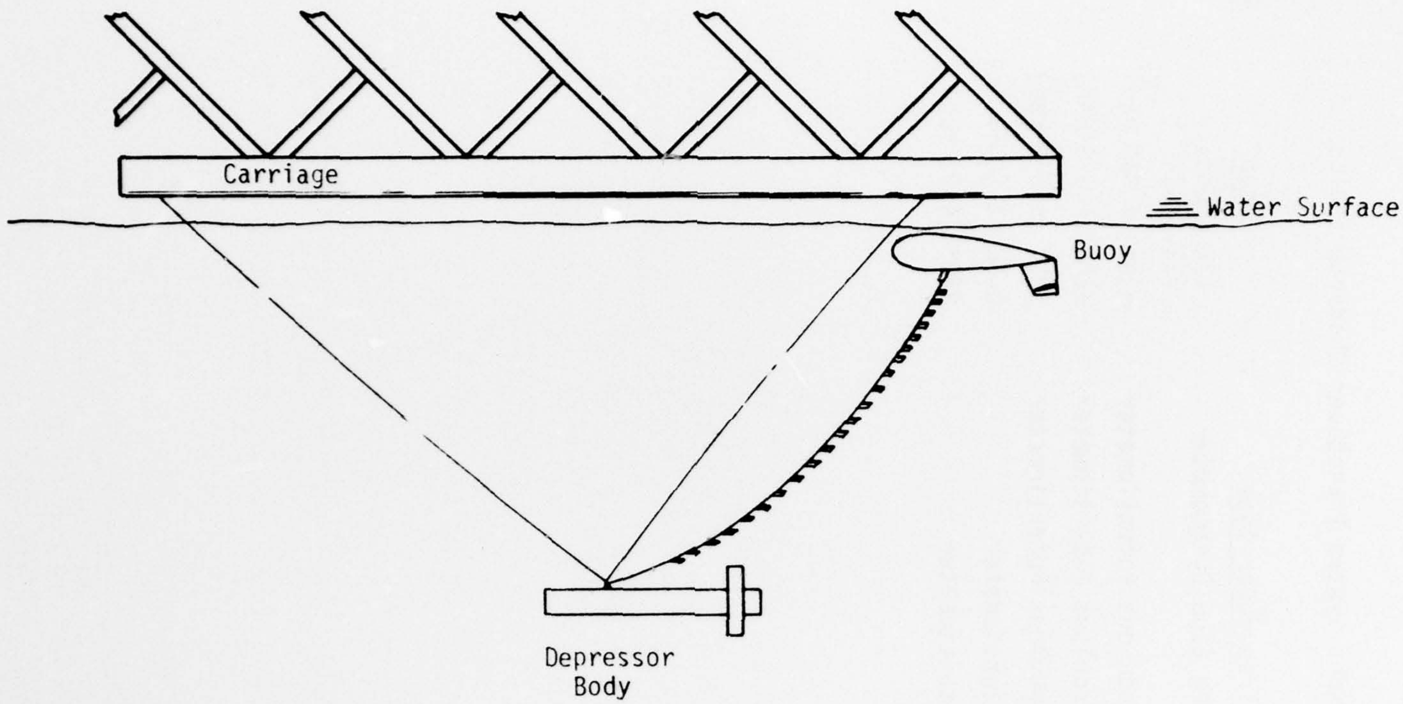


Figure 5 - General Towing Arrangement in Deep-Water Basin

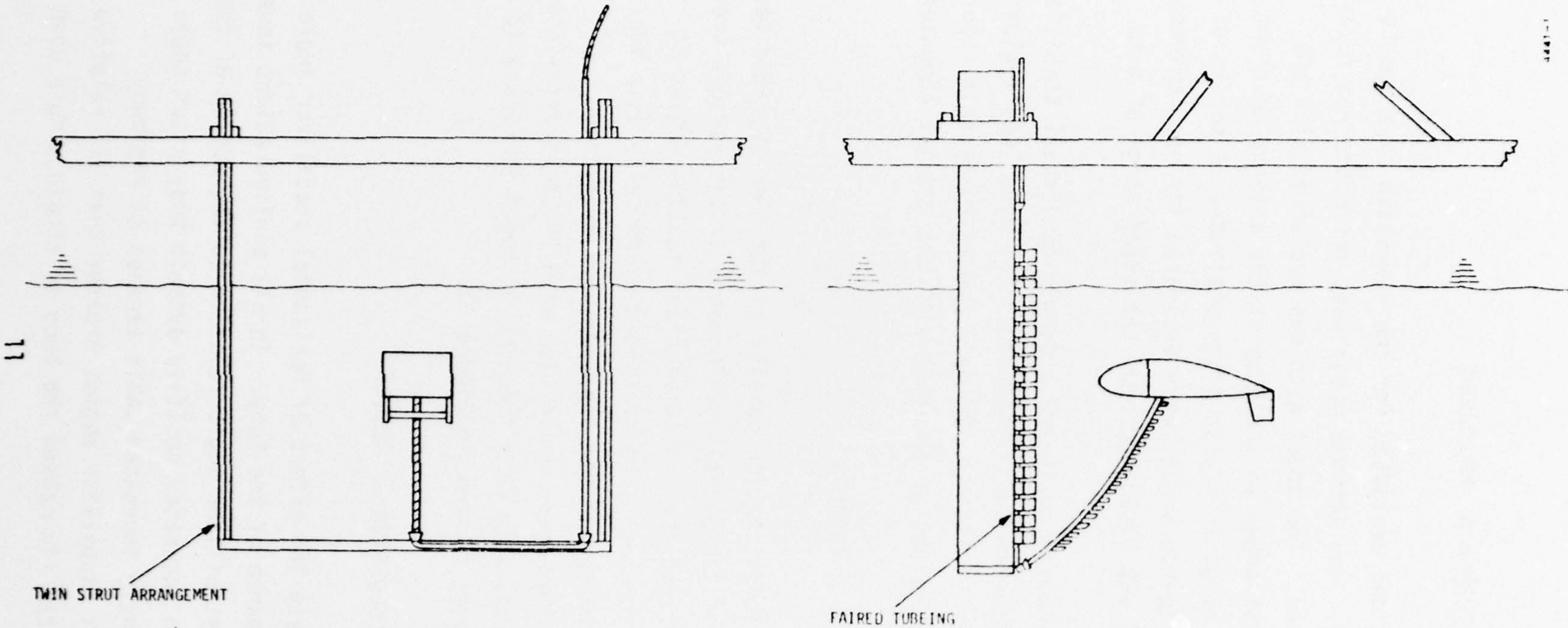


Figure 6 - General Towing Arrangement in High-Speed Basin

EXPERIMENTAL PROCEDURE

The model configurations evaluated for the low-speed experiments are identified in Table 3. Two antenna positions, retracted and fully extended, were investigated. The model also was evaluated with the antenna removed and ballast added to the buoy at the antenna mounting location to maintain the original static pitch attitude. A series of horizontal stabilizer incidence angles were evaluated for each antenna configuration. The model was evaluated over the speed range of 0 to 14 knots.

The high-speed experiments evaluated a single horizontal stabilizer incidence angle for the antenna fully extended. The model was evaluated over a speed range of 0 to 25 knots. The data presented in this report represent time - averaged values as obtained with the digital computer.

RESULTS

The results of the investigation consist of the time-averaged data as well as observations of the overall performance of the various buoy configurations. The measured towline tension and towline angles at the buoy and the buoy pitch angle are presented graphically as a function of speeds in Figures 7 through 11 for the low-speed evaluation.

The results of the high-speed evaluation with the horizontal stabilizer pinned are presented graphically as a function of speed in Figure 12 and with the stabilizer allowed to move in Figure 13.

DISCUSSION OF RESULTS

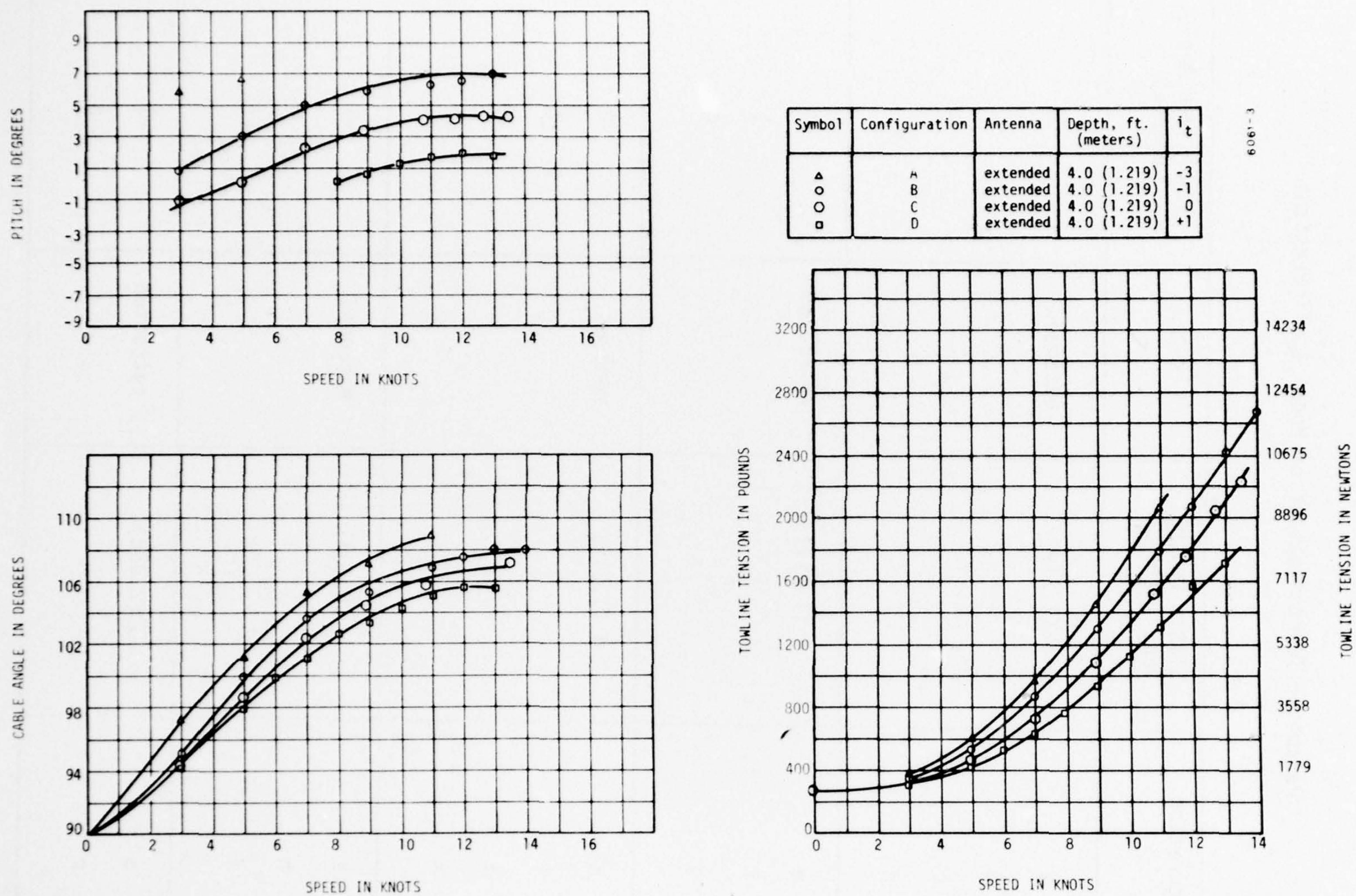
The graphs illustrate the effect of horizontal stabilizer angle upon the hydrodynamic performance of the buoy. In all configurations investigated, a more negative stabilizer angle relative to the bottom of the vertical fin produced an increased positive dynamic buoy pitch angle and therefore a correspondingly increased cable tension at the buoy.

Positive horizontal stabilizer angles greater than +1° relative to the bottom of the vertical fin caused the buoy to attain a nose down

TABLE 3

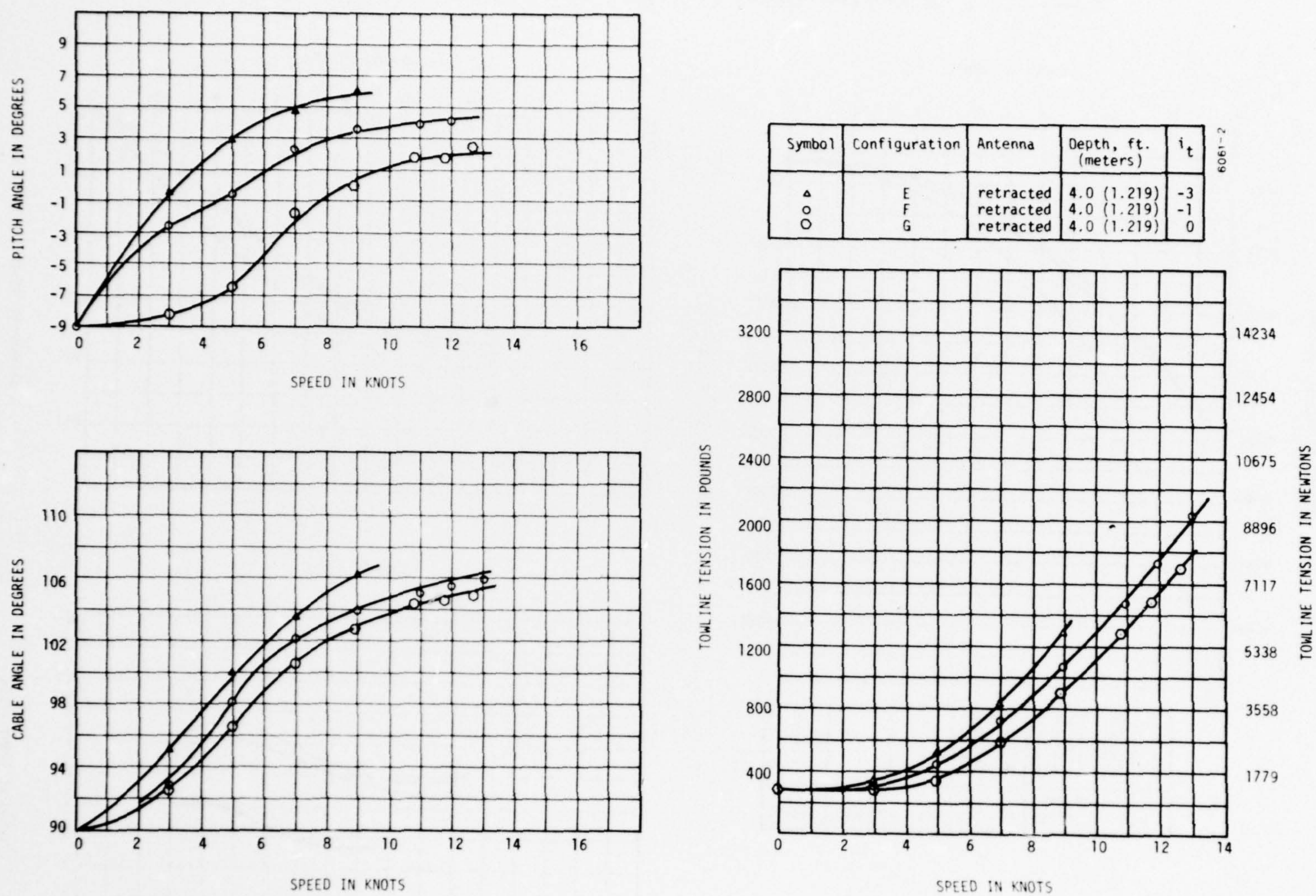
Parameter Identification of Model Configurations

Configuration	Static Depth, feet (meters)	Antenna	Stabilizer Angle, degrees
a	4 (1.219)	extended	-3
b			-1
c			0
d			+1
e	4 (1.219)	retracted	-3
f			-1
g			0
h	4 (1.219)	removed	-3
i			-1
j			0
k			+1
l	8 (2.438)	extended	-1
m			0
n			+1
o	8 (2.438)	retracted	-1
p			0



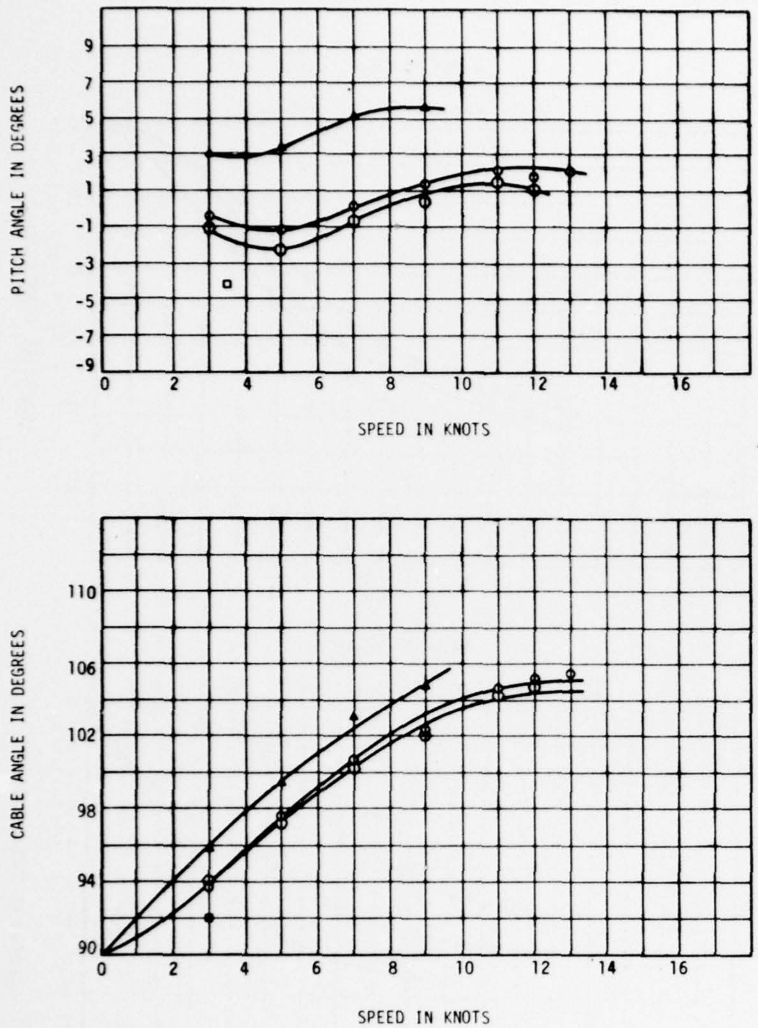
Symbol	Configuration	Antenna	Depth, ft. (meters)	i_t
△	A	extended	4.0 (1.219)	-3
○	B	extended	4.0 (1.219)	-1
◯	C	extended	4.0 (1.219)	0
□	D	extended	4.0 (1.219)	+1

Figure 7 - Hydrodynamic Characteristics of Configurations A, B, C, and D



Symbol	Configuration	Antenna	Depth, ft. (meters)	i_t
△	E	retracted	4.0 (1.219)	-3
o	F	retracted	4.0 (1.219)	-1
O	G	retracted	4.0 (1.219)	0

Figure 8 - Hydrodynamic Characteristics of Configurations E, F, and G



Symbol	Configuration	Antenna	Depth, ft. (meters)	i_t
△	H	removed	4.0 (1.219)	-3
○	I	removed	4.0 (1.219)	-1
◯	J	removed	4.0 (1.219)	0
□	K	removed	4.0 (1.219)	+1

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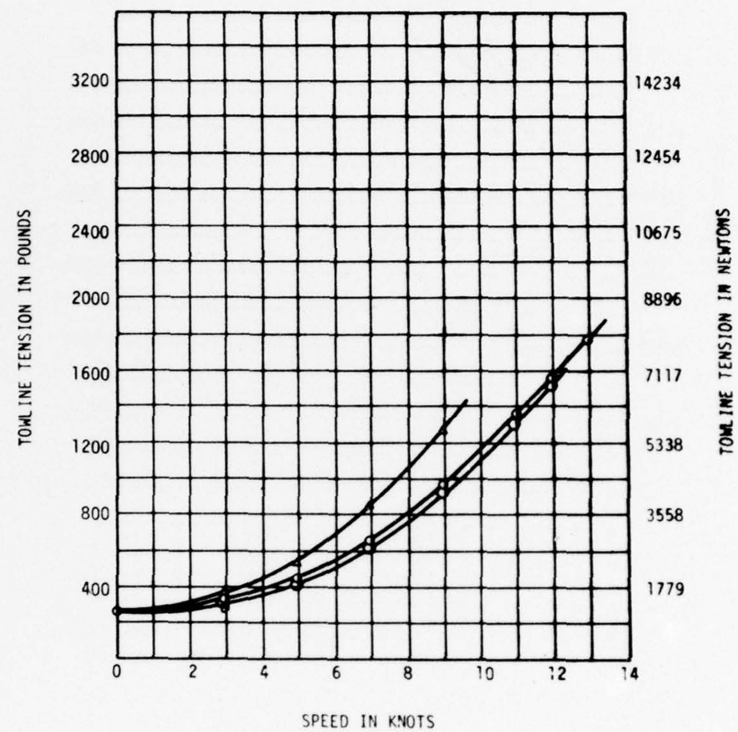
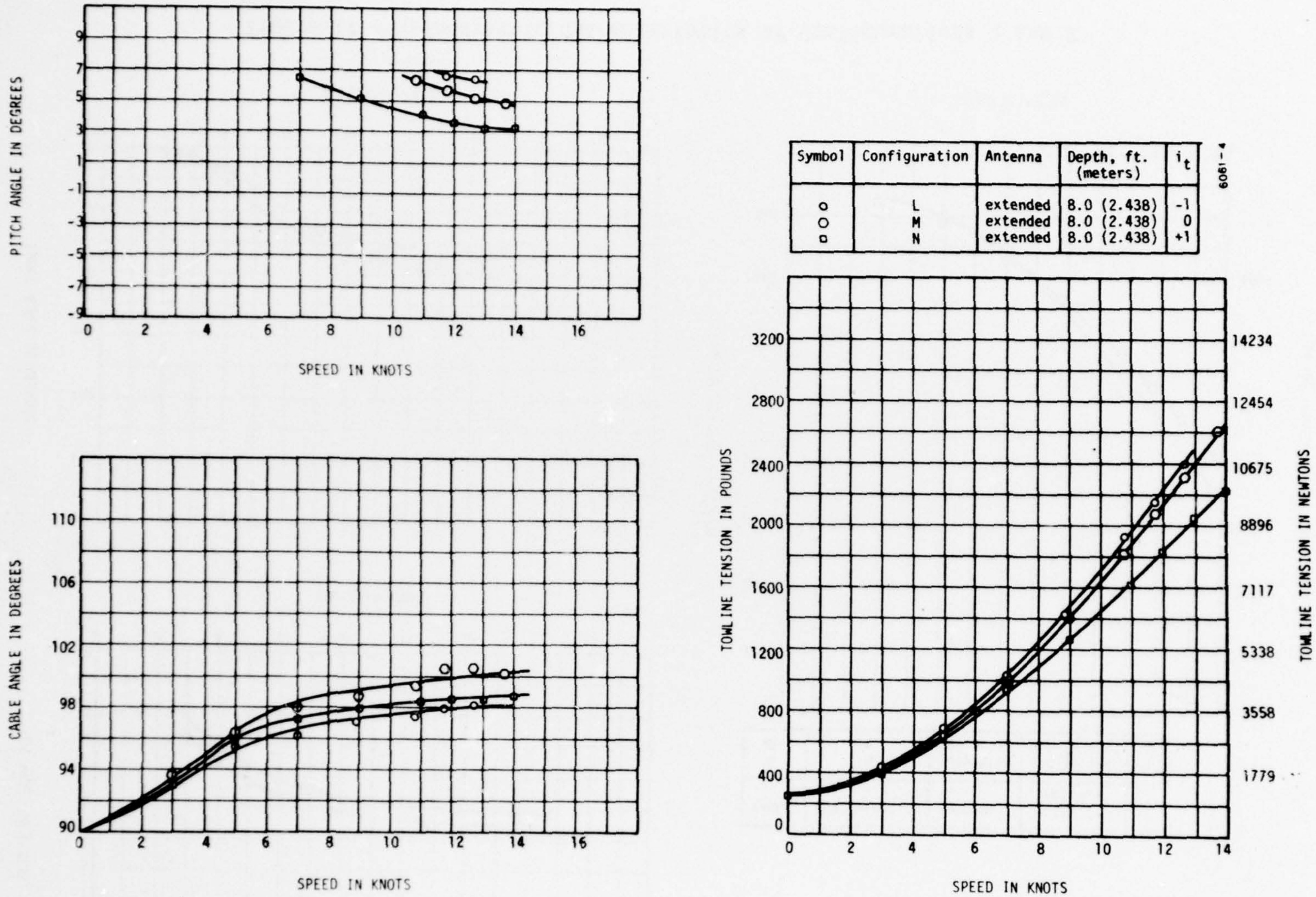
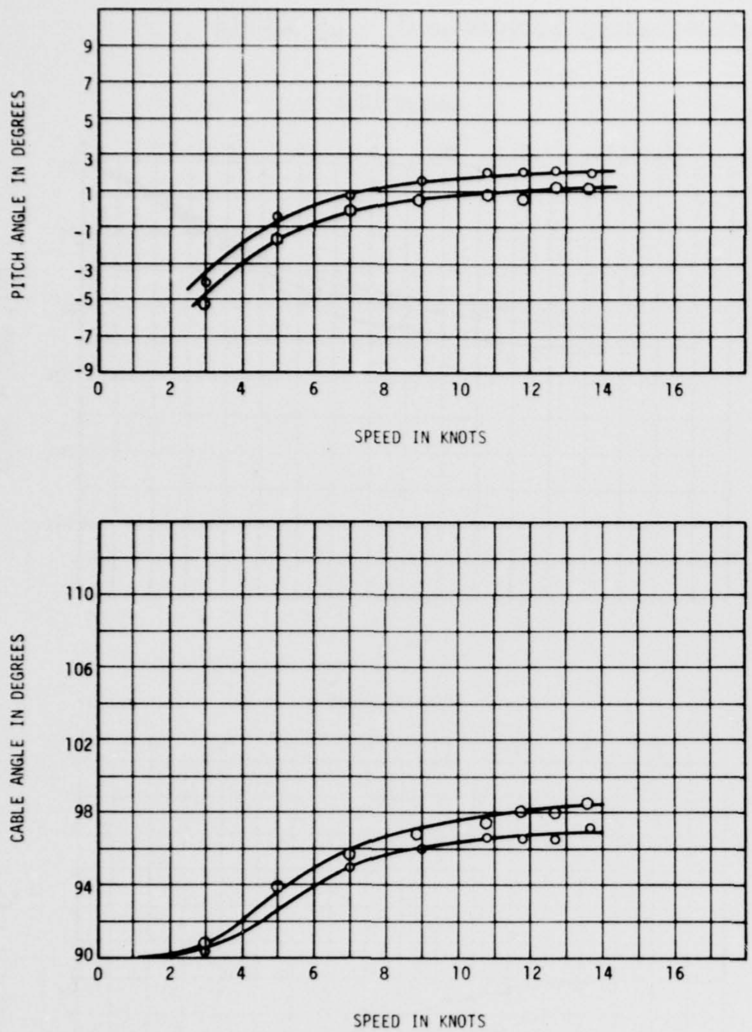


Figure 9 - Hydrodynamic Characteristics of Configurations H, I, J, and K



Symbol	Configuration	Antenna	Depth, ft. (meters)	i_t
o	L	extended	8.0 (2.438)	-1
O	M	extended	8.0 (2.438)	0
□	N	extended	8.0 (2.438)	+1

Figure 10 - Hydrodynamic Characteristics of Configurations L, M, and N



Symbol	Configuration	Antenna	Depth, ft. (meters)	i_t
o	O	retracted	8.0 (2.438)	-1
O	P	retracted	8.0 (2.438)	0

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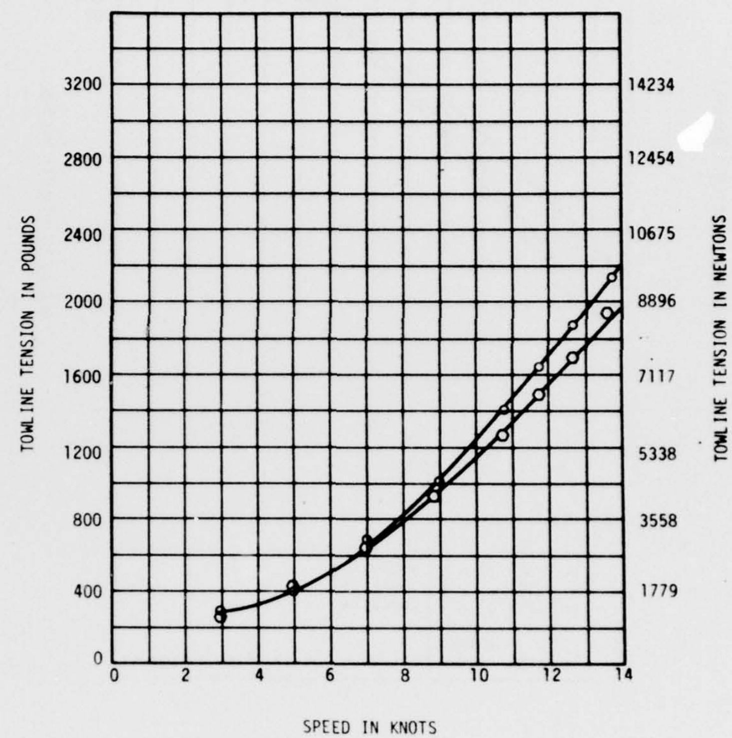

Figure 11 - Hydrodynamic Characteristics of Configurations O and P

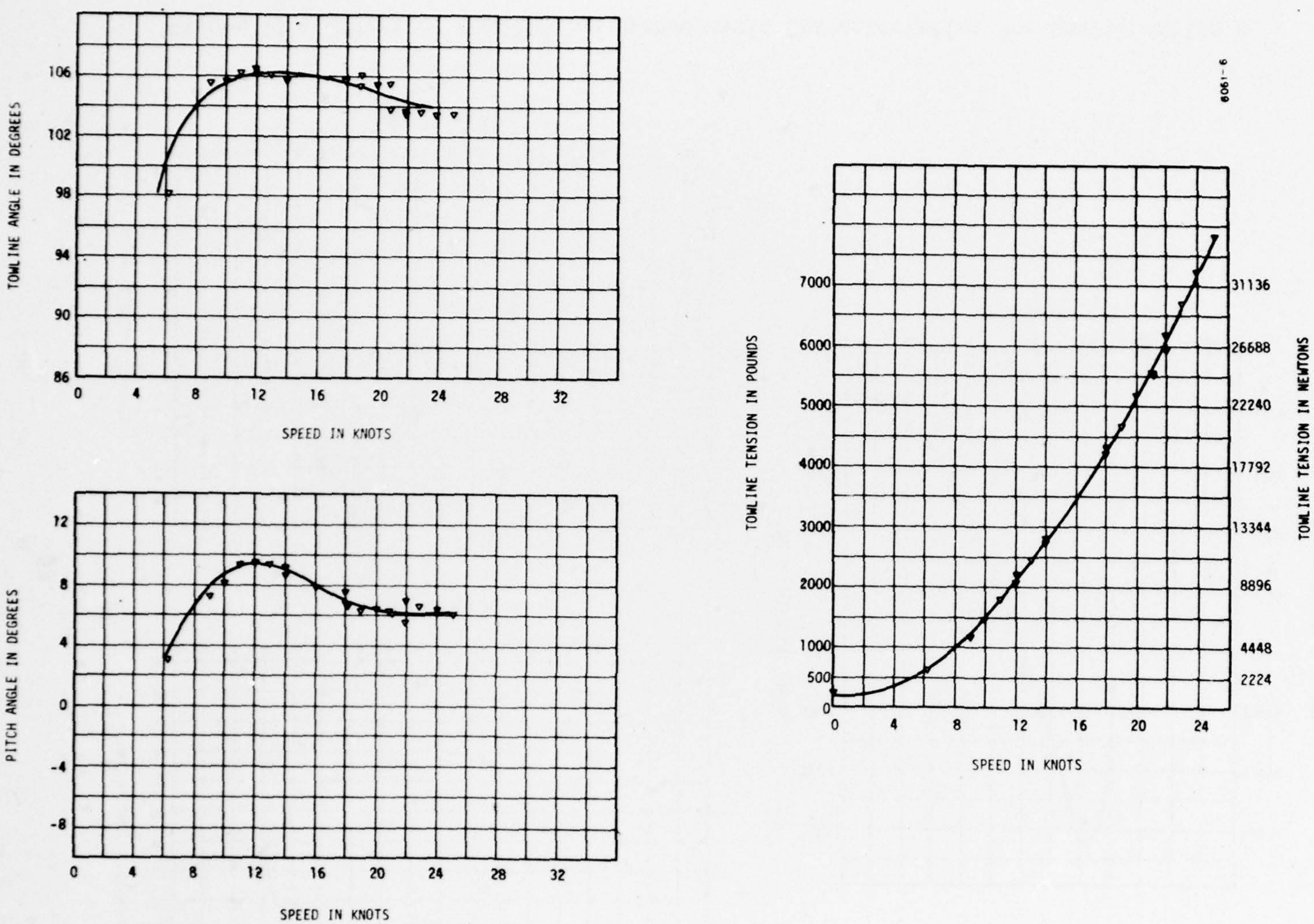

Figure 12 - Hydrodynamic Characteristics of Configuration B at Speeds Up to 25 Knots

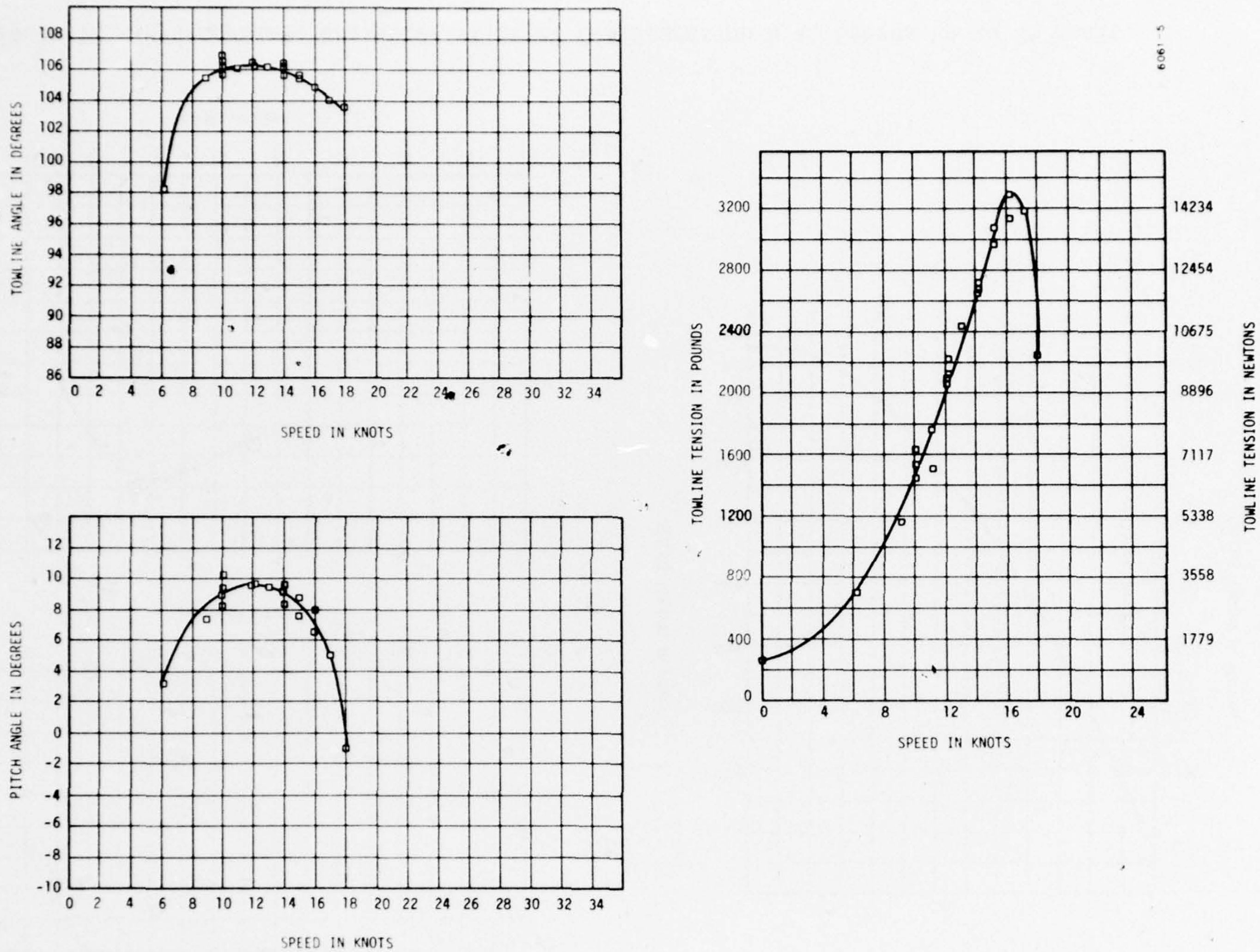

Figure 13 - Effect of Dumplift on Hydrodynamic Characteristics for Configuration B.

atitude and to dive. The buoy with the antenna extended exhibited pitch instability at speeds up to 8 knots with a horizontal stabilizer angle setting of +1° and a depth of 4 feet (1.219m).

The buoy exhibited an increase in pitch angles with the antenna extended and the buoy 8 feet deep (2.438m) due to the additional drag forces resulting from the antenna being completely submerged.

For the results shown in Figure 13, the horizontal stabilizer was allowed to move about its pivot point. This movement was a result of the center of pressure of the hydrodynamic forces acting on the horizontal stabilizer acting aft of the pivot point resulting in a moment being applied to the fin that increased with increasing speed. Opposing this moment was the torque developed by a torsion rod inside the horizontal stabilizer. When the hydrodynamic forces became larger than the torsional forces in the rod, deflection of the fin occurred in a positive direction (See Figure 2 for sign convention). This deflection which began at 14 knots resulted in a decrease in buoy pitch angle and therefore a decrease in buoy tension. This concept appears to be effective in minimizing the tension at the higher speeds and would only require the addition of a mechanical stop to limit the distance that the stabilizer moves.

The buoy model provided a stable platform throughout the investigations. The model was stable up to speeds of 25 knots with the antenna extended.

CONCLUSIONS

The following conclusions are made based on the results of this evaluation:

1. The Advanced Buoy will perform satisfactorily over the speed range of zero to 25 knots.

2. The horizontal stabilizer settings must be maintained at 0 degrees or less up to 8 knots. At speeds above 8 knots the stabilizer angle can be increased to minimize the tension at the higher speeds.

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