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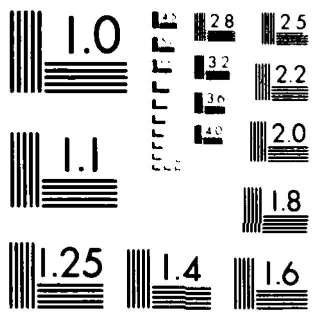

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DAVID W. TAYLOR NAVAL SHIP
RESEARCH AND DEVELOPMENT CENTER

Bethesda, Maryland 20084

CALM WATER TOWING STABILITY EXPERIMENTS OF THE EMPRESS II

By

Raymond P. Para

Approved for Public Release; for Distribution Unlimited

Ship Performance Department

OCTOBER 1983

DTNSRDC/SPD 1090-01

CALM WATER TOWING STABILITY EXPERIMENTS OF THE EMPRESS II

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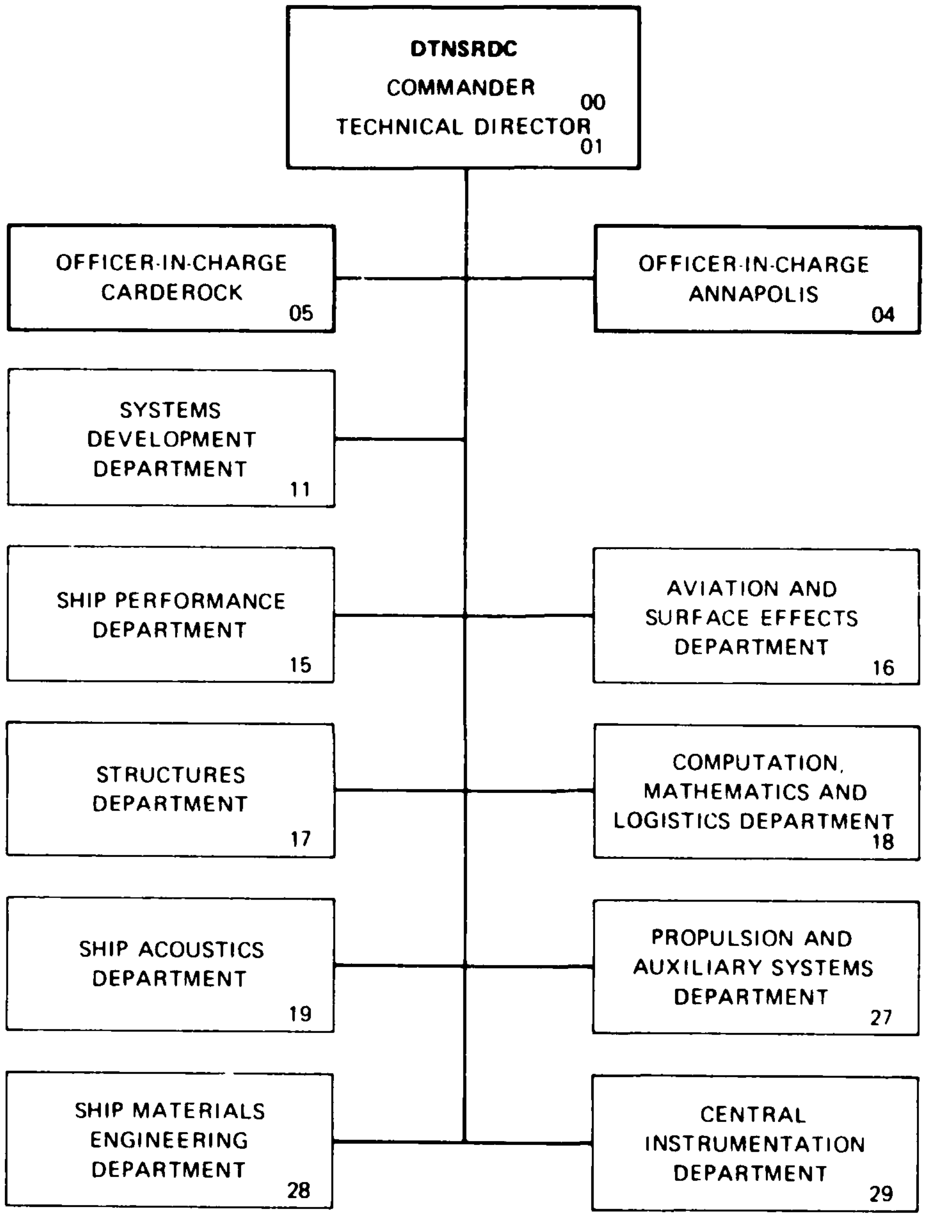

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An experimental evaluation was conducted of the towing characteristics of the EMPRESS II antenna barge. A 1/28 scale model of the EMPRESS II was towed in the DTNSRDC deep-water towing basin with measurements taken of towline tension and horizontal towline angle. The results indicate that the EMPRESS II can be satisfactorily towed from the bow with a bridle for either of two pulser configurations and for displacements corresponding to the 3- and 7-foot waterlines.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF FIGURES (Cont'd)

LIST OF FIGURES (Cont'd)

LIST OF TABLES

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ABSTRACT

An experimental evaluation was conducted of the towing characteristics of the EMPRESS II antenna barge. A 1/28 scale model of the EMPRESS II was towed in the DTNSRDC deep-water towing basin with measurements taken of towline tension and horizontal towline angle. The results indicate that the EMPRESS II can be satisfactorily towed from the bow with a bridle for either of two pulser configurations and for displacements corresponding to the 3- and 7-foot waterlines.

ADMINISTRATIVE INFORMATION

This project was sponsored by the Naval Surface Weapons Center through work request W0331 of 28 February 1983. The work was performed by the Towed Systems Branch of the David Taylor Naval Ship R&D Center under work unit number 1-1541-045.

INTRODUCTION

At the request of the Naval Surface Weapons Center (NSWC), the David Taylor Naval Ship Research and Development Center (DTNSRDC) investigated the towing stability of the EMPRESS II antenna barge. The experimental investigation addressed a number of design parameter variations that included: two hull designs, two waterlines, two barge trim angles, several skeg angles, and two bridle locations in both towing and mooring configurations.

This report describes the model and the experimental procedure. The primary data, towline tension and horizontal towline angles are presented as a function of speed.

STABILITY CRITERIA

In the field of Naval arthitecture, the longitudinal stability of a ship is defined by how well it will go in a straight line without turning. In towing applications the term takes on two characteristics: Decay and Position.

DECAY

Decay means the rate at which a tow will reduce its outboard excursion behind the tug. The accepted definition of a stable tow is one that will decay at the rate of one half of its excursion amplitude per cycle. If the tow yaws and moves outboard a distance D_1 to starboard of the centerline of the tug on its first excursion, the next excursion D_2 to starboard will have to be one half less of D_1 to be considered stable. See Figure 1. Stability in decay is always a desirable quality of a tow and actions should be taken to ensure and improve its occurence.

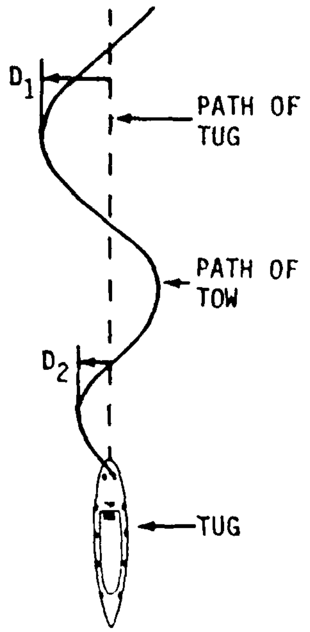

Figure 1 - Decay Mode Stability

POSITION

The classic description of a stable tow has the tow positioned directly astern of the tug. A tow that yaws and moves outboard to one side and stays at one position in repeated tests also is a stable tow. Obviously both situations are not equally desirable. See Figure 2, which describes positional stability. The desirability of positional stability is a function of the needs and circumstances of the towing situation.

UNSTABLE TOW

An unstable tow does not display positional stability on centerline or to either side. It persistently wanders behind the tug. As the unstable tow completes an excursion to one side it will not decay at an acceptable rate or may not decay at all. See Figure 3.

STABILITY FROM THE TUG HANDLING STANDPOINT

Once the tow goes to sea the success of the tow depends on a variety of factors such as horsepower, type of tow gear, tug configuration, experience of the tug crew and skipper, etc. For these reasons it is difficult to put exact numbers on the towing stability. It is obvious, however, that there is a desirable range to have the tow stay within. If it stays close to the centerline of the tug path there will be little difficulty in handling it. If the tow yaws to an acceptable limit, some loss of speed will be experienced. If the tow yaws to a greater degree, the situation becomes difficult. A significant loss of speed will be experienced, and the tow would be dangerous to itself and other ships when in restricted waters. Furthermore, yaw could be uncontrollable and could put the tug in danger of tripping; that is, rolling over due to side loading (Figure 4).

MODEL DESCRIPTION

A 4.3-foot (1.3-m) long model of the EMPRESS II barge with a linear scale ratio of 1/28 was built of fiberglas and styrofoam. The barge physical characteristics are presented in Table 1. Two hull designs were evaluated, each corresponding to one of the two pulser configurations. Each hull design was to be evaluated at 3- and 7-foot (0.91- and 2.1-m) drafts. One pulser configuration was contained within the general barge shape while the second required the addition of a centerboard keel below the baseline of the barge. Both barge hull design's included skegs extending down to the lowest part of the barge. In the case of the first hull design this was the barge baseline while for the second it was the bottom of the pulser keel. The first barge configuration with skegs is shown in Figures 5 and 6, while the second barge configuration with the pulser keel and skegs is shown in Figures 7 and 8.

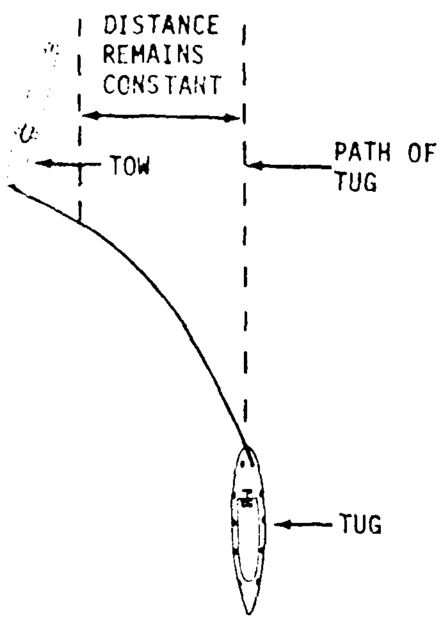

Figure 2 - Postional Stability

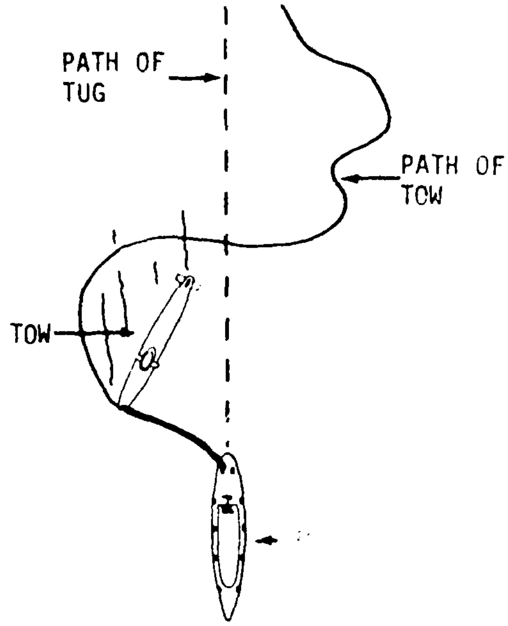

Figure 3 - Example of Tow Wandering

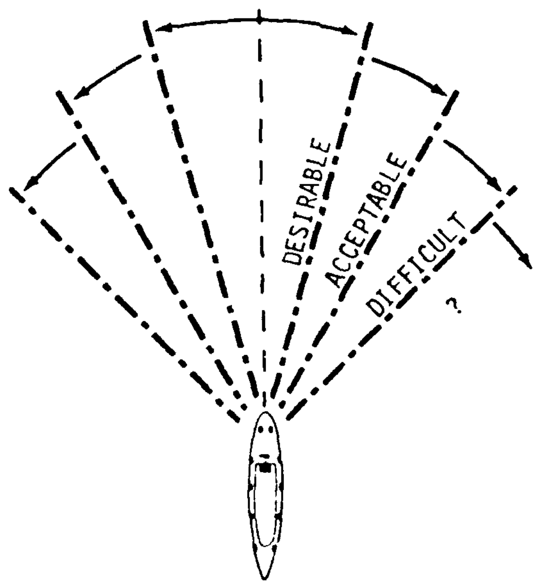

Figure 4 - Degrees of Difficulty Caused by Wandering of the Towed Vessel

TABLE 1 - EMPRESS II PHYSICAL CHARACTERISTICS

Dimensions	Barge feet (meters)	Model feet (meters)
Linear Scale Ratio	1	1/28
Length	120.0 (36.6)	4.29 (1.31)
Beam	105.0 (32.0)	3.75 (1.14)
GM (3 ft WL)	255.0 (77.7)	9.11 (2.78)
GM (7 ft WL)	130.0 (39.6)	4.64 (1.42)

Two bridle towing arrangements were evaluated at speeds equivalent to full-scale speeds from 3 to 10 knots and are shown in Figures 9 and 10. The primary bridle towing arrangement was positioned as far outboard as possible with each bridle leg equal in length to the barge beam width. For the second bridle, the towing attachment points were moved inboard with each bridle leg and separation distance equal to approximately 0.6 beam widths. The model towline consisted of a 20-foot (6.1-meters) length of 1/8-inch (3-mm) nylon rope and the bridle section which was in one configuration 1/8-inch (3-mm) nylon rope and in the second, steel chain.

An attempt was made to simulate the wind surface area of the full-scale antenna by placing on the deck a cylindrical shape structure 30 inches (0.8 meter) in height, as shown in Figure 11. An electric fan on the towing carriage was positioned to generate a wind to the model beam.

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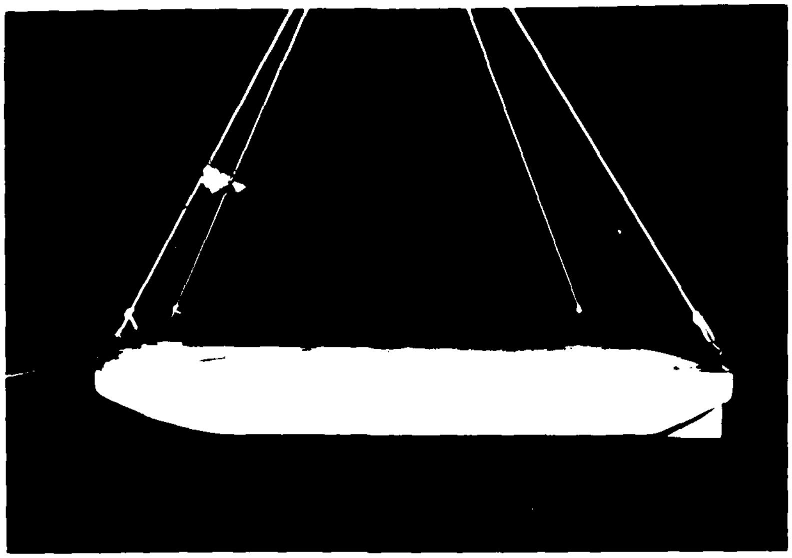

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Figure 5 - Side View of EMPRESS II
Antenna Barge without Pulser Keel

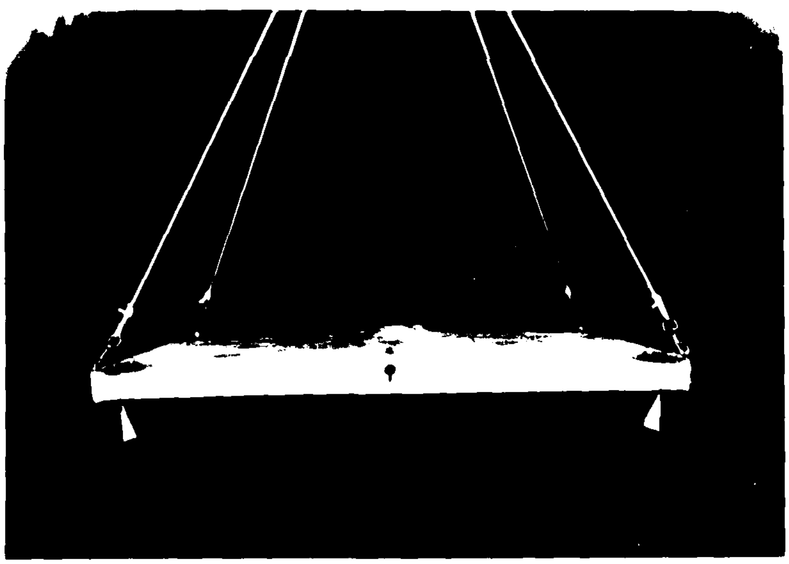

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Figure 6 - Stern View of EMPRESS II
Antenna Barge without Pulser Keel

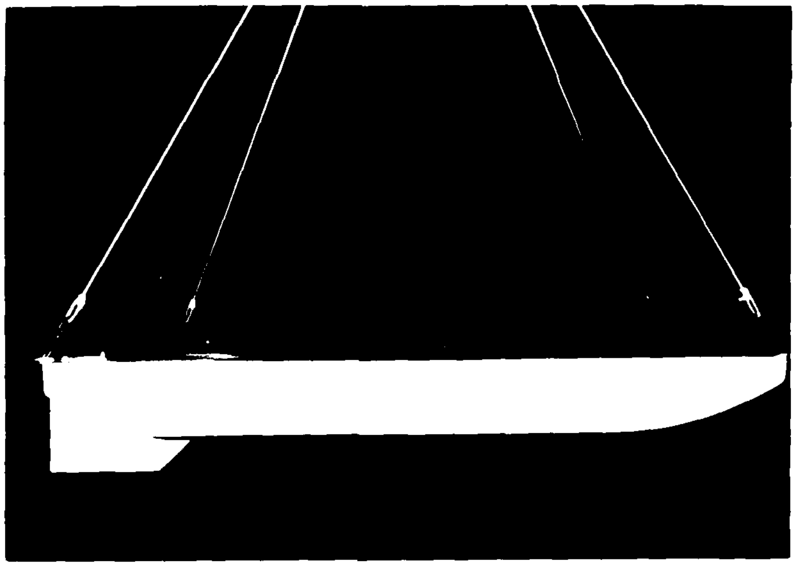

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Figure 7 - Side View of EMPRESS II
Antenna Barge with Pulser Keel

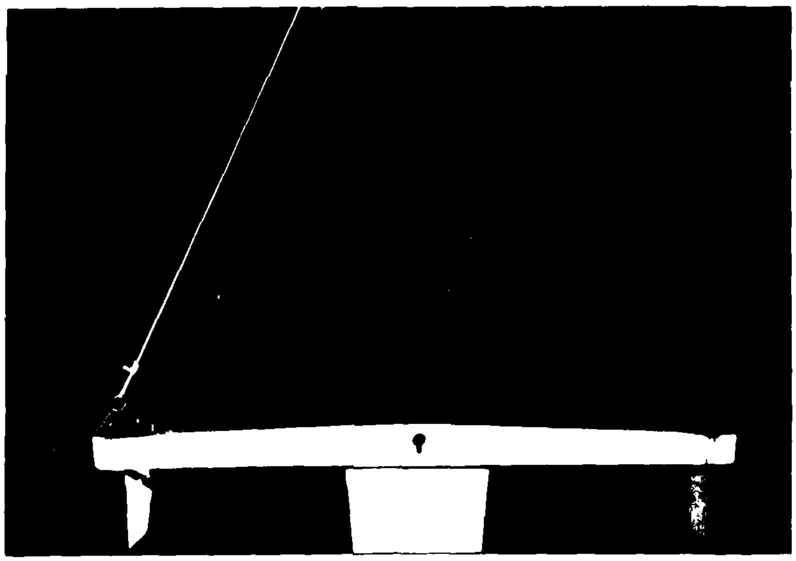

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Figure 8 - Stern View of EMPRESS II
Antenna Barge with Pulser Keel

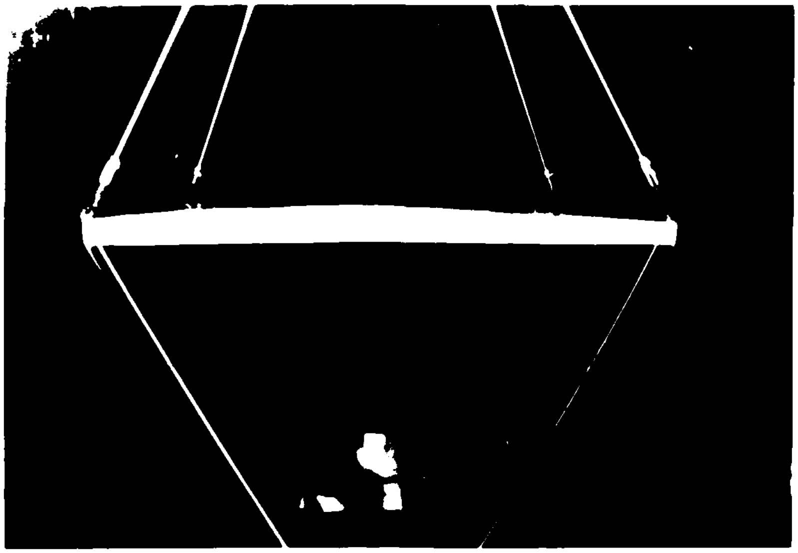

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Figure 9 - EMPRESS II Antenna Barge
with Wide Towing Bridle

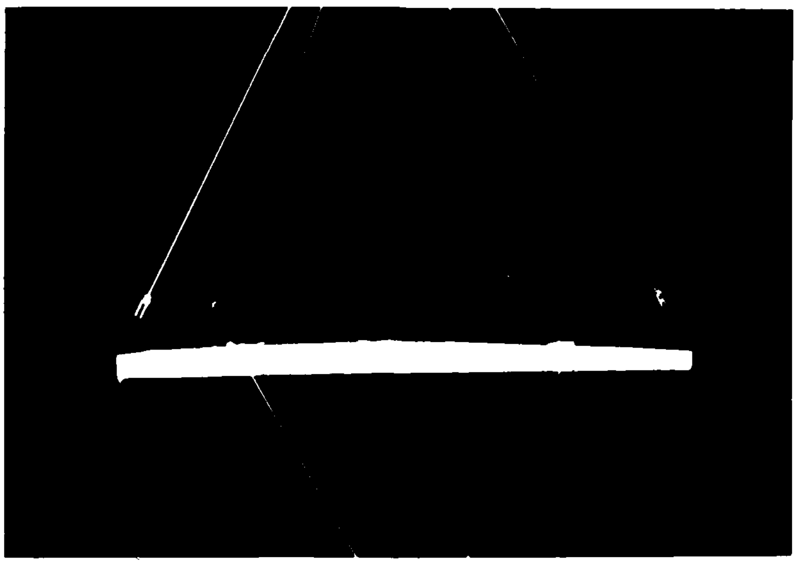

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Figure 10 - EMPRESS II Antenna Barge
with Narrow Towing Bridle

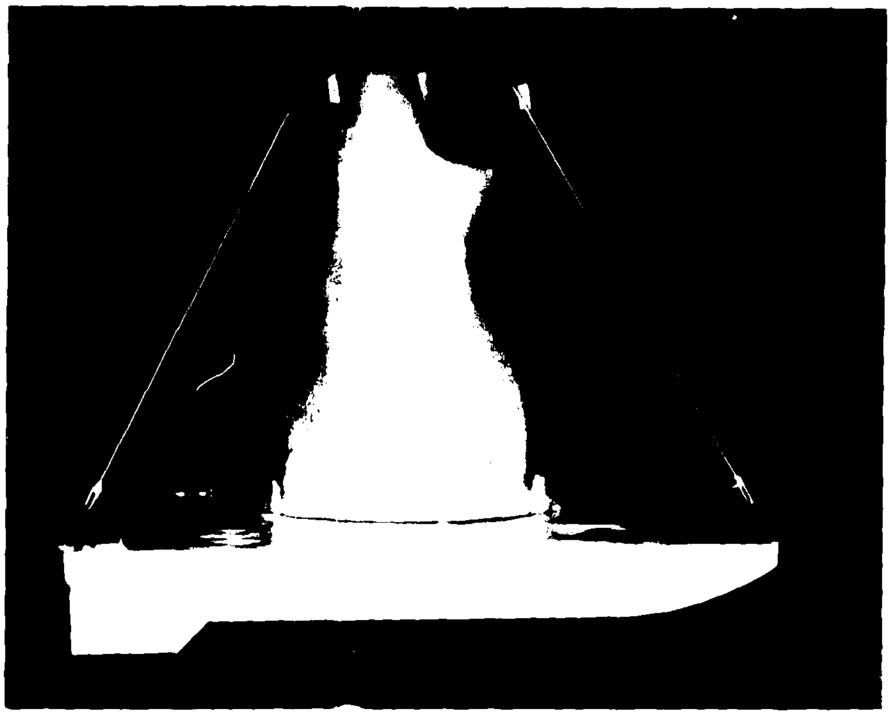

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Figure 11 - CYPRESS II Antenna Barge
with Simulated Antenna

PROCEDURE

First the ballast and trim conditions for both models were established. The barge model with pulser keel was initially trimmed to a waterline equivalent of 3-foot (0.9-meter) full scale. A trim of 1-foot (0.3-meter) down by the stern was obtained by shifting lead ballast aft. Additional ballast weights were added to obtain a 7-foot (2.1-meters) waterline. After removing the pulser keel, the model was again trimmed to the 3- and 7-foot (0.9- and 2.1-meters) waterlines. Inclining experiments were performed for each waterline to obtain the (transverse) metacentric heights (GM) for each condition of ballast and trim.

The towing stability evaluation was conducted in the deep-water towing basin at DTNSRDC. The basin is 22-feet (6.7-meters) deep and 51-feet (15.5-meters) wide.

At the beginning of each run the model was displaced to one side of the basin approximately two beam widths off center and released which allowed the model to seek an equilibrium position. The model test configurations are presented in Table 2. All parameter combinations were not evaluated. As configurations were found to be stable, the need to evaluate some configurations were eliminated. For example, the barge with an even keel was found to be stable; therefore, it was not necessary to continue to evaluate a trim down by the stern.

In the mooring related experiments the model was towed from the bow, beam, and quarter at speeds equivalent to the full-scale speed range from 0.5 to 3.0 knots. A bridle towline of lightweight wax cord approximately 5-feet (1.5-meters) long was used to maintain the desired model heading. The tension data obtained were used to predict mooring loads. A towing strut assembly attached to the carriage provided a towing point approximately 10 inches (0.25 meter) above the water surface.

TABLE 2 - EMPRESS II BARGE TEST CONFIGURATION

Configuration	Hull Design	Ballast	Trim	Skeg	Skeg Angle	Skeg Trim Tab	Bridle Geometry	Towline Material	Simulated Antenna	Comments
1	w/pk*	[illegible]	1 ft dn by stern	w	[illegible]	[illegible]	Wide	Steel & nylon	No	
2	w/pk*	[illegible] ft	1 ft dn by stern	w	15° OB	20°	Wide	Steel & nylon	No	
3	w/pk*	7 ft	1 ft dn by stern	w/o	None	None	Wide	Steel & nylon	No	
4	w/pk*	7 ft	1 ft dn by stern	w/o	None	None	Narrow	Steel & nylon	No	
5	w/pk*	7 ft	even keel	w/o	None	None	Narrow	Steel & nylon	No	
6	w/pk*	3 ft	even keel	w/o	None	None	Narrow	Steel & nylon	No	
7	w/o pk	7 ft	even keel	w	0°	None	Wide	Steel & nylon	No	
8	w/o pk	7 ft	even keel	w	0°	None	Narrow	Steel & nylon	No	
9	w/o pk	7 ft	even keel	w/o	None	None	Narrow	Steel & nylon	No	
10	w/o pk	3 ft	even keel	w/o	None	None	Wide	Steel & nylon	No	
11	w/o pk	3 ft	even keel	w/o	None	None	Narrow	Steel & nylon	No	
12	w/o pk	3 ft	even keel	w	0°	None	Wide	All nylon	No	
13	w/o pk	3 ft	even keel	w	0°	None	Narrow	All nylon	No	
14	w/o pk	3 ft	even keel	w	0°	None	Narrow	All nylon	Yes	
15	w/o pk	3 ft	even keel	w	15° OB	None	Wide	All nylon	No	
16	w/o pk	3 ft	even keel	w/o	None	None	Wide	All nylon	No	
17	w/o pk	3 ft	even keel	w/o	None	None	Port bridle leg only	All nylon	No	
18	w/o pk	3 ft	even keel	w/o	None	None	None	All nylon	No	Single leg Stern towpoint

* pk = pulser keel

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INSTRUMENTATION

The instrumentation located at the towing strut consisted of:

1. An angle potentiometer to provide measurements of horizontal towline angle with an overall system accuracy of ±0.5 degree.

2. A 50-pound (222-newtons) and a 10-pound (44-newtons) capacity ring-gage dynamometer to provide measurements of towing tension at the higher towing speeds with an overall system accuracy of ±0.25 pound (1-newton) and ±0.05 pound (0.2 newton) respectively. At the lower speeds, a 1000-gram (10-newtons) capacity dynamometer with an overall system accuracy of ±5 grams (0.05 newton) measured towing tension.

Additional instrumentation consisted of a magnetic pickup on the towing carriage to provide measurements of speed with an accuracy of ±0.01 knot. For all measurements, data readout was provided by a six-channel strip-chart recorder, and an HP 9835 computer.

RESULTS AND DISCUSSION

The basin towing tests were conducted with a 1/28 scale model of the EMPRESS II antenna barge to identify a stable towing configuration. The results are presented for full-scale conditions. Towline tension was scaled by $\left(\frac{\rho \text{ sea}}{\rho \text{ fresh}} \lambda^3\right)$ and speed was scaled by $(1/\sqrt{\lambda})$.

The experimental results are presented in Figures 12 through 25. These results include horizontal towline angle and towline tension as a function of time and speed, respectively. The results also include observations of the model stability. The results showed the EMPRESS II antenna barge to be stable in all configurations evaluated. The horizontal towline angle as a function of time is shown in Figure 12 for barge configuration 2 with pulser keel and skeg angles of 15° outboard with trim tab angles of 20° outboard. The horizontal towline angle increases as the model is displaced to one side and gradually returns to a stable position after being released. The horizontal towline angle for configuration 13 without pulser keel and 0° skeg angles is shown in Figure 13 for the model being displaced to both port and starboard and returning to a stable position behind the towpoint. The horizontal towline angle for configuration 16 with the skegs removed and without

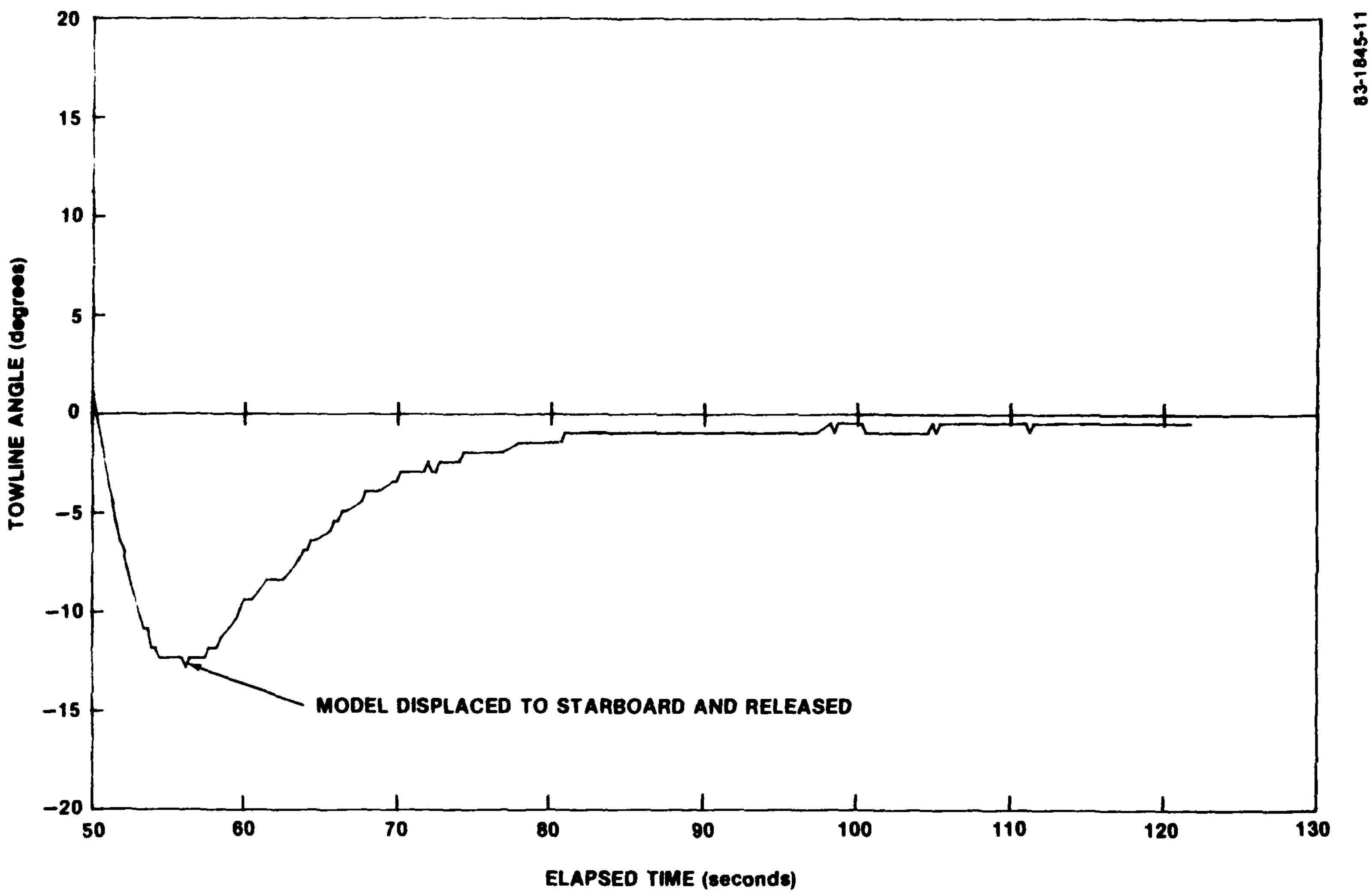

Figure 12 - Horizontal Towline Angle as a Function of Time for Barge Configuration 2 with Pulser Keel and Skeg Angles of 15° Outboard at 6 Knots

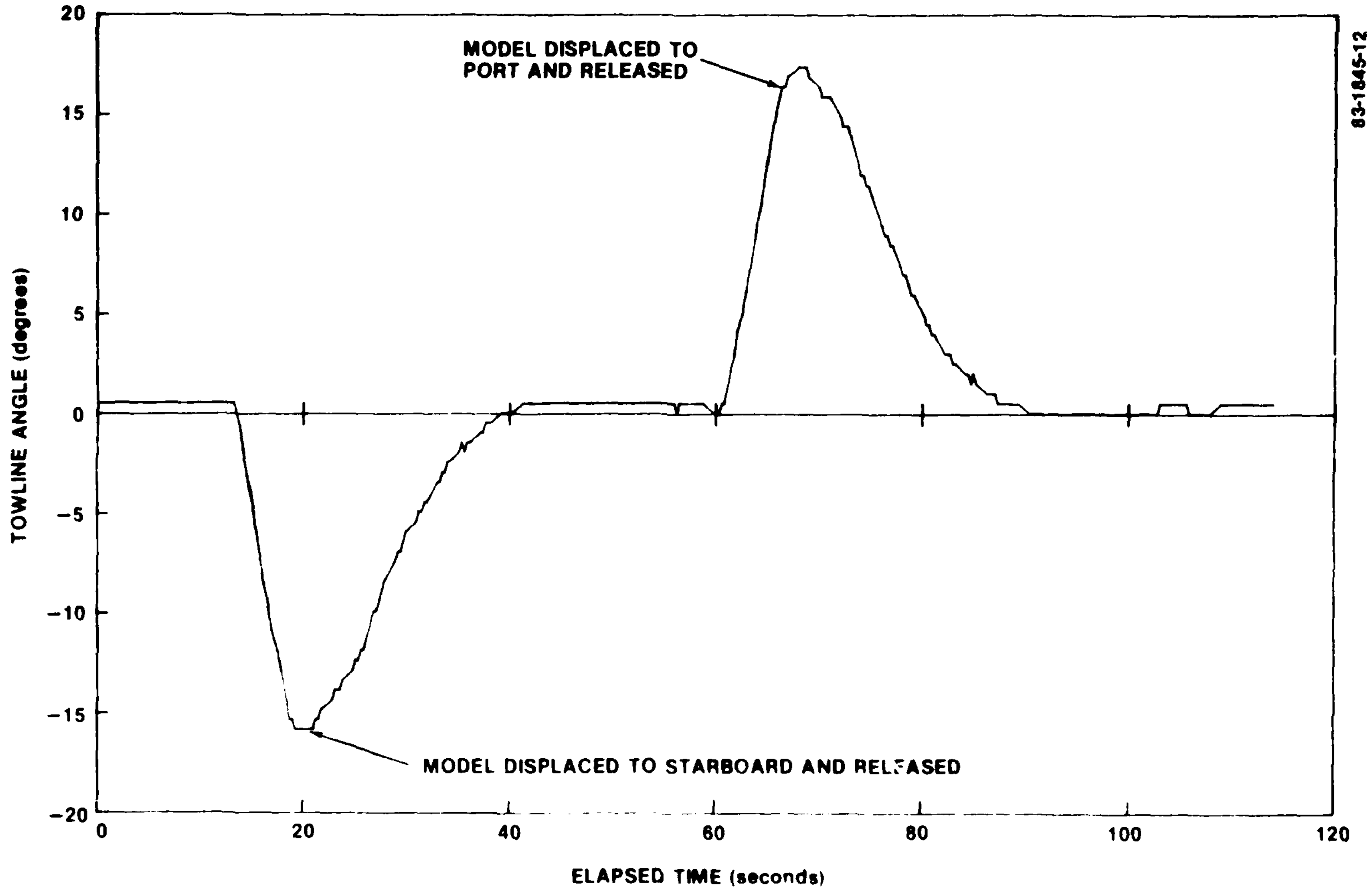

Figure 12 – Horizontal Towline Angle as a Function of Time for Barge Configuration 1 without [illegible] Keel and 0° Skeg Angles at [illegible] Knots

the pulser keel is shown in Figure 14. This configuration had the least amount of wetted surface and no skegs, but the model met the stability criteria described earlier for decay and position.

The effect of skeg angle on towline tension is shown in Figure 15 for model configurations 1, 2 and 3 with the pulser keel, and in Figure 16 for model configurations 12, 15 and 16 without the pulser keel. The difference in towline tension for the barge with even keel and a 1-foot trim down by the stern is shown in Figure 17 for configurations 4 and 5. This difference ranged from 29 percent at 3 knots to 9 percent at 10 knots. A comparison of towline tension between the wide and narrow towing bridle configuration is shown in Figure 18 for the barge with pulser keel. The effects of the pulser keel and barge waterline on towline tension are shown in Figure 19. The increase in towline tension resulting from the pulser keel is approximately 46 percent for the 3-foot (0.9-meter) and 31 percent for the 7-foot (2.1-meters) waterline. The increase in towline tension due to the change in waterline from 3-feet (0.9-meter) to 7-feet (2.1 meters) is approximately 43 percent with pulser keel and 52 percent without pulser keel. The effect of a chain bridle on towline tension is shown in Figure 20 for configurations 10 and 16. The additional towline tension caused by wind on the simulated antenna is shown in Figure 21. The towline tension is presented in Figure 22 for the special cases of towing with only the port bridle leg and towing from the stern.

Bow, quarter, and beam mooring loads are presented in Figure 23 through 25 for the 3- and 7-foot (0.9-and 2.1-meters) waterlines with and without the pulser keel.

CONCLUSIONS

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

1. The EMPRESS II antenna barge will produce a stable tow in calm water for all configurations evaluated.

2. The pulser keel will increase the towline tension by 46 percent for the 3-foot (0.9 meter) waterline and 31 percent for the 7-foot (2.1-meter) waterline.

3. Increasing the skeg angle will increase towline tension but will not significantly affect towing stability.

4. The width of the towing bridle will not significantly affect towing stability or towline tension.

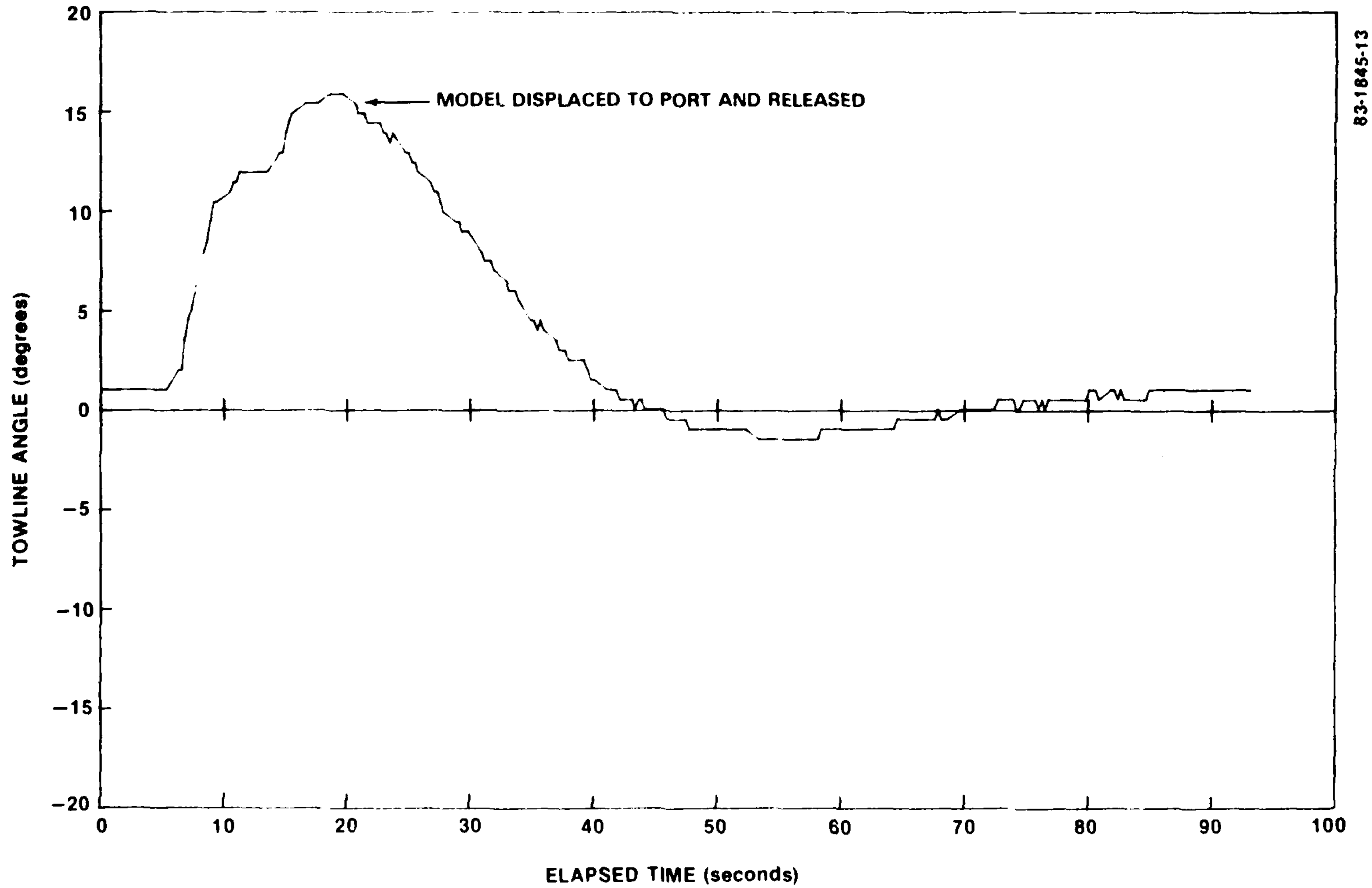

Figure 14 - Horizontal Towline Angle as a Function of Time for Barge Configuration 16 with Skegs

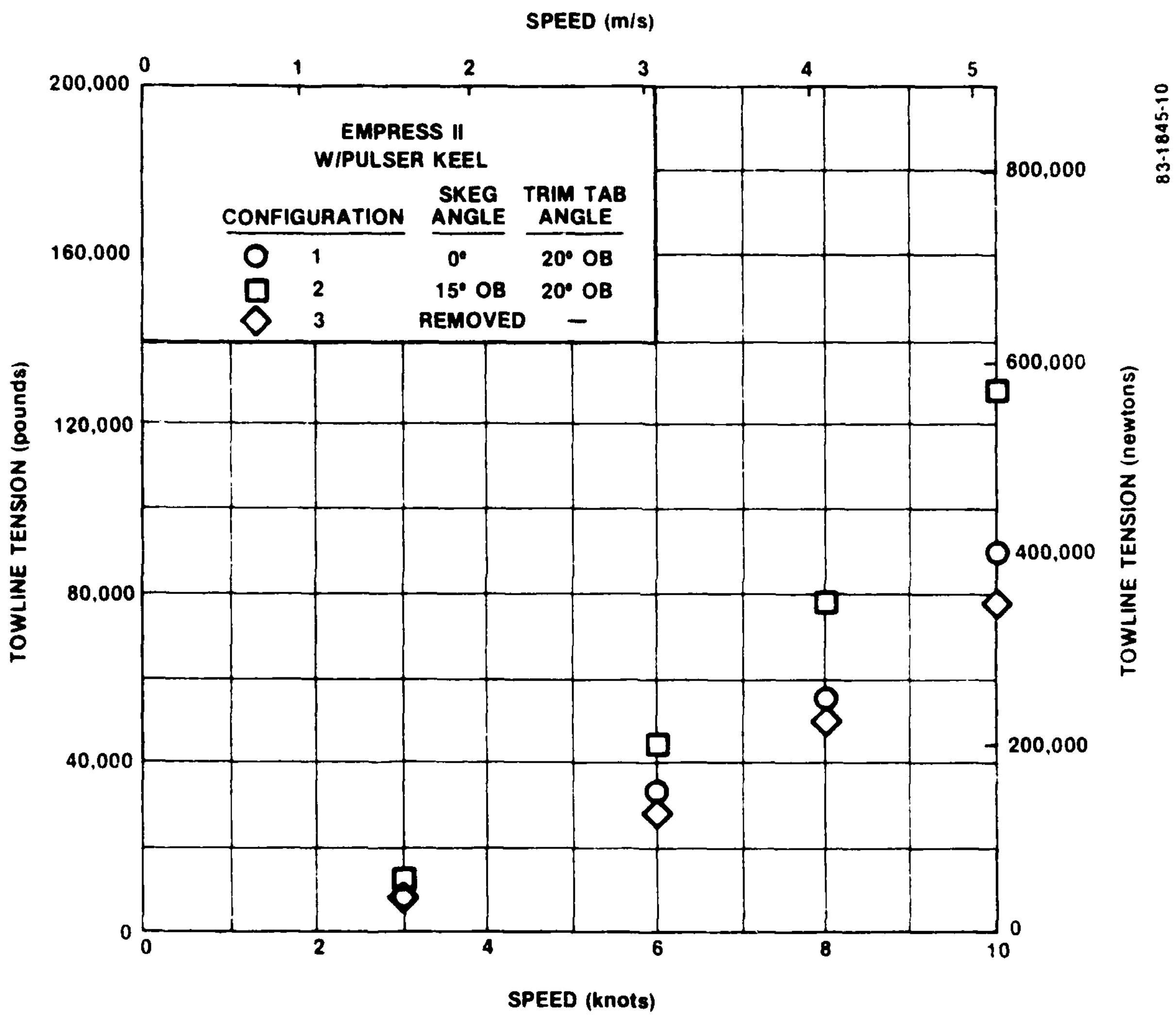

Figure 15 - Towline Tension as a Function of Speed for Various Skeg Angles for the EMPRESS II Barge with Pulser Keel

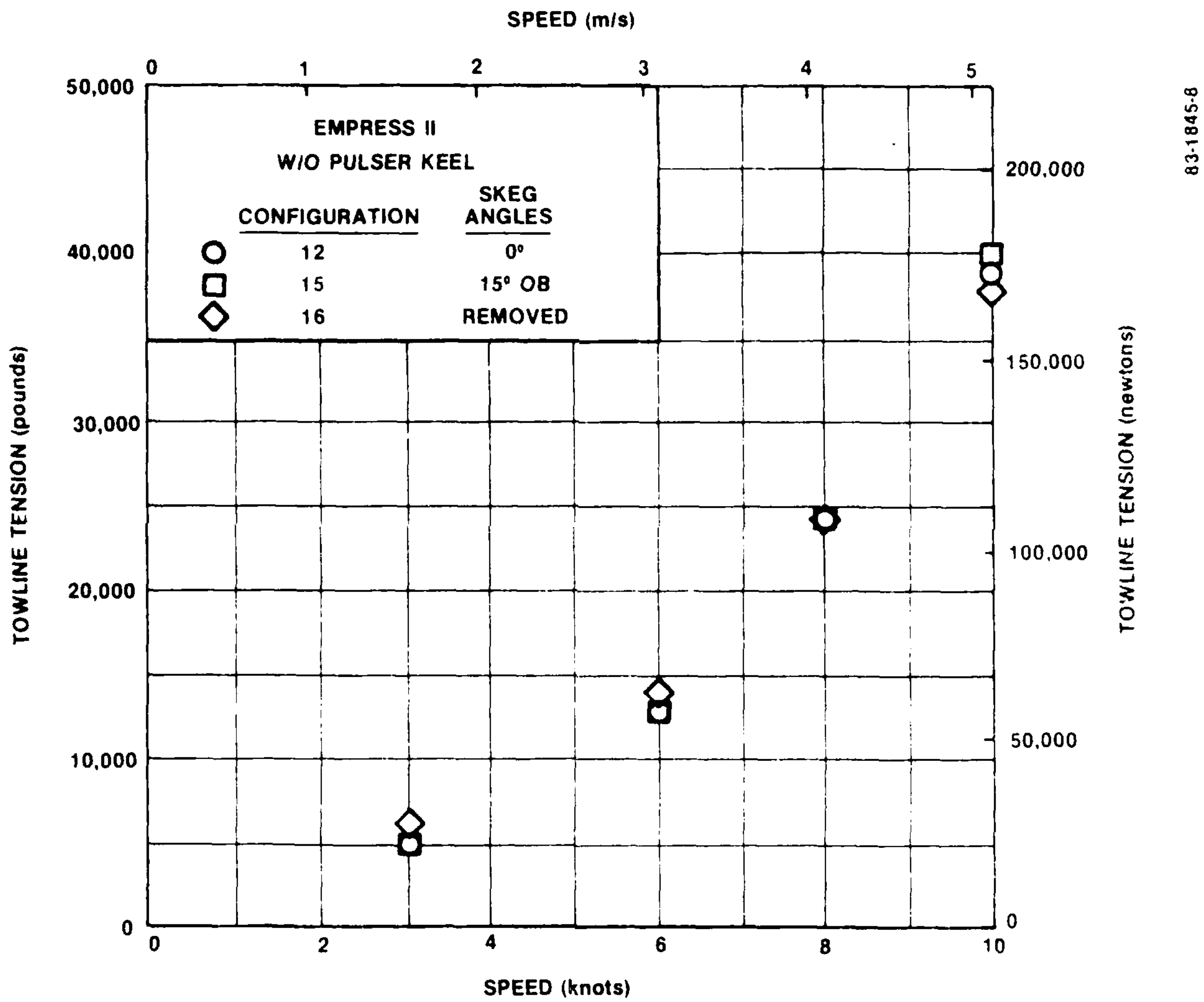

Figure 16 - Towline Tension as a Function of Speed for the Various Skeg Angles for the EMPRESS II Barge without Pulser Keel

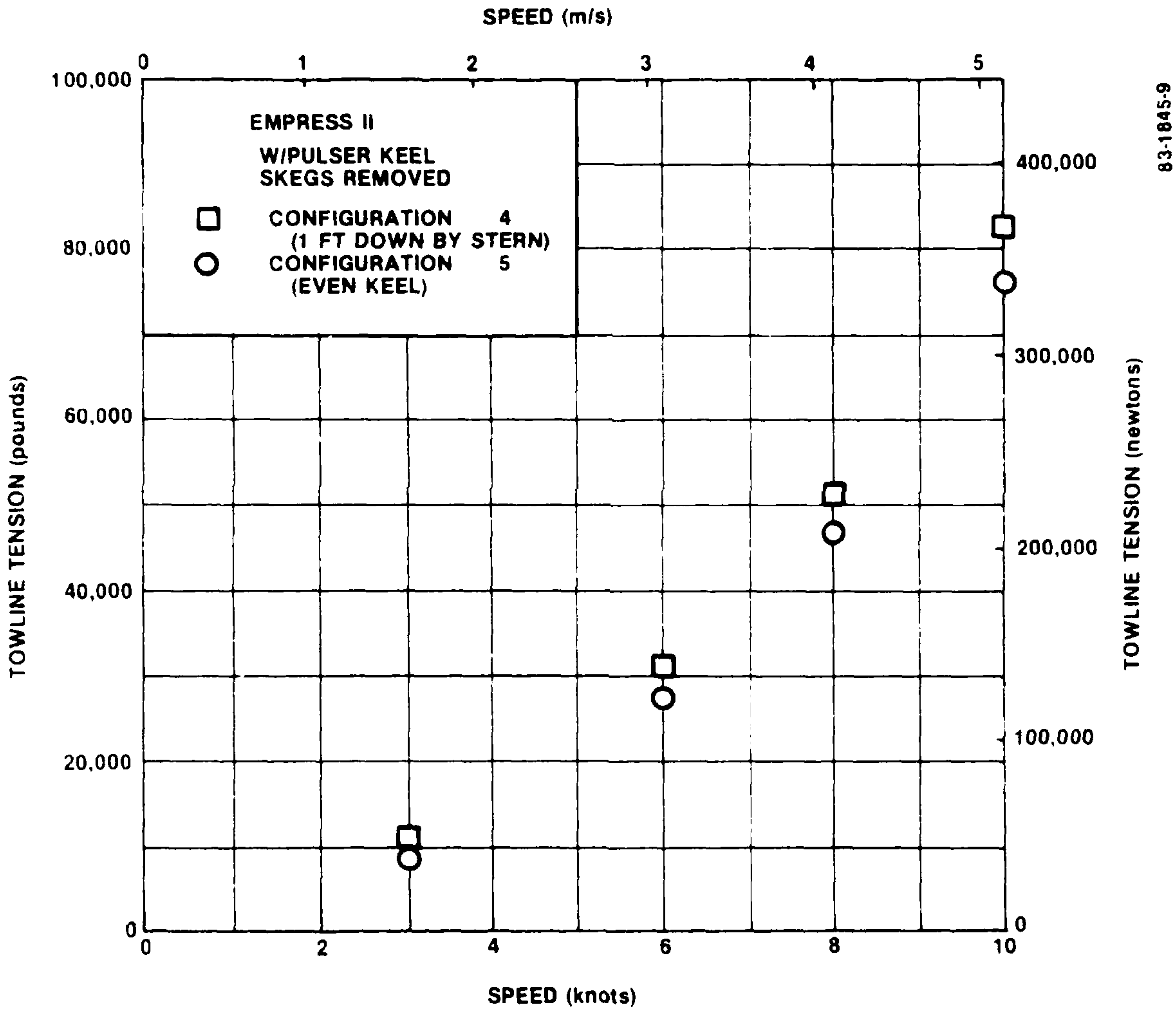

Figure 17 - Towline Tension as a Function of Speed for the Two Barge Trim Conditions

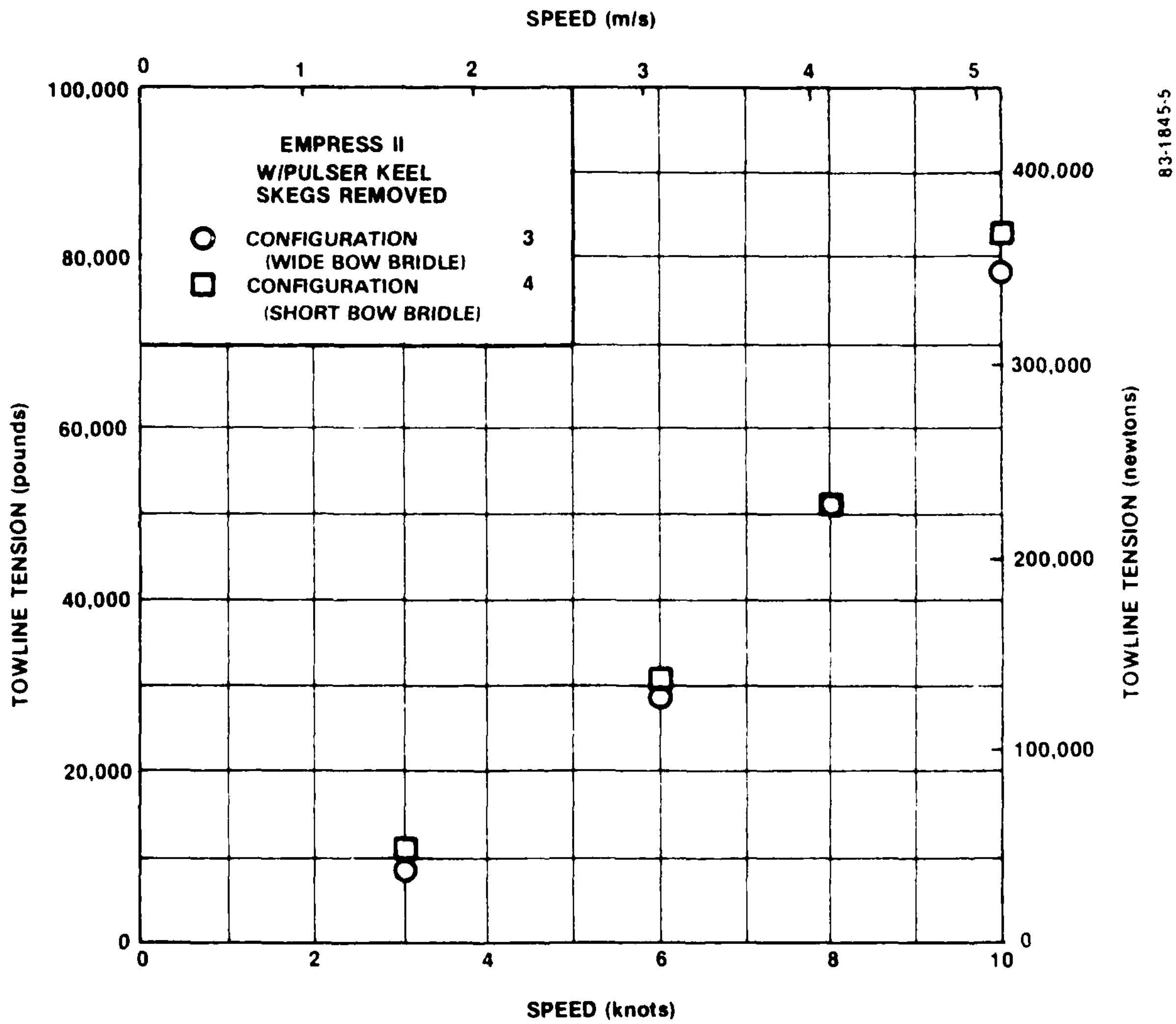

Figure 18 - Comparison of Towline Tension between the Wide and Narrow Towing Bridle Configurations

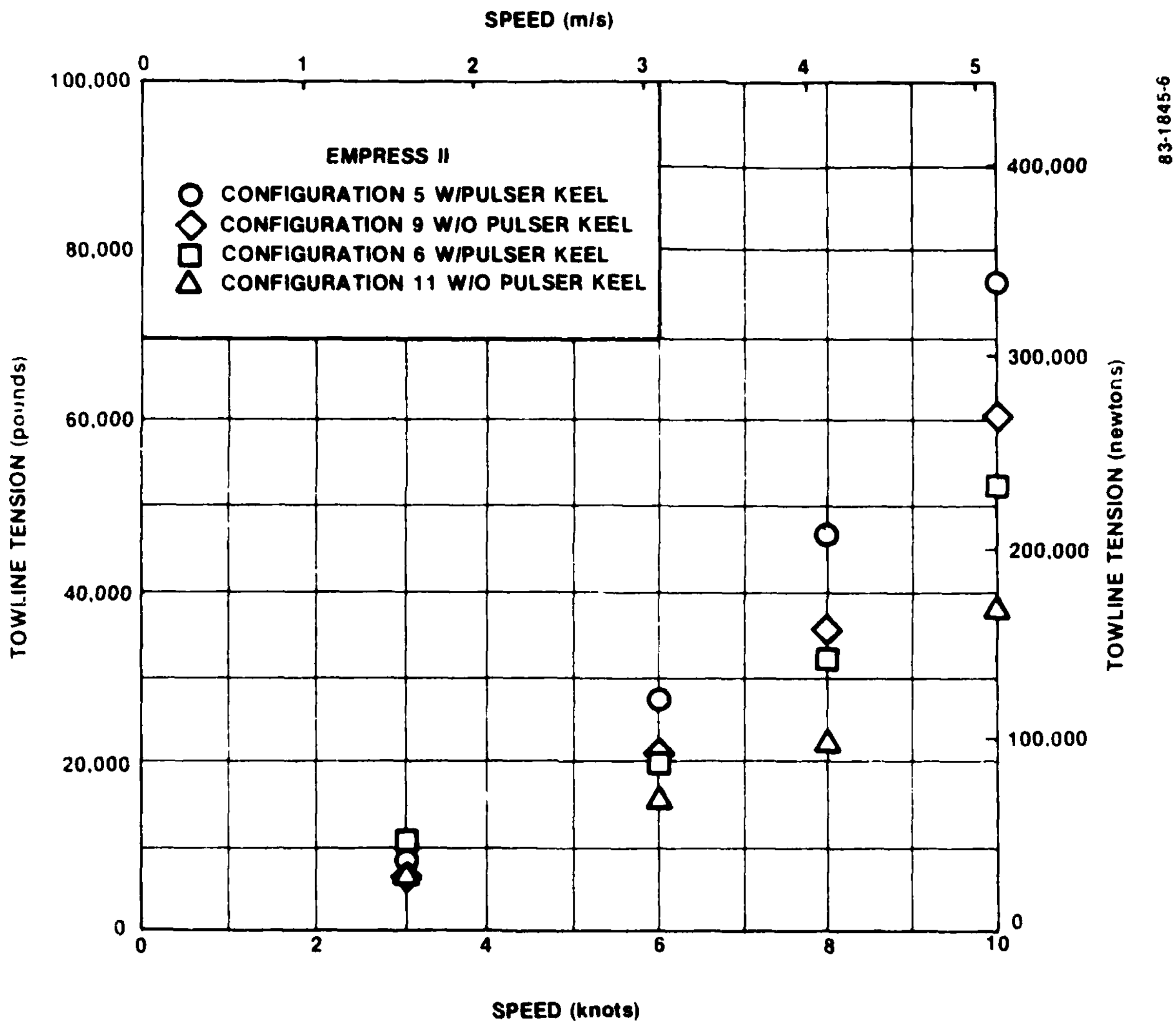

Figure 19 - Comparison of Towline Tension between the Barge with 3- and 7-foot Waterline with and without Pulser Keel

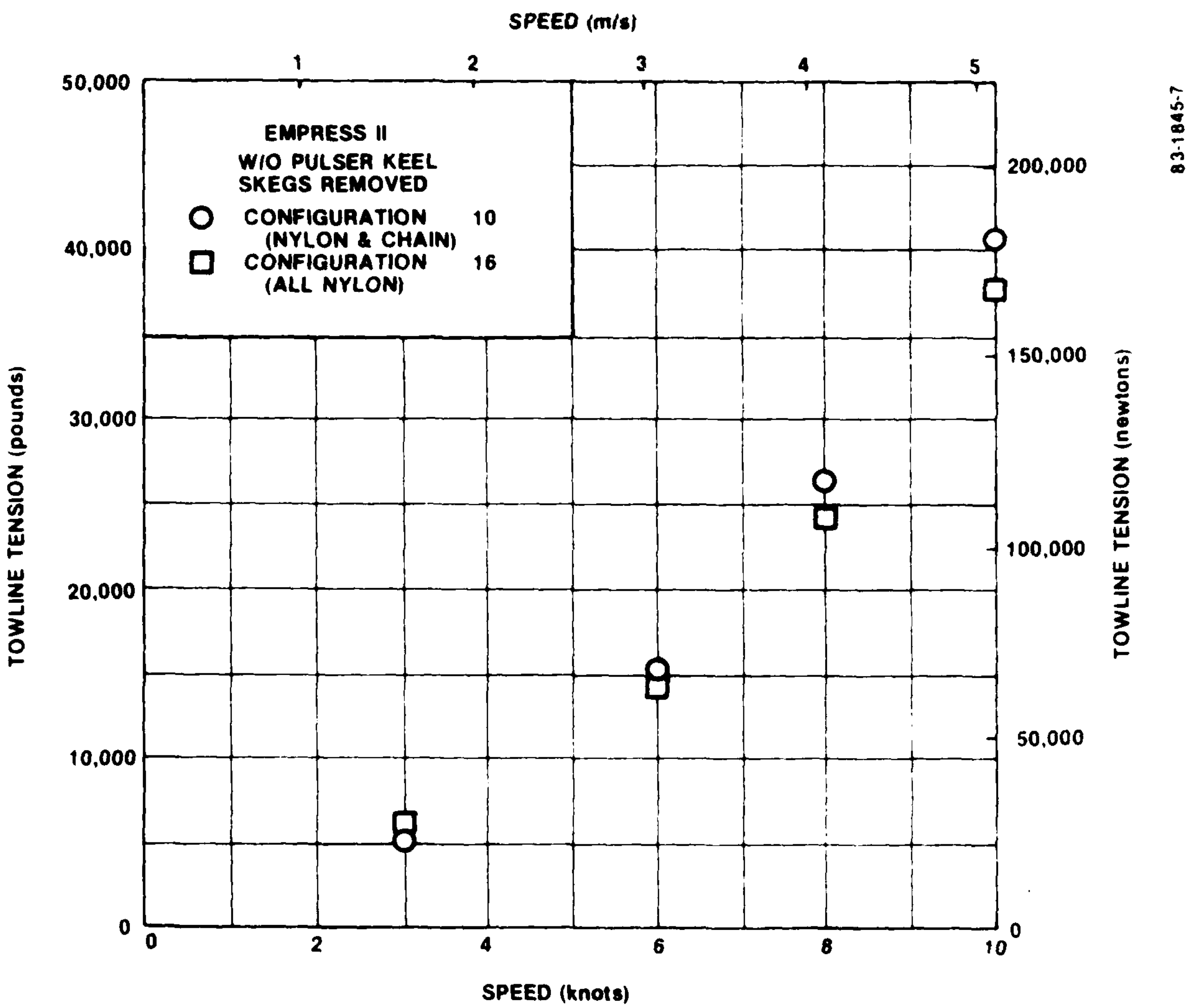

Figure 20 - Comparison of Towline Tension between Chain and Nylon Towing Bridles

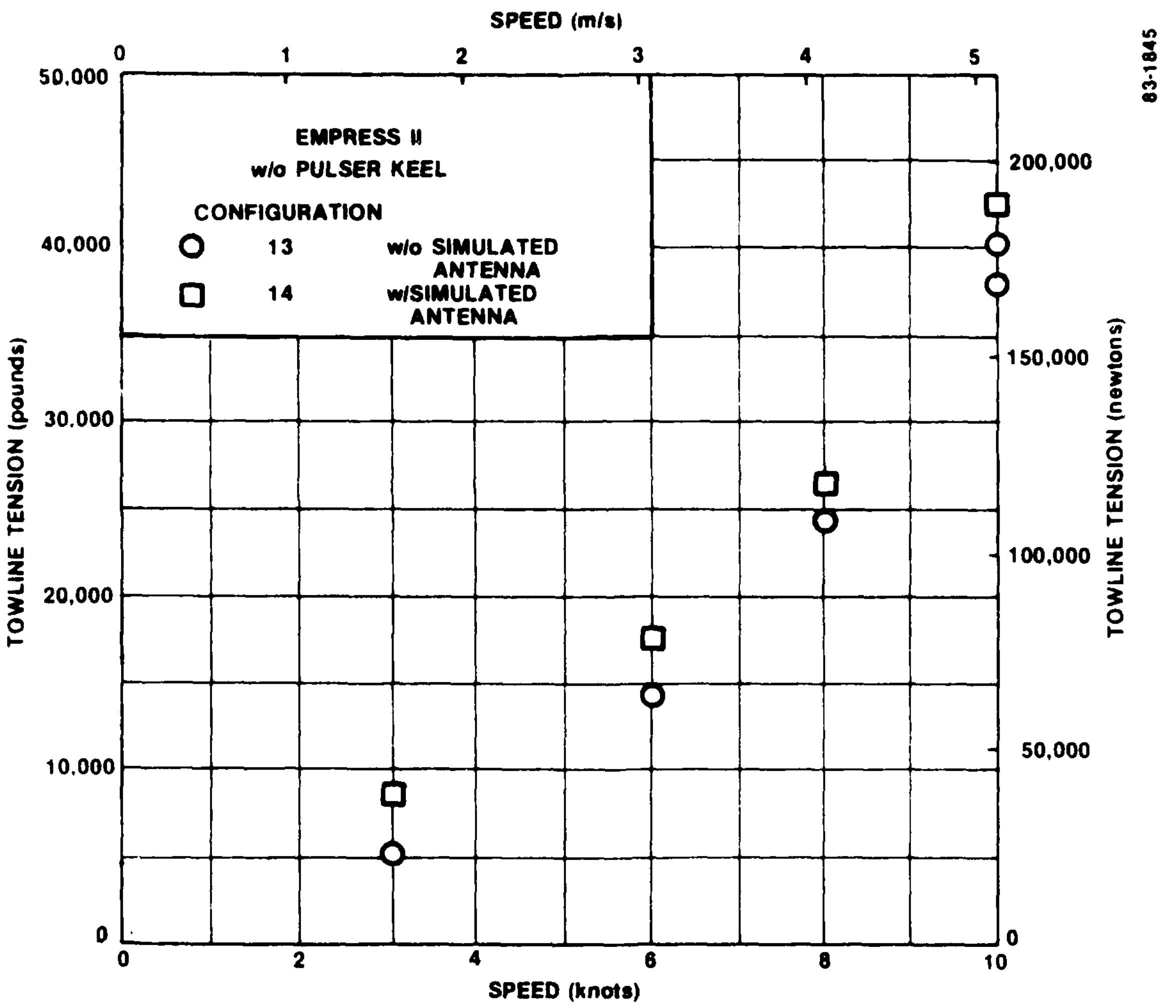

Figure 21 - Towline Tension as a Function of Speed with and without the Simulated Antenna

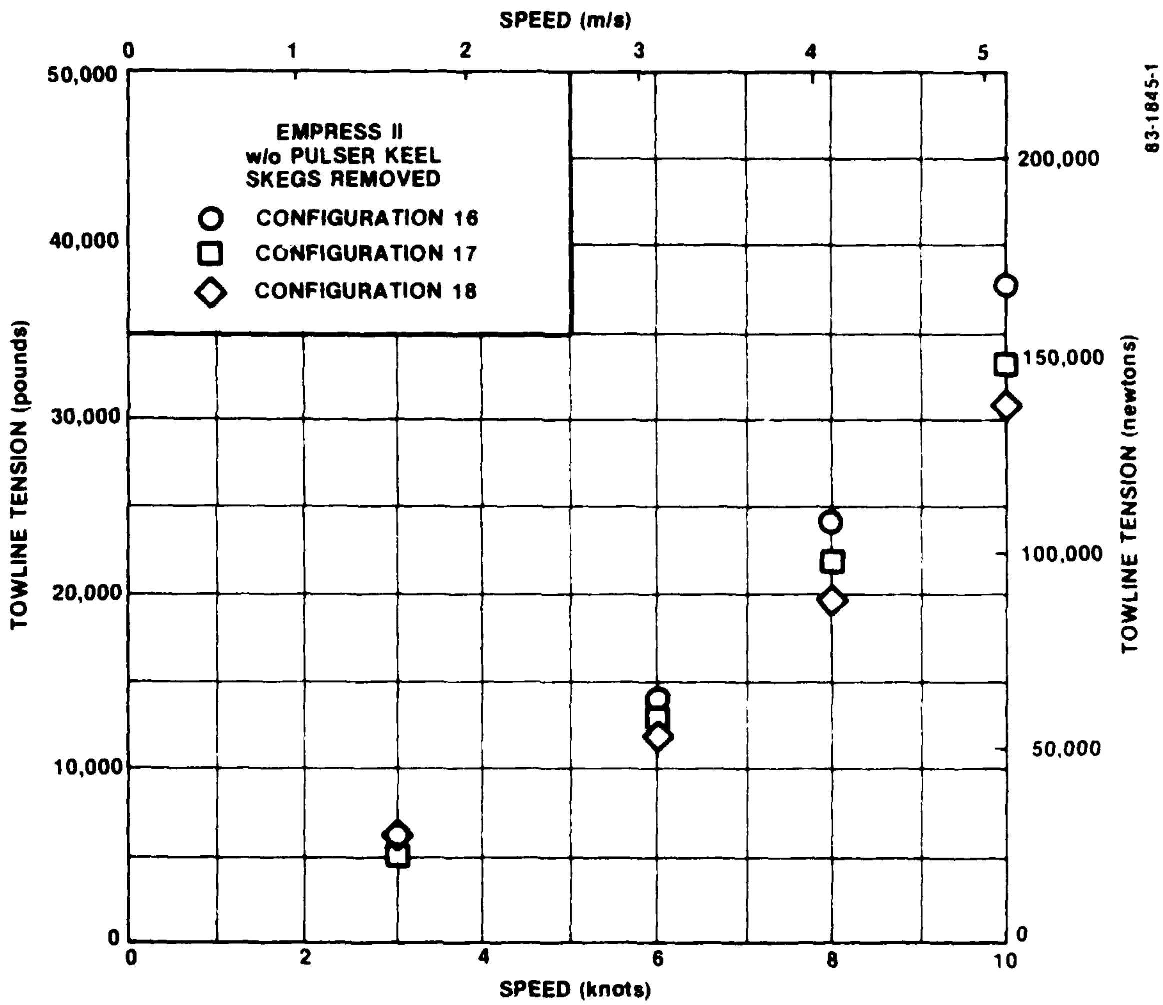

Figure 22 - Towline Tension as a Function of Speed for Configuration 16, 17, and 18

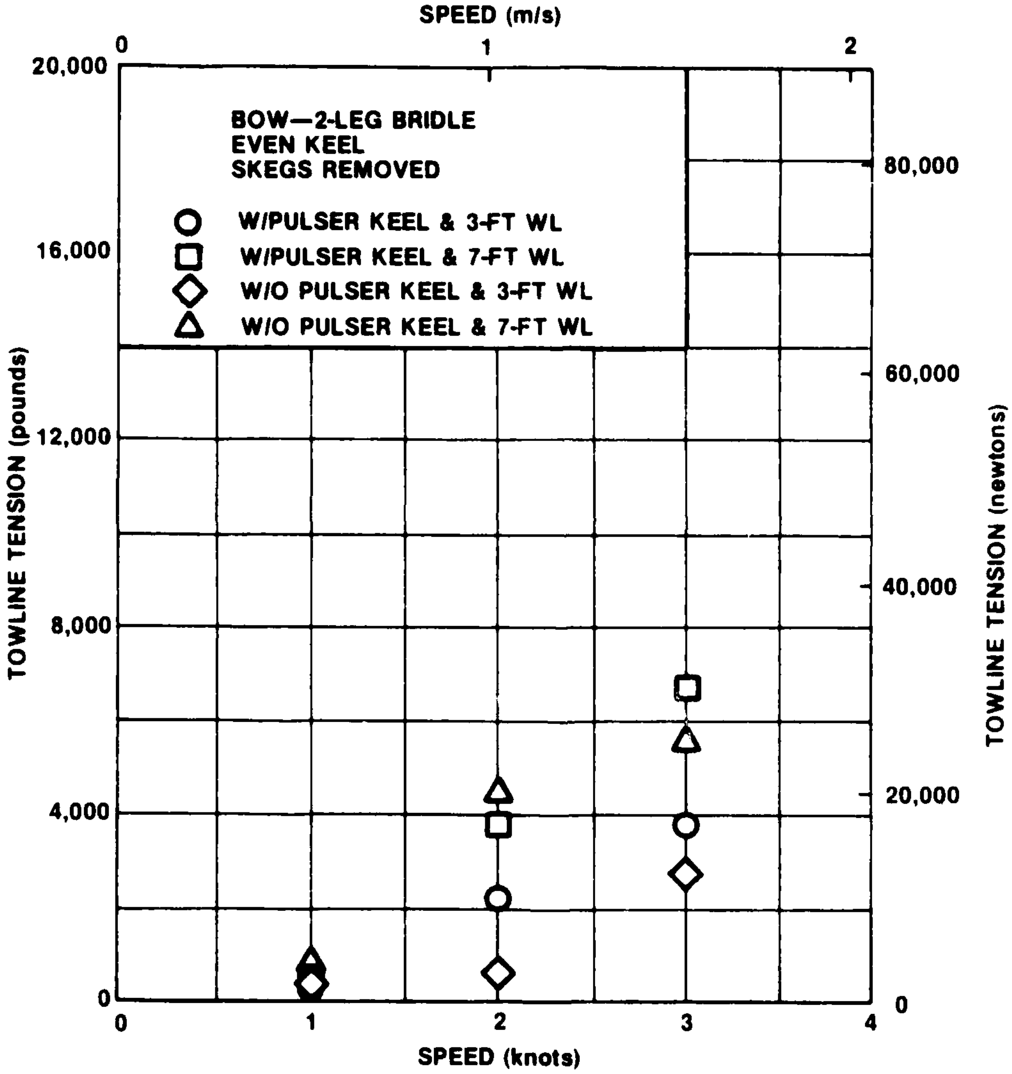

Figure 23 - Mooring Loads as a Function of Speed for 2-Leg Bridle from the Bow

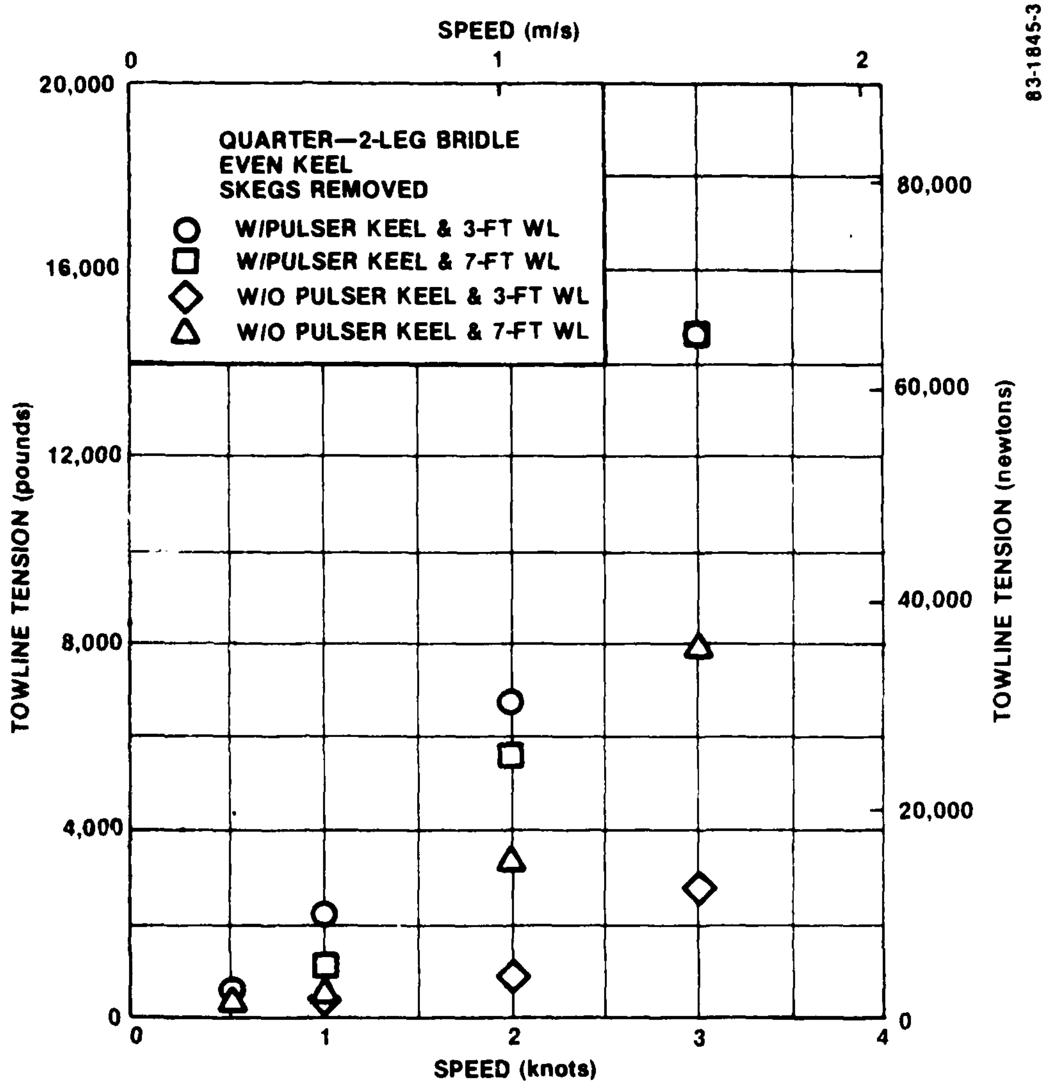

Figure 24 - Mooring Loads as a Function of Speed for 2-Leg Bridle from the Quarter

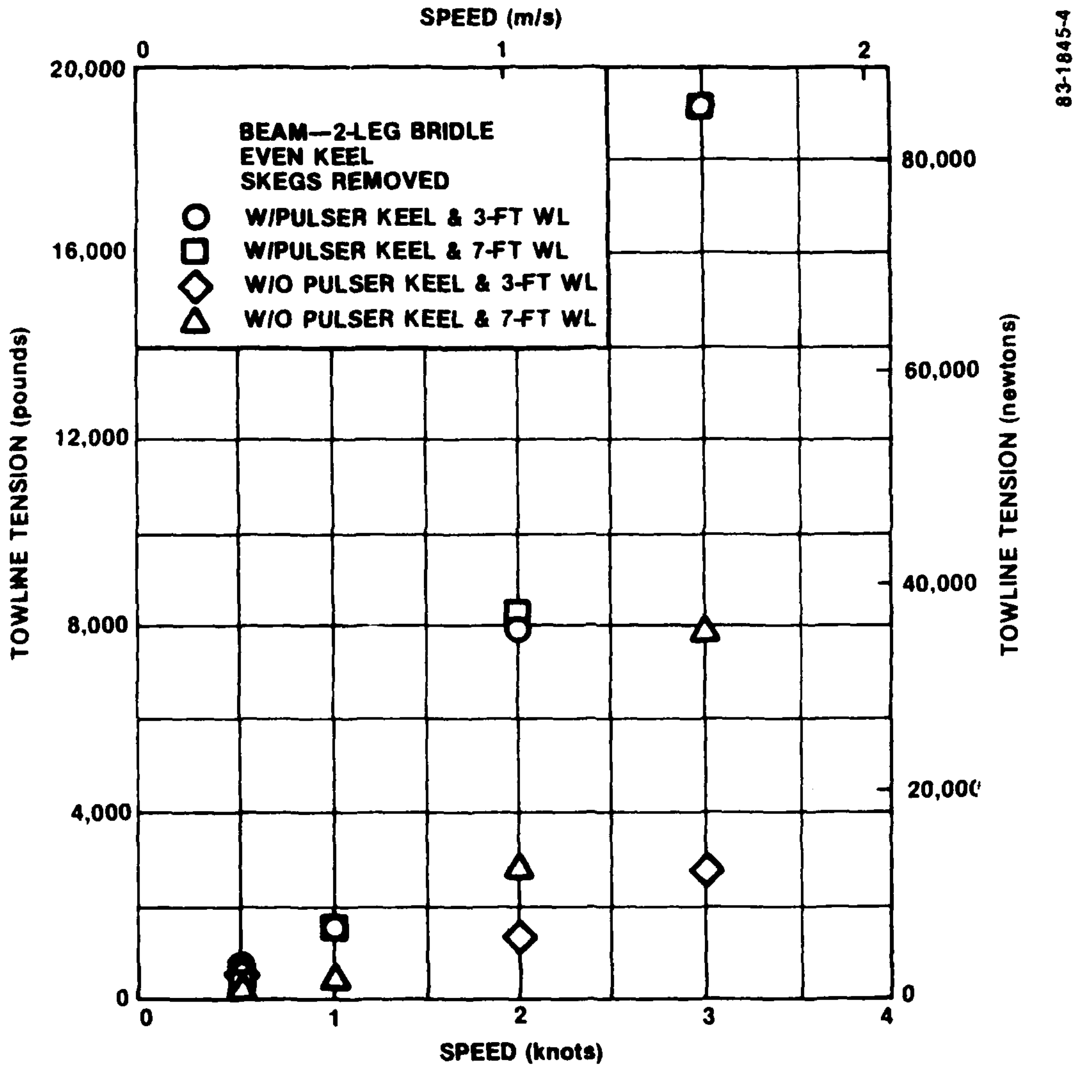

Figure 25 - Mooring Loads as a Function of Speed for 2-Leg Bridle from the Beam

5. The effect of a chain bridle will be negligible for towing stability but will increase the towline tension slightly.

6. The effect of wind loads on the antenna cannot be ascertained from the basin evaluation.

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8