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IMPERIAL IRANIAN NAVY DD 993 CLASS SEAKEEPING REPORT,(U)
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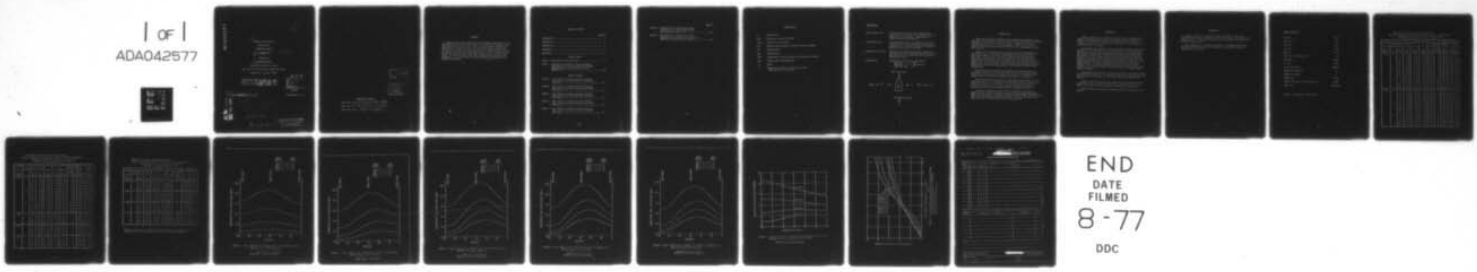

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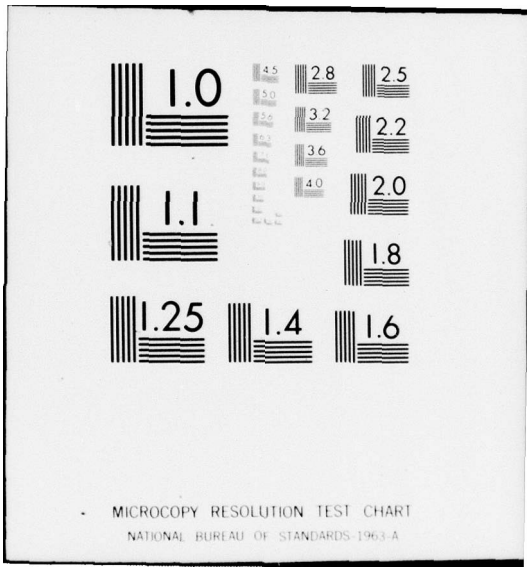
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Imperial Iranian Navy

DD 993 Class

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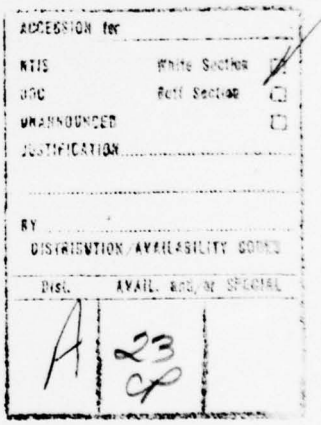

Approved for NAVSEC

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Head, IIN DD 993 McCall 12/5/76

ABSTRACT

This report contains experimental and analytical predictions of the seakeeping characteristics applicable to the DD 993 in accordance with a ship displacement of 8000 tons. Random wave experimental results are presented for various sea states at various ship speeds and headings. Roll motions are predicted for irregular, short-crested seas for various sea states at various ship speeds and headings. Roll is largest at the 70 degree heading; while the 100 degree heading results in the largest heave. For the IIN DD 993, there are no performance requirements for seakeeping. Those predictions contained herein are provided for ship operator information.

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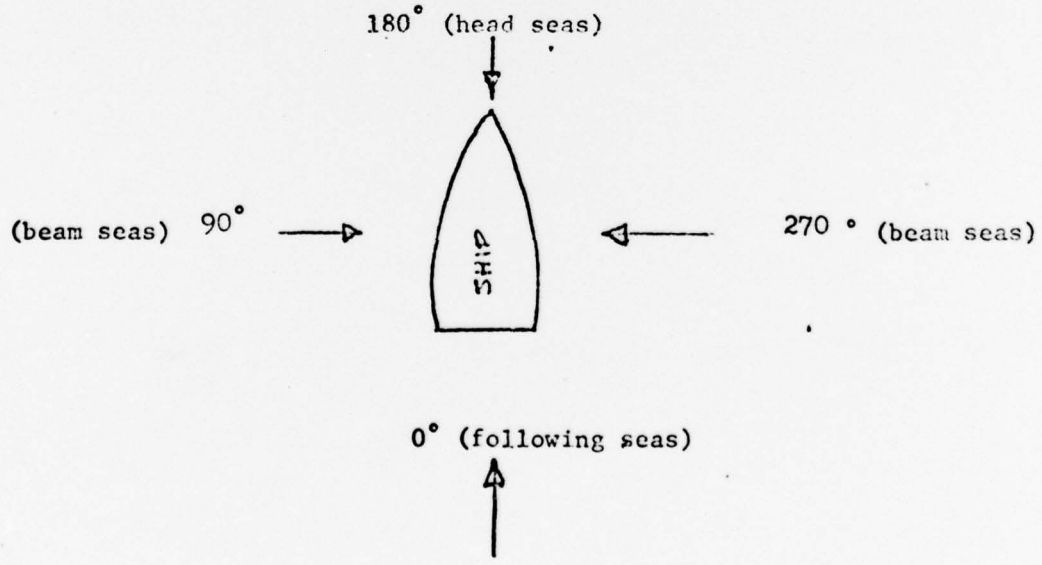
NOMENCLATURE

B	Maximum beam
GM_T	Transverse metacentric height
$H_{1/3}$	Significant wave height
KG	Distance from baseline to vertical center of gravity
$K\theta$	Pitch gyradius
K_ϕ	Roll gyradius
LCG	Longitudinal center of gravity as referenced to midship
Lpp	Length between perpendiculars
T	Draft
Δ	Displacement (weight) of ship in long tons (one long ton = 2240 pounds)

DEFINITIONS

Short crested seas	A sea condition which is most representative of real life. The waves are multidirectional, as opposed to unidirectional. Represented by a Pierson-Moscowitz sea spectrum.
Long crested seas	A sea condition which has irregular waves, all travelling in the same direction (unidirectional, represented by a Pierson-Moscowitz sea spectrum). Does not occur often in real life.
Significant amplitude	Term used in statistical analysis. Defined as the mean value of the one-third highest amplitudes. The significant roll amplitude is 1.6 times the average roll value.
Ship heading	Ship heading is defined on the basis of head seas ..... 180° beam seas ..... 90° and 270° following seas .... 0°



INTRODUCTION

This report contains experimental and analytical predictions of the seakeeping characteristics which are applicable for the DD 993 in accordance with the ship particulars listed in TABLE 1. Although the results contained herein are for a ship displacement of 8000 tons, it is felt that no significant changes would be realized for a displacement change of $\pm$ 400 tons.

Random wave experiments were conducted in waves representative of a Sea State 4 ($H_{1/3}$ = 6.9 feet) at ship speeds of 0, 8, 16, 24 and 30 knots for headings of 220, 200, and 180 degrees; Sea State 5 ($H_{1/3}$ = 10.0 feet) at ship speeds of 12, 16, 20 and 24 knots for headings of 220, 200 and 180 degrees; and Sea State 6 ($H_{1/3}$ = 15.0 feet) at ship speeds of 0, 8, 16 and 24 knots for headings of 220, 200, 180, 120, 110, 100, 90, 70, 40 and 0 degrees. TABLE 2 presents the measured significant amplitudes of the motions representative of the DD 993 in random long-crested waves.

The predicted roll motions in irregular, short-crested seas are presented in FIGURES 1 - 5 for ship speeds of 0, 8, 16, 20 and 24 knots. Significant roll amplitudes in degrees are shown as a function of ship heading angle for the four sea states of interest (4, 5, 6 and 7).

The significant roll amplitudes at the worst heading angles (heading angle with maximum roll response) for short-crested seas are shown as a function of ship speed in FIGURE 6. The significant roll amplitudes at the worst heading angles for short-crested seas are presented as a function of significant wave height (double amplitude) in FIGURE 7.

It should be pointed out that TABLE 2 represents the results of Model Testing. FIGURES 1 through 7 are based upon Computer Predictions which use a roll decay coefficient obtained from Model Test. Notwithstanding this, the curves shown in FIGURES 1 through 7 are more realistic, since they are given for Short Crested Seas (see definition).

DISCUSSION

TABLE 2 contains mean values of yaw angle and sway displacement, in addition to significant values of Pitch, Roll, Heave and Relative Bow Motion. When reading the values of yaw and sway, the correct sign conventions for yaw (bow to starboard is positive) and sway (positive to starboard) should be applied.

As expected, the highest Sea State generates the highest amplitudes of motion. The most critical ship speed, however, is not so obvious. TABLE 2 does not show any particular speed for which all of the motions are largest, although roll motion decreases with increased ship speed. The table does show, however, that the pitch is greatest for headings between 220 and 110 degrees, with all of the headings within that range resulting in about the same pitch motion. The roll is largest at the 70 degree heading; while the 100 degree heading seems to result in the largest heave. The largest relative bow motion is at the 0 degree heading, with the second largest at the 220 degree heading; although the differences between the results at the 220, 200 and 180 degree heading seem to be slight.

The predicted roll motions in short-crested seas, for random headings can be found in FIGURES 1 - 5. These roll angles range from a significant roll value of $\pm$ 5.08 degrees in Sea State 4 to $\pm$ 21.6 degrees in Sea State 7.

FIGURE 6 shows significant roll amplitude at worst heading plotted against ship speed. It should be noted that, in the higher Sea States (above S.S. 5), the rolling decreases with increase in ship speed.

FIGURE 7 shows the increase of rolling motion with significant wave height.

REFERENCES

1. Rossignol, Grant A., Lawrence C. Ruth, and Everett L. Woo, "Experimental Evaluation of the Seaworthiness Characteristics of the DD 963 Class Destroyer as Represented by Model 5265-1A," NSRDC T and E Report SPD-P-311-35, February 1975,

2. Barr, Roderick A., and Vladimir Ankudinov, "Calculated Roll Motions for the DD 963 Class Destroyer," Hydronautics, Incorporated Technical Report 7522-1, May 1975.

SHIP PARTICULARS

B, feet	55.2
GM_T, feet	3.9
KG, feet	22.3
K_θ % Lpp	25.0
K_ϕ, % B	37.0
LCG (aft of midship), feet	7.3
Lpp, feet	529.0
T, feet	19.6
Δ, tons sea water	8000.0
NUMBER OF PROPELLERS	2
NUMBER OF RUDDERS	2
RUDDER TYPE	SPADE
RUDDER AREA (PER RUDDER), square feet	162.0
TRIM, feet	EVEN KEEL

TABLE 1 - PARTICULARS OF THE DD 993

(Experimental Results in Long Crested Seas)

TABLE 2 - SIGNIFICANT WAVE HEIGHT (DOUBLE AMPLITUDE), SIGNIFICANT SHIP MOTIONS (SINGLE AMPLITUDES), AND MEAN YAW AND SWAY FOR THE DD 993 IN RANDOM WAVES

Conditions			Significant Values					Mean Values	
Heading Degrees	Sea State	Ship Speed Knots	Wave Height Feet	Pitch Degrees	Roll Degrees	Heave Feet	Relative Bow Motion Feet	Mean Yaw * Degrees	Mean Sway * Feet
220	4	0	6.46	0.59	2.68	1.13	5.33	+0.58	+ 5.06
		8	7.03	0.73	1.87	1.23	5.17	-1.93	+ 1.87
		16	7.10	0.75	1.31	1.44	5.32	-0.28	+ 1.76
		24	7.14	0.69	1.43	1.66	5.67	+0.06	- 0.29
		30	6.95	0.57	2.04	1.63	5.35	-0.44	+ 2.76
	5	12	10.04	1.34	2.79	2.40	8.63	-0.59	+ 4.17
		16	9.81	1.36	2.25	2.80	9.02	+0.71	-10.59
		20	9.85	1.25	2.24	3.15	9.11	+0.14	- 4.51
		24	10.07	1.20	2.38	2.95	9.13	+0.54	- 8.43
	6	0	14.49	1.67	7.57	6.58	12.10	-0.18	+ 5.46
		8	15.30	2.12	6.38	4.58	13.52	-1.23	+ 6.47
		16	15.19	2.24	3.73	4.86	14.06	+0.52	- 0.92
		24	14.79	2.05	3.22	5.47	14.35	-0.26	+ 4.20
200	4	0	7.46	0.46	1.80	1.20	4.95	+2.69	+ 2.21
		8	7.12	0.57	1.12	1.02	4.66	-1.25	+14.25
		16	7.21	0.61	0.72	1.12	5.06	-0.93	+13.49
		24	6.68	0.51	0.92	1.20	4.63	-0.35	+ 4.02
		30	6.90	0.48	1.25	1.29	4.77	-0.21	+ 2.37
	5	12	9.74	1.02	1.54	1.86	7.40	-0.14	- 0.31
		16	9.56	1.04	1.33	1.97	7.61	+0.13	- 3.83
		20	9.23	1.08	1.30	2.18	7.94	-0.16	+ 0.98
		24	9.85	1.00	1.30	2.29	7.92	-0.08	- 2.18
	6	0	15.29	1.64	4.70	5.35	12.00	+2.64	+ 3.39
		8	14.72	1.66	3.38	3.40	11.72	-1.01	-10.46
		16	14.42	1.88	2.04	3.88	12.18	-0.25	+ 2.30
		24	14.07	2.01	2.27	4.73	14.17	-1.21	+ 2.93

(Experimental Results in Long Crested Seas)

TABLE 2 - SIGNIFICANT WAVE HEIGHT (DOUBLE AMPLITUDE), SIGNIFICANT SHIP MOTIONS (SINGLE AMPLITUDES), AND MEAN YAW AND SWAY FOR THE DD 993 IN RANDOM WAVES

(Continued)

Conditions			Significant Values					Mean Values	
Heading Degrees	Sea State	Ship Speed Knots	Wave Height Feet	Pitch Degrees	Roll Degrees	Heave Feet	Relative Bow Motion Feet	Mean Yaw * Degrees	Mean Sway * Feet
180	4	0	6.13	0.42	0.94	0.70	4.53	-0.64	- 5.18
		8	6.26	0.44	1.64	1.18	4.38	-0.32	-12.39
		16	5.62	0.46	0.39	0.93	3.88	+0.39	+ 0.04
		24	5.65	0.51	0.78	1.13	4.37	-0.29	+ 2.51
		30	5.88	0.49	1.13	1.22	4.32	-0.69	+ 5.53
	5	12	8.75	0.90	0.68	1.72	6.58	-0.63	+ 8.93
		16	8.83	1.00	0.56	1.93	7.38	-0.22	+ 1.16
		20	8.76	0.99	0.60	2.01	7.23	-0.42	+ 4.65
		24	8.75	0.96	0.98	2.16	7.77	-0.53	+ 5.69
	6	0	14.86	1.65	2.00	3.86	11.03	-1.40	+ 3.21
		8	13.33	1.55	1.52	3.42	10.45	+0.28	- 6.69
		16	13.97	1.92	0.93	3.99	12.71	+0.05	- 2.45
		24	14.11	2.19	1.49	5.15	15.00	-0.19	- 1.63
120	6	0	16.36	2.12	12.48	--	--	-0.22	+14.42
		8	15.81	2.19	10.05	5.77	--	+5.91	+ 7.42
		16	15.38	2.13	6.12	5.74	--	+2.86	+ 4.86
		24	15.49	2.27	5.39	6.87	--	+2.40	- 5.71
110		0	13.55	1.88	11.75	5.55	--	-2.15	+12.25
		8	16.00	2.21	12.43	6.65	--	+4.51	- 4.17
		16	16.88	2.08	6.93	7.31	--	+1.65	+ 2.84
		24	15.01	1.76	5.87	9.09	--	+1.72	+ 4.17
100		0	16.06	1.67	11.66	--	--	+2.36	+ 1.71
		8	15.84	1.73	11.32	9.36	--	+4.80	- 0.60
		16	16.02	1.36	7.53	8.62	--	+1.41	+ 8.36
		24	16.40	1.26	7.63	10.15	--	+0.76	- 8.10

(Experimental Results in Long Crested Seas)

TABLE 2 - SIGNIFICANT WAVE HEIGHT (DOUBLE AMPLITUDE), SIGNIFICANT SHIP MOTIONS (SINGLE AMPLITUDES), AND MEAN YAW AND SWAY FOR THE DD 993 IN RANDOM WAVES

(Continued)

Conditions			Significant Values					Mean Values	
Heading Degrees	Sea State	Ship Speed Knots	Wave Height Feet	Pitch Degrees	Roll Degrees	Heave Feet	Relative Bow Motion Feet	Yaw * Degrees	Sway * Feet
90	6	0	15.06	0.73	13.28	--	--	+0.66	- 6.29
		8	15.46	0.67	7.97	8.86	--	+3.38	+ 9.30
		16	15.96	0.64	7.77	8.31	--	+1.06	+ 6.28
		24	15.20	0.61	7.39	7.81	--	+0.64	+ 9.44
70		0	17.79	2.30	14.48	--	--	+0.52	+ 6.41
		8	11.92	1.79	10.95	5.28	--	+2.30	- 1.15
		16	15.32	1.70	15.54	5.55	--	+0.37	+15.59
		24	14.80	1.61	15.90	8.52	--	+0.59	+ 3.89
40		0	13.88	1.45	8.17	3.81	--	-6.17	- 8.65
		8	15.26	1.46	7,77	3.85	--	-4.50	+ 8.64
		16	12.12	1.39	6.11	3.87	--	-1.71	+ 1.24
		24	13.51	0.93	10.91	3.74	--	-0.84	+ 9.91
0		0	13.68	1.40	1.59	3.20	8.30	-1.73	+ 1.57
		8	14.17	1.35	1.38	3.03	17.51	+0.05	- 6.57
		16	14.98	1.01	0.90	2.63	17.42	+0.07	+ 0.74
		24	16.35	1.09	2.67	2.81	16.67	+0.39	- 0.22

*The values of yaw and sway indicate the effectiveness of the automatic steering system more than the actual sway and yaw that the ship would experience.

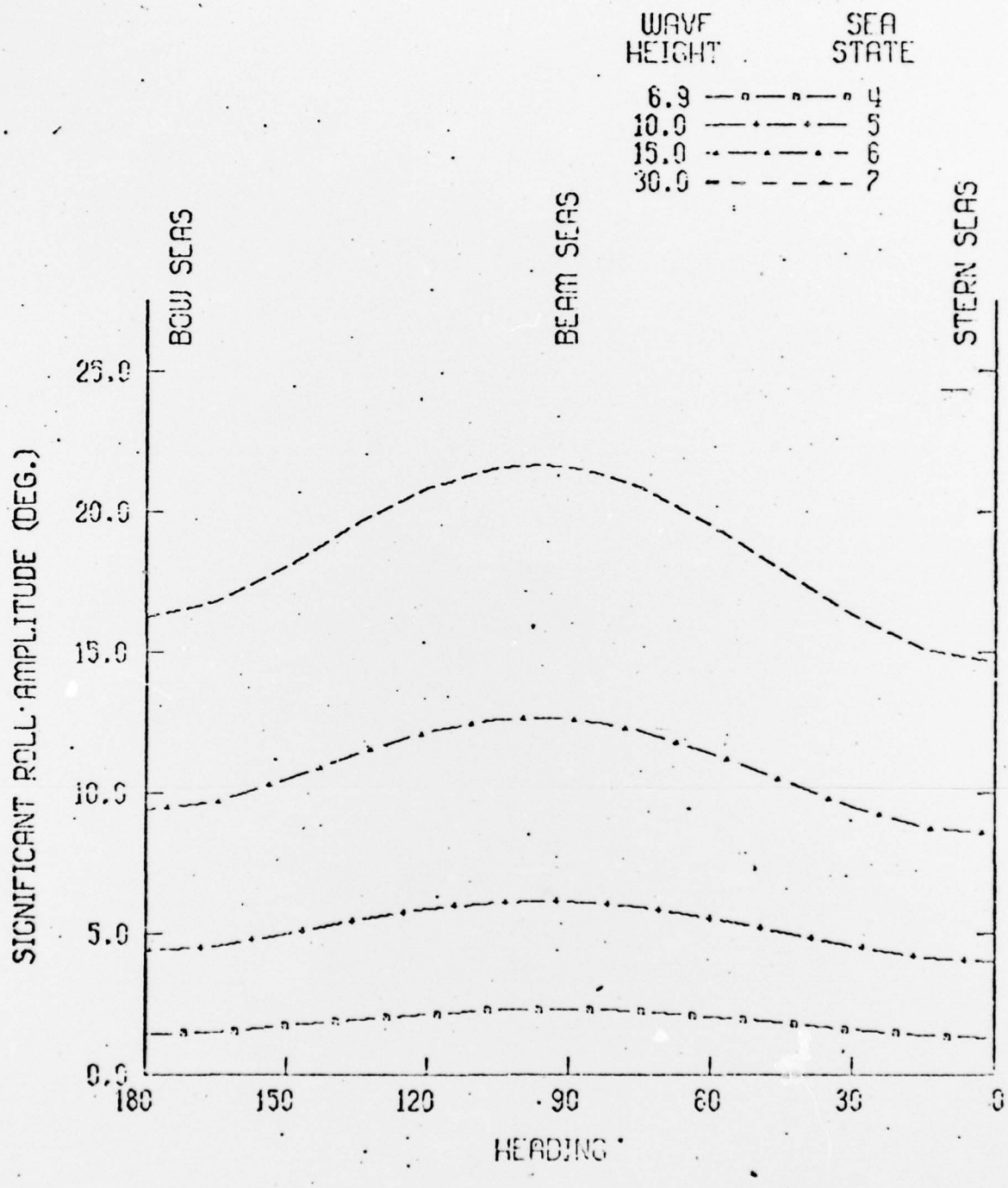


FIGURE 1 - ROLL MOTION VS. HEADING INTO SHORT CRESTED SEAS
DD 993 FULL LOAD CONDITION

SHIP SPEED 0.0 KNOTS
BASED UPON COMPUTER PREDICTIONS

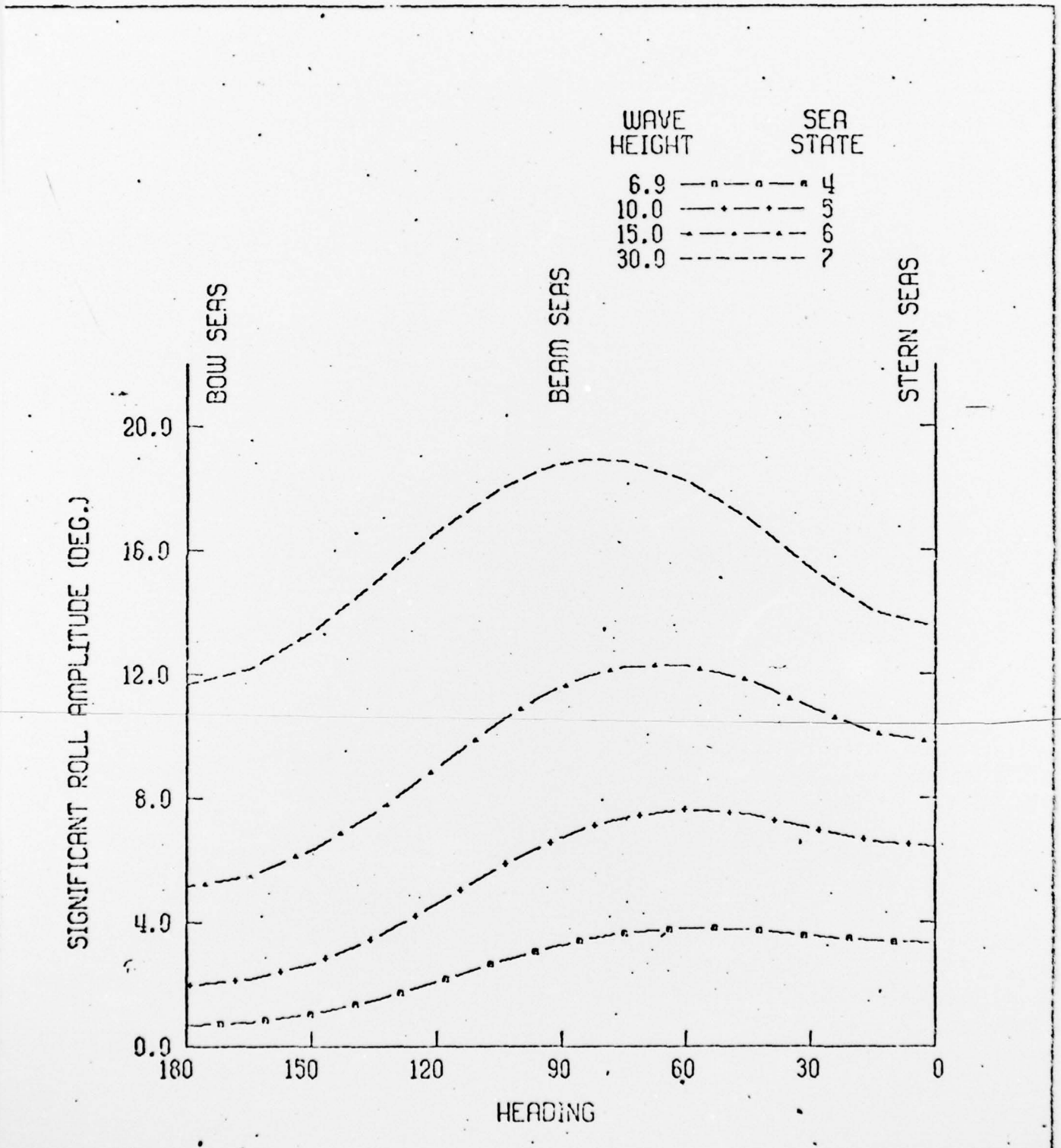


FIGURE 2 - ROLL MOTION VS. HEADING INTO SHORT CRESTED SEAS
DD 993 FULL LOAD CONDITION

SHIP SPEED 8.0 KNOTS

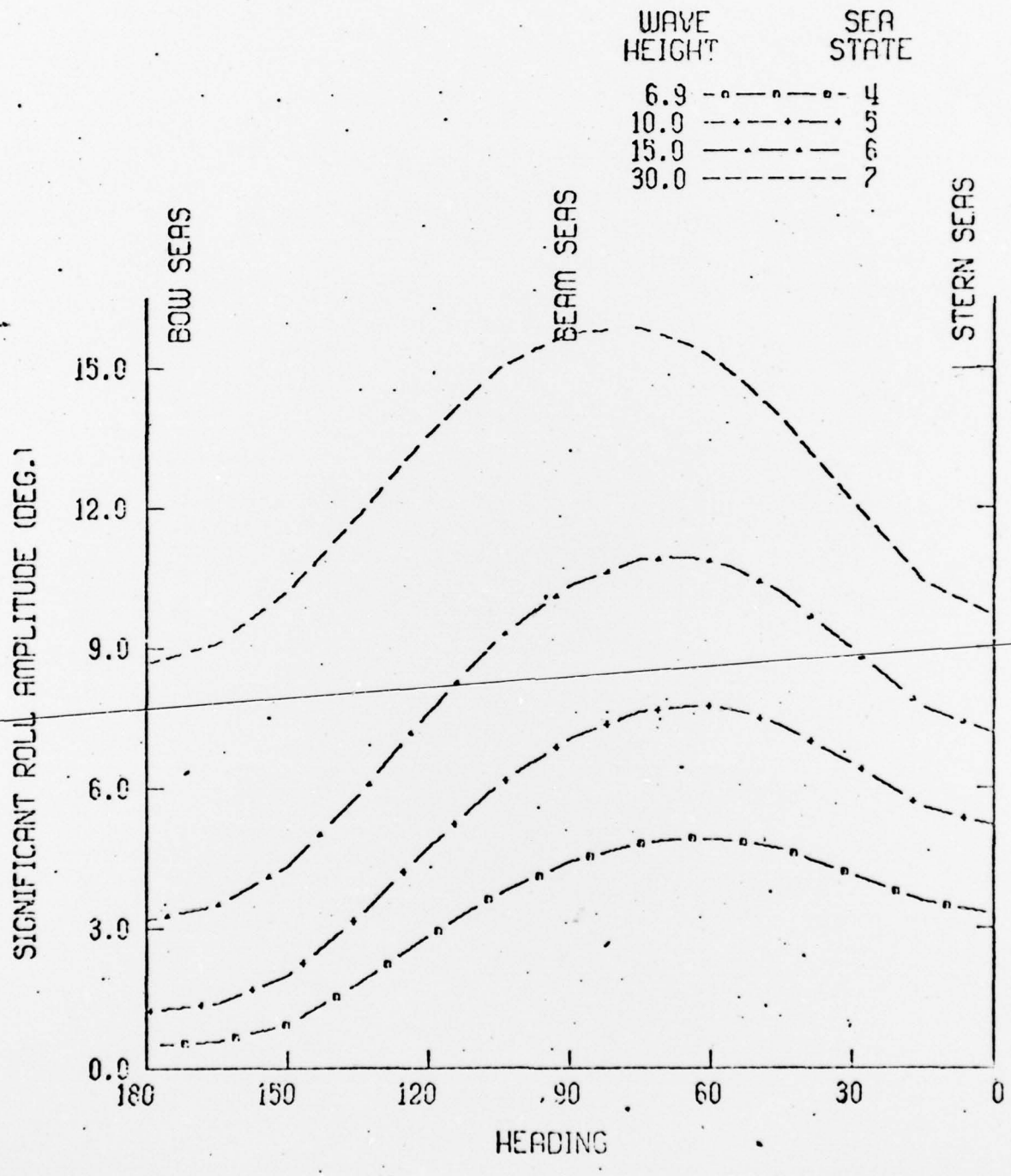


FIGURE 3 - ROLL MOTION VS. HEADING INTO SHORT CRESTED SEAS
DD 993 FULL LOAD CONDITION

SHIP SPEED 16.0 KNOTS
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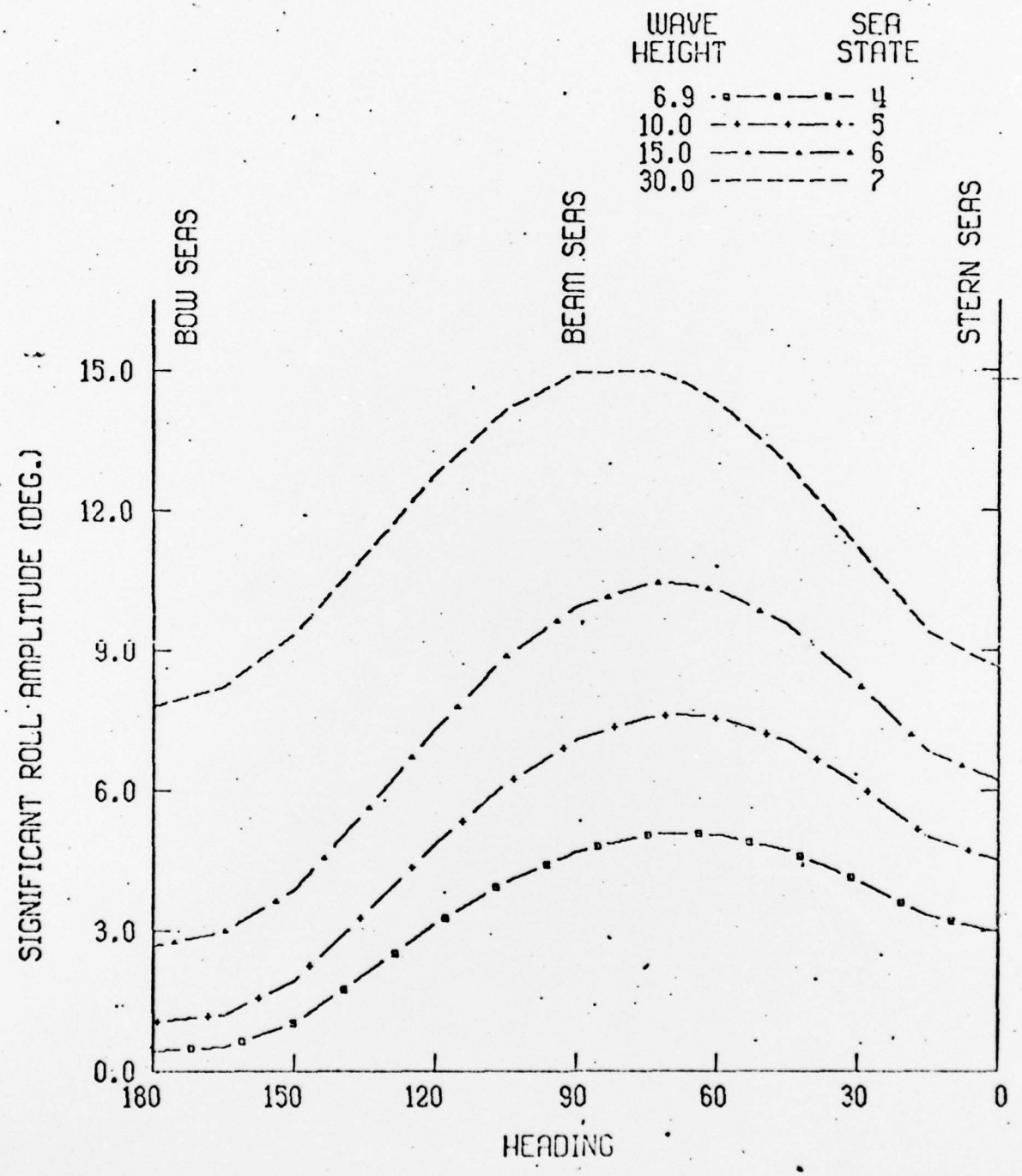

FIGURE 4 - ROLL MOTION VS. HEADING INTO SHORT CRESTED SEAS
DD 993 FULL LOAD CONDITION

SHIP SPEED 20.0 KNOTS
BASED UPON COMPUTER PREDICTIONS

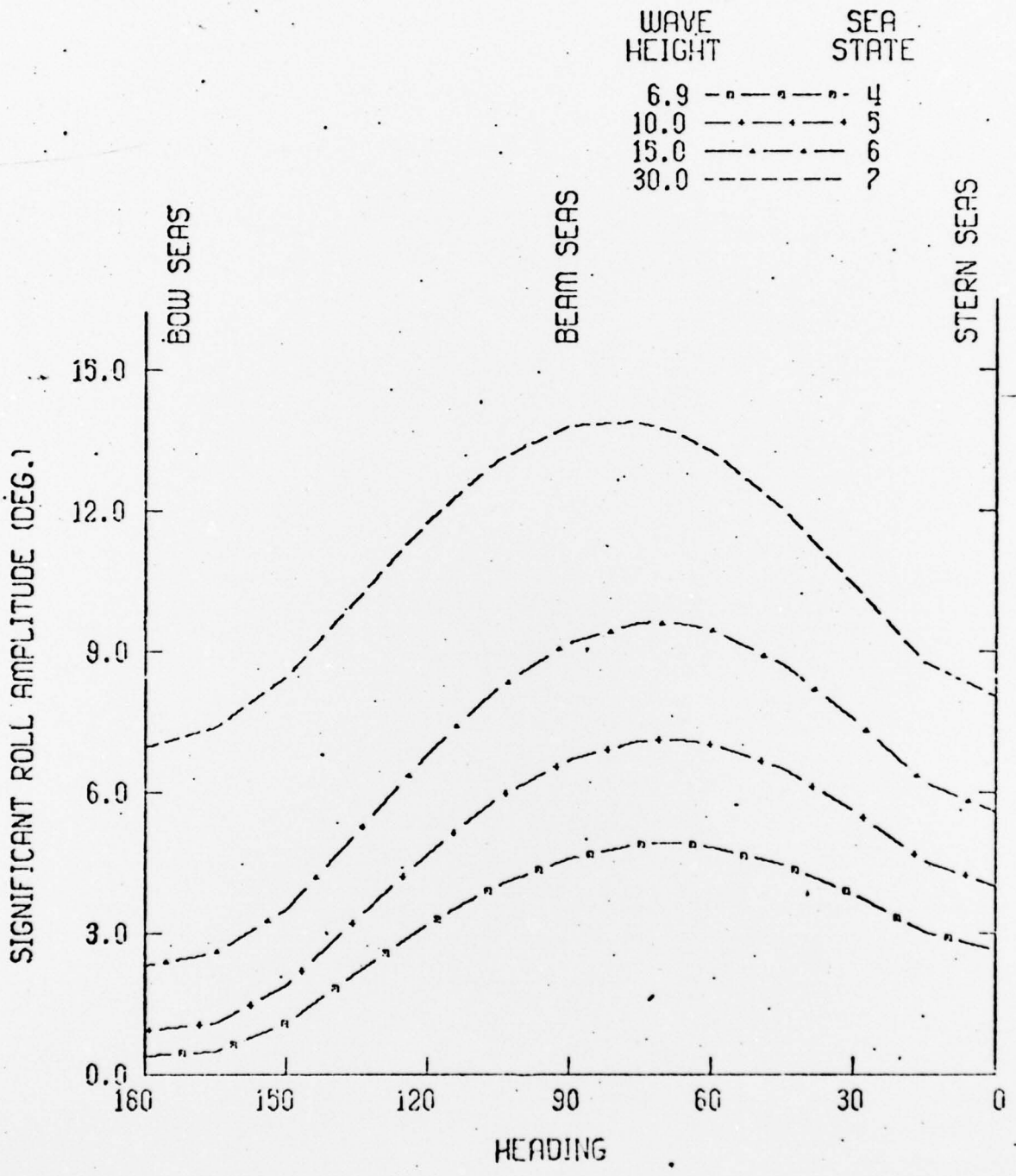

FIGURE 5 - ROLL MOTION VS. HEADING INTO SHORT CRESTED SEAS
DD 993 FULL LOAD CONDITION

SHIP SPEED 24.0 KNOTS
BASED UPON COMPUTER PREDICTIONS

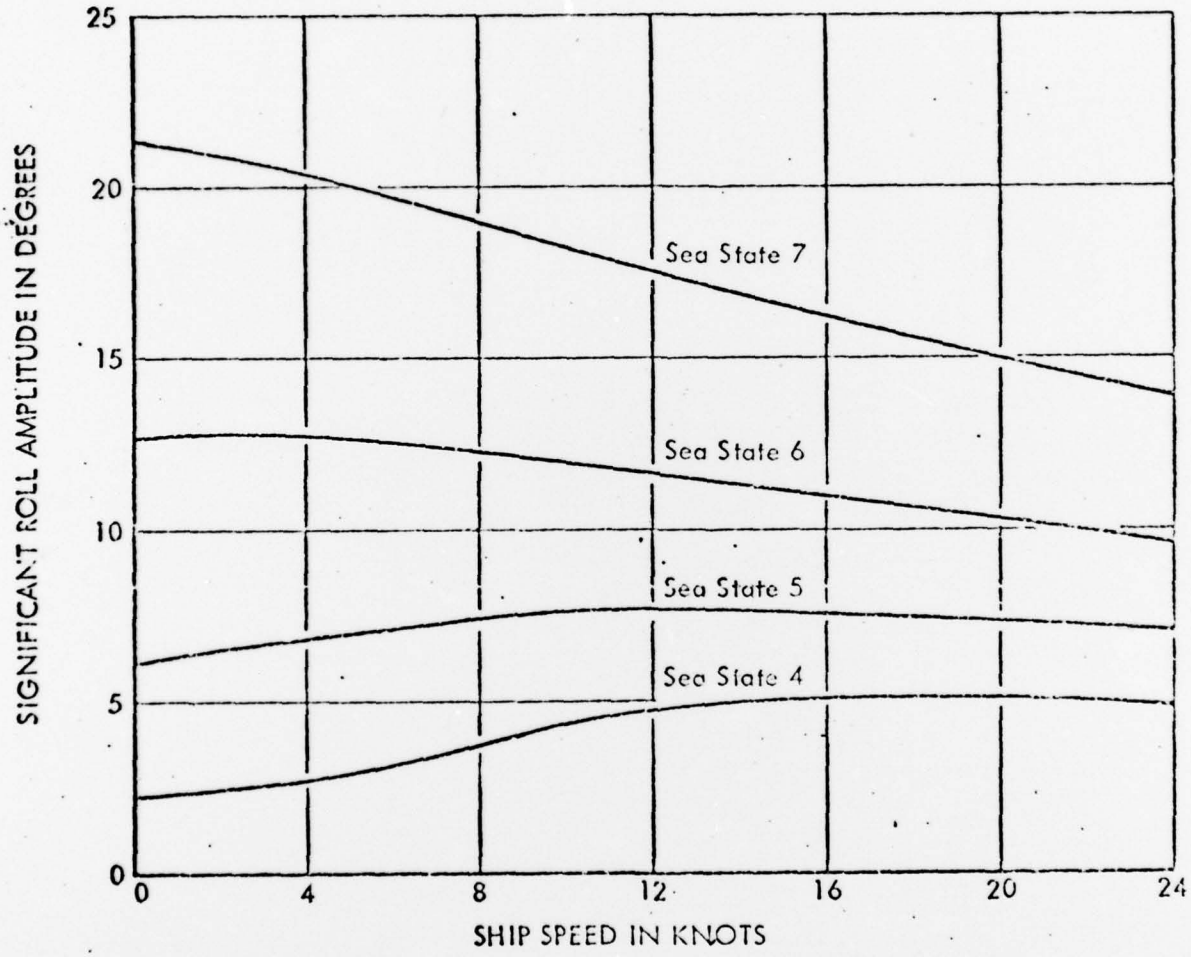

FIGURE 6 - SIGNIFICANT ROLL AMPLITUDE FOR SHORT-CRESTED SEAS AT WORST HEADING ANGLES AS A FUNCTION OF SHIP SPEED

BASED UPON COMPUTER PREDICTIONS

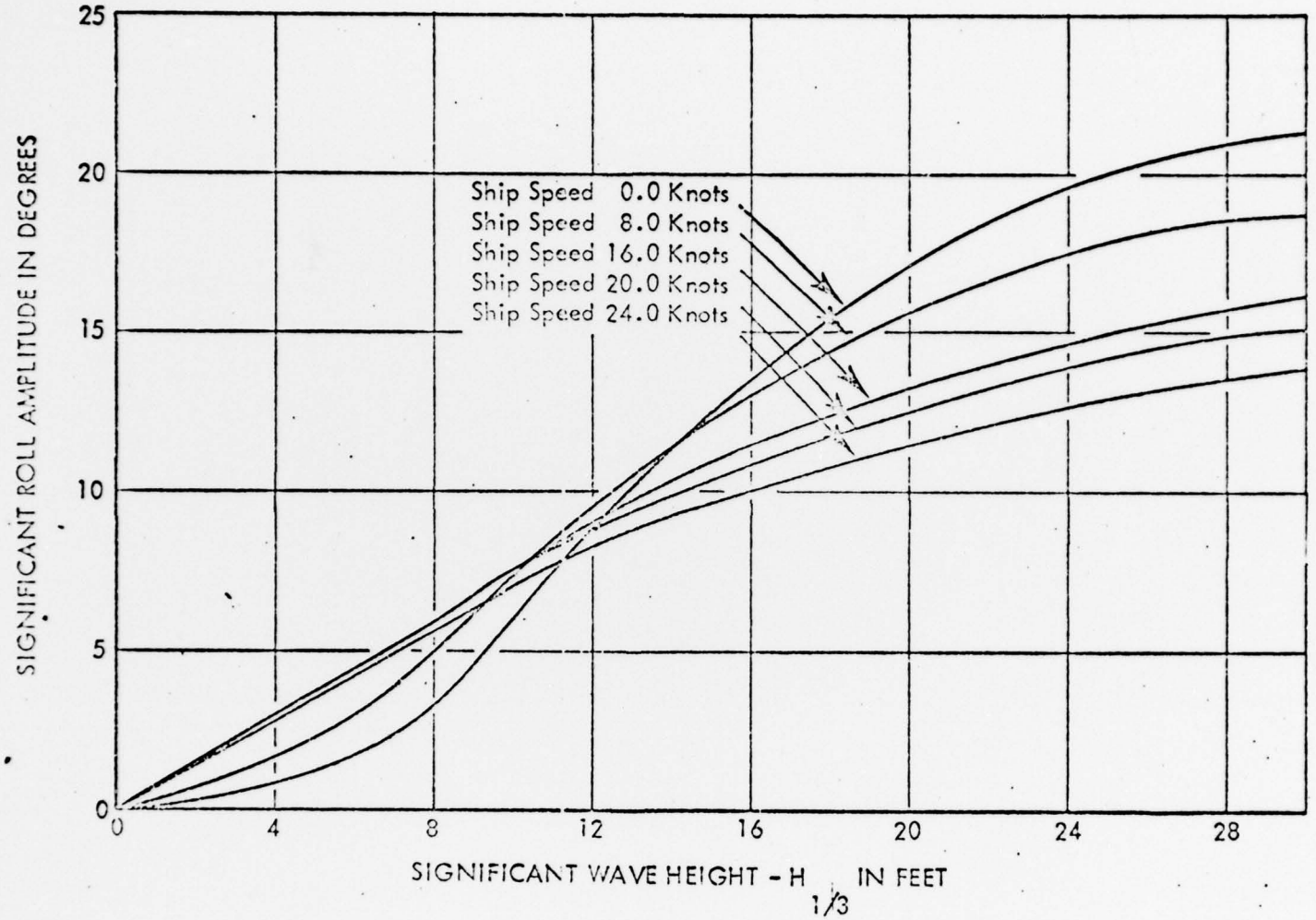

FIGURE 7 SIGNIFICANT ROLL AMPLITUDE FOR SHORT-CRESTED SEAS AT WORST HEADING ANGLES AS A FUNCTION OF SIGNIFICANT WAVE HEIGHTS
BASED UPON COMPUTER PREDICTIONS

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