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RESEARCH INSTITUTE

LABORATORY TECHNICAL REPORT

LTR - SH - 342

NAVIGATION AIDS VESSEL
RESULTS OF SEAKEEPING AND
MANOEUVRING EXPERIMENTS WITH MODEL 349

W.D. MOLYNEUX

RAPPORT TECHNIQUE DE LABORATOIRE

L'INSTITUT DE RECHERCHE MARITIME
ET SUR LES NAVIRES ARCTIQUES

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REPORT
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NAVIGATION AIDS VESSEL

RESULTS OF SEAKEEPING AND

MANOEUVRING EXPERIMENTS

WITH MODEL 349

SUBMITTED BY
PRESENTE PAR
SECTION HEAD
CHEF DU SECTION

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DIRECTOR
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1.0 INTRODUCTION

This report describes seakeeping and turning circle experiments carried out by the Arctic Vessel and Marine Research Institute (AVMRI) for Saint John Marine Consultants Ltd. of Saint John, New Brunswick. The model tested represents a design for a Type 1100 Navigation Aids Vessel for the Canadian Coast Guard. Resistance, propulsion and wake survey experiments, carried out prior to these tests are described in Reference 1. Results of similar experiments carried out with Model 338, also a design proposal for the same class of ship are described in Reference 2.

2.0 MODEL DESCRIPTION

The model, 349, was made of wood with a final gloss finish and was supplied to AVMRI complete with bow thruster tunnel, rudder, shaft bossings and ice horn. The model was also fitted with working stabilizer tanks, used during some of the seakeeping tests. Tripwires were fitted at stations 9.5 and 9.125, corresponding to 5 per cent and 8.75 per cent LBP aft of the fore perpendicular, throughout the test.

A bodyplan, supplied by Saint John Marine Consultants Ltd., drawing number 902-002/B, dated 6 August, 1982, is given in Figure 1. The bow and stern profiles are shown in Figures 2 and 3, together with details of the bossing and rudder design.

Hydrostatic particulars interpolated from data given by Saint John Marine Consultants Ltd. for the condition tested are given in Table 1.

The model was fitted throughout the test with plastic copies of propellers 76L and 76R, rather than the metal propellers used in the propulsion tests. Details of the propeller design are given in Table 2. The propellers were fitted to the model so that when viewed from astern they were outboard turning.

3.0 MODEL EXPERIMENTS

3.1 Seakeeping Experiments

The model was fitted with instrumentation to record body motions and rudder angle together with radio control and telemetry equipment.

The rotations and accelerations of the model were measured by means of a calibrated stable platform positioned at the centre of gravity for the model. Model speed was not measured directly, but was calibrated against propeller revolutions by timing the model on pairs of straight runs approximately 60 m long in two opposite directions. The rate of rotation in calm water was held constant for tests in waves.

The model was ballasted to the displacement, radii of gyration for pitch and roll, centre of gravity and metacentric height given in Table 1. The metacentric height corresponded to the fluid GM for the ship, excluding the free surface of the stabilizer tanks (when they were operating). The natural period of roll in water for the model in the condition described corresponded to 12.1 seconds on the ship.

The model was tested in regular waves with a nominal amplitude of Lpp/100 at the natural period of roll for the ship. The wave frequency was varied to cover the range from approximately 7 seconds to 14.5 seconds for the ship. Wave heights and periods were recorded using two sonic wave probes located at fixed points above the water surface. Figure 4 shows the wave heights obtained for each series of tests plotted against wave frequency.

The model was tested, without the stabilizer tanks operating, at a speed corresponding to 10 knots for the ship, with waves incident at 90^{o} (beam sea) and 45^{o} (quatering seas) always from the starboard side. The tests were repeated with the stabilizer tanks filled to their operating depths of 1.0 m in the upper tank and 1.2 m in the lower tank.

3.2 Turning Circle Experiments

The model, in the condition described in Table 1, was tested for manoeuvrability over a range of speeds and rudder angles. During these tests, the anti-rolling tanks were empty.

The tests carried out were to determine the features of the turning circles produced by a given combination of speed and rudder angle. Each combination was tested for both port and starboard rudder angles. The model was tested at nominal speeds of 14, 9 and 4 knots at rudder angles of 10, 20 and 30 degrees. The model was steered manually and the rudder could be slewed at a rate of 3.9 degrees per second for the ship.

During the testing, the model was tracked by means of two self-tracking telescopes. The model was steered on a straight course and the nominal rudder angle applied, and the model allowed to turn until the heading had changed at least 540 degrees. During the turning circles, the values of roll angle and rudder angle were measured.

4.0 EXPERIMENT RESULTS

4.1 Seakeeping Experiments

The recorded time histories of the model motions were transformed into amplitudes and phases using a spectrum analysis technique in which the effects of harmonics in the incident wave train were filtered out.

It was known that the amplitude of waves were not constant over the whole area of the tank. To estimate the amplitude of the waves encountered by the moving model, heave response divided by measured wave amplitude was faired against non-dimensional wave frequency. Any deviations of experimental points from this line were assumed to be caused by variation of wave amplitude. The estimated wave amplitude was then calculated from the faired line and used in the analysis of all other motions. Figures 5 and 10 show the measured heave amplitude divided by measured wave amplitude, and the fair line drawn through them. Responses for other motions calculated using the above method, and the faired curves are shown in Figures 6 to 9 for 90° heading, and Figures 11 to 16 show responses for 45° heading.

The values interpolated from the faired curves at even non-dimensional frequencies are given in Tables 3 to 6. All tables and figures show non-dimensional data derived using the method explained at the foot of Tables 3 to 6.

The phase angles presented are phase leads, so that the measured motion response leads the measured heave The sign convention for the motions is as follows: heave, positive down, pitch positive bow up, roll positive starboard side down, sway positive to starboard.

4.2 Turning Circle Experiments

The measured track of the model was faired for both x and y positions against time. The run up into the circle was assumed to be a straight line, and the circular track was faired into this portion. An example of the measured track and the faired line is shown in Figure 17.

A wind drift correction was applied by assuming a constant drift velocity may be added to the ship velocity. This is computed by superimposing the sections of the turn between 135° and 180° change of heading and 495° to 540° change of heading. Figure 18 shows a circle corrected for wind drift effects. All circles included a wind drift correction, even though in most cases the wind was light and therefore the correction was small.

Table 7 presents a summary of the data obtained from the turning circle experiments, scaled to ship size. This was obtained by fairing circle parameter against applied rudder angle for all runs at the same nominal speed, using a least squares deviation curve fitting technique. No allowance was made for any consistent split between port and starboard hand circles, since the design is symetrical about the centreline.

The speeds presented in Table 7 are the mean speed for each group. The circle parameters presented are interpolated from the faired curves, shown in Figures 19 to 24 at the nominal rudder angles.

A definition of the terms used is given below. Advance is defined as the distance (parallel to the ship's initial course) at which the velocity vector has changed direction by 90°. Transfer is defined as the distance (perpendicular to the ship's initial course at which the velocity vector has changed direction by 180°. The final diameter is the diameter of the turning circle once a steady turning state has been achieved. The average speed in the turn is the average speed from 135 to 360 degrees change of course. The average yaw rate is defined over the same segment.

5.0 DISCUSSION

5.1 Seakeeping Experiments

It can be seen that the required gyradius for roll was not obtained. This was due to the physical constraints of the scale model. The only way to obtain the increased radius of gyration would have been to extend weight beyond the beam of the model. This was not done, since it was felt that these weights would effect the motion of the model, by submerging at large roll angles. The obtained radius of gyration for roll is thought to be realistic for a ship at the design stage, and the effect on the measured motions should be small.

Figure 6 clearly shows the effectiveness of the antirolling tanks in beam seas. The maximum roll amplitude is reduced by approximately 80 per cent when anti-rolling tanks are used. However, their effectiveness at the highest and lowest frequencies tested is negligible.

Figure 13 shows the effect of anti-rolling tanks in quartering seas. The roll amplitude around the natural frequency of the undamped ship is decreased by approximately 75 per cent when anti-rolling tanks are used. The maximum roll angle in quartering seas however, is much less than the beam sea case, as would be expected.

It should be noted that the anti-rolling tanks do increase the roll amplitude at the lowest frequencies tested. This is due to the wave encounter frequency approaching the natural frequency of the combined ship and anti-rolling tank system.

The apparent shift in frequency of the maximum roll response between the two headings is due to the presentation chosen. The measured responses are plotted against wave frequency. When the wave encounter frequency with the model is considered, the maximum response occurs at similar frequencies.

A comparison of roll response taken from Reference 2 is shown in Figure 30 for the 90° heading and Figure 31 for the 45° heading. It can be seen from Figure 30 that there is no significant difference in maximum roll amplitude between Models 349 and 338. This is however assuming there is no effect of wave slope on roll amplitude. Thus, Figures 30 and 31 assume that both models were tested in waves of a similar height so the different roll damping effects due to different wave slopes can be ignored.

There is a shift in the natural frequency between Models 338 and 349. The direction of the shift is consistent with the reduction in GM between Models 338 and 349 and the reduced radius of gyration between Models 338 and 349 .

It can be seen from Figure 31 that the maximum roll response in quartering seas without flume tanks is lower for Model 349 than Model 338. Around the natural period however, the response with flume tanks operating is about the same for the two models. Model 349 also shows less increase in roll amplitude at low encounter frequencies than Model 338.

The shift in natural frequency may effect the relative merits of the two designs in irregular waves. The best way to investigate this would be to consider an irregular wave prediction for both models in seastates which were realistic with respect to the operation of the vessel using the response amplitude operators derived from model tests.

5.2 Turning Circle Experiments

The results given in Table 7 can also be presented as turning circle parameter against appproach speed, for contours of constant rudder angle. These are shown in Figures 25 to 29. It is felt these figures indicate trends with speed better than the curves shown in Figures 19 to 24.

Figures 25 to 27 show that advance, transfer and final diameter are virtually independent of speed. In each case, rudder angle has the most effect on circle parameter.

Figure 28 shows average yaw rate against approach speed. Average yaw rate may also be thought of as average rate of change of heading, and is therefore a function of speed and circle diameter. Figure 28 shows that average yaw rate increases with both increase in speed and increase in rudder angle. This is because the final diameter is virtually independent of speed and depends primarily on rudder angle.

Figure 29 shows roll angle against approach speed. This shows roll angle is also a function of ship speed and rudder angle. It should be noted that the roll angle is such that the ship heels out of the turn. Thus, for a starboard turn the ship heels to port, and vice versa.

Some comment may also be made of Figure 22, which shows average speed in turn against rudder angle. This shows that the average speed decreases with increased applied rudder angle. This is reasonable, as larger rudder angles will produce a larger braking effect. The braking effect becomes smaller at lower speeds for a given rudder angle. This may be explained by lower water velocities over the rudder, and therefore lower drag forces.

Figure 32 shows a comparison of final diameter against speed for Model 338, taken from Reference 2. The points plotted are the mean of the port and starboard circles given in Table 66. This shows for 30° angles there is virtually no difference in final diameter between the two models. At 4 knots with 20° rudder angles Model 349 has a final diameter approximately 8 per cent higher than Model 338. However

at 10^{o} rudder angles Model 349 shows a substantial reduction (between 8 and 20 per cent) in final diameter over Model 338. All comparisons are based on non-dimensional values of diameter divided by ship length.

6.0 CONCLUSIONS

The use of anti-rolling tanks produces a considerable reduction in roll amplitude in beam and quartering seas, at the natural frequency of the undamped ship. The anti-rolling tanks increase the roll amplitude at the lowest frequency of encounter tested in quartering seas.

There is no significant difference in undamped roll amplitude between Model 349 and Model 338 in beam seas. This assumes that the difference in waveslopes between the two series of tests is small and so the effect of waveslope on the response amplitude operators is small also. The shift in natural frequency of roll response for the two models is probably due to the changes in GM and radius and gyration of roll.

Model 349 shows superior performance in quartering seas where the undamped roll response at the natural frequency is lower than that of Model 338. There is also less increase in roll response at lower encounter frequencies when the flume tank is operational.

The turning circle diameters are not significantly different between Models 338 and 349, except at small rudder angles, when Model 349 shows a considerable reduction in turning circle diameter.

7.0 REFERENCES

1. Molyneux, W.D. — Navigation Aids Vessel, Results of Resistance, Propulsion and Wake Survey Experiments with Model 349 and Propellers 76L, R AVMRI, NRC LTR-SH-340 October 1982.

2. Michailidis, M. — Resistance, Propulsion, Wake Survey, Manoeuvring & Seakeeping Tests with Model 338 and Propellers 71L, R "Navigation Aids Vessel" AVMRI, NRC LTR-SH-321 December 1981.

TYPE 1100 NAVIGATION AIDS VESSEL
MODEL 349
SUMMARY OF HYDROSTATIC PARTICULARS
SCALE: 1:20

LENGTH OVERALL (L_{OA})	(M)	:	83.0
LENGTH BETWEEN PERPENDICULARS (L_{BP})	(M)	:	75.0
BEAM MOULDED (B)	(M)	:	16.2
DRAUGHT MOULDED (T)	(M)	:	5.75
TRIM	(M)	:	0
DISPLACEMENT ($\triangle$)	TONNES	:	4662
VOLUME OF DISPLACEMENT (∇)	(M^3)	:	4544
WETTED SURFACE AREA (NAKED)	(M^2)	:	1544.6
WETTED SURFACE AREA (APPENDED)	(M^2)	:	1620.7
LCB (AFT OF MIDSHIPS)	(M)	:	1.09
KG (VERTICAL CENTRE OF GRAVITY)	(M)	:	6.21
KM_T (TRANSVERSE METACENTRIC HEIGHT)	(M)	:	7.54
GM_F (EXCLUDING FLUME TANKS)	(M)	:	1.14
TRANSVERSE RADIUS OF GYRATION 0.43B (NOMINAL)	(M)	:	6.97
TRANSVERSE RADIUS OF GYRATION 0.39B (ACTUAL)	(M)	:	6.35
LONGITUDINAL RADIUS OF GYRATION $0.25L_{BP}$	(M)	:	18.75
C_B		:	0.650
C_M		:	0.934
C_P		:	0.696
C_W		:	0.857

TABLE 2
LTR-SH-342
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PROPELLERS 76L, R
DESIGN DETAILS
SCALE 1:20

DIAMETER	3600mm
PITCH AT 0.7R	3050mm
PITCH RATIO	0.847mm
BLADE AREA RATIO	0.402
NUMBER OF BLADES	4
RAKE	15^{o}
Bossing Length	890mm
Bossing Forward Diameter	930mm
Bossing Aft Diameter	810mm
Propeller Centre	2270mm fwd of aft perpendiculars

Design — Sections and pitch distributions as 0.9 P/D Wageningen B-Screw.

RESULTS OF SEAKEEPING EXPERIMENTS WITH MODEL NUMBER 349

NAVIGATION AIDS VESSEL
5.75M TMLD LEVEL KEEL

HEADING 90 degrees
SHIP SPEED 10 knots
FLUME TANK EMPTY

WAVE		HEAVE	PITCH		ROLL		SWAY		YAW	
FREQ	AMP	AMP	AMP	PHASE	AMP	PHASE	AMP	PHASE	AMP	PHASE
1.200	0.843	0.998	0.000	0.	2.297	87.	0.968	-87.	0.000	0.
1.300	0.959	0.996	0.000	0.	3.328	83.	0.952	-86.	0.000	0.
1.400	1.026	0.994	0.000	0.	4.791	68.	0.931	-86.	0.000	0.
1.500	1.034	0.995	0.000	0.	7.067	25.	0.904	-86.	0.000	0.
1.600	1.147	0.998	0.000	0.	6.352	-28.	0.866	-86.	0.000	0.
1.700	1.154	1.005	0.000	0.	2.704	-59.	0.821	-86.	0.000	0.
1.800	1.107	1.016	0.000	0.	1.534	-71.	0.776	-86.	0.000	0.
1.900	1.046	1.032	0.000	0.	1.028	-74.	0.737	-85.	0.000	0.
2.000	0.974	1.051	0.000	0.	0.748	-75.	0.705	-84.	0.000	0.
2.100	0.899	1.075	0.000	0.	0.573	-76.	0.683	-83.	0.000	0.
2.200	0.834	1.103	0.000	0.	0.469	-75.	0.669	-81.	0.000	0.
2.300	0.787	1.133	0.000	0.	0.402	-74.	0.661	-79.	0.000	0.
2.400	0.766	1.165	0.000	0.	0.350	-71.	0.659	-76.	0.000	0.
2.500	0.761	1.198	0.000	0.	0.297	-69.	0.659	-73.	0.000	0.

DATA ARE NON-DIMENSIONALIZED AS FOLLOWS:
WAVE FREQUENCY IS MULTIPLIED BY SQRT(L/G) WHERE L IS MODEL LENGTH
WAVE AMPLITUDE IS MULTIPLIED BY 100/L
LINEAR MOTIONS ARE DIVIDED BY WAVE AMPLITUDE
ANGULAR MOTIONS ARE DIVIDED BY MAXIMUM WAVE SLOPE

TABLE 3
LTR-SH-342
LIMITED

RESULTS OF SEAKEEPING EXPERIMENTS WITH MODEL NUMBER 349

NAVIGATION AIDS VESSEL
5.75M TMLD LEVEL KEEL

HEADING 90 degrees
SHIP SPEED 10 knots
FLUME TANK OPERATING

WAVE		HEAVE	PITCH		ROLL		SWAY		YAW	
FREQ	AMP	AMP	AMP	PHASE	AMP	PHASE	AMP	PHASE	AMP	PHASE
1.200	0.000	0.000	0.000	0.	1.211	48.	0.967	-87.	0.000	0.
1.300	0.853	0.997	0.000	0.	1.364	41.	0.947	-87.	0.000	0.
1.400	0.945	0.997	0.000	0.	1.626	33.	0.921	-86.	0.000	0.
1.500	1.062	0.998	0.000	0.	1.956	23.	0.887	-86.	0.000	0.
1.600	1.162	0.998	0.000	0.	2.148	10.	0.848	-85.	0.000	0.
1.700	1.208	0.998	0.000	0.	2.045	-7.	0.807	-85.	0.000	0.
1.800	1.181	0.997	0.000	0.	1.674	-25.	0.767	-84.	0.000	0.
1.900	1.095	0.995	0.000	0.	1.315	-41.	0.732	-83.	0.000	0.
2.000	0.969	0.997	0.000	0.	1.016	-52.	0.700	-82.	0.000	0.
2.100	0.836	1.009	0.000	0.	0.775	-60.	0.674	-81.	0.000	0.
2.200	0.746	1.030	0.000	0.	0.598	-65.	0.653	-79.	0.000	0.
2.300	0.720	1.059	0.000	0.	0.472	-67.	0.635	-77.	0.000	0.
2.400	0.743	1.094	0.000	0.	0.383	-67.	0.620	-75.	0.000	0.
2.500	0.795	1.132	0.000	0.	0.317	-67.	0.606	-72.	0.000	0.

DATA ARE NON-DIMENSIONALIZED AS FOLLOWS:
WAVE FREQUENCY IS MULTIPLIED BY SQRT(L/G) WHERE L IS MODEL LENGTH
WAVE AMPLITUDE IS MULTIPLIED BY 100/L
LINEAR MOTIONS ARE DIVIDED BY WAVE AMPLITUDE
ANGULAR MOTIONS ARE DIVIDED BY MAXIMUM WAVE SLOPE

TABLE 4
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LIMITED

RESULTS OF SEAKEEPING EXPERIMENTS WITH MODEL NUMBER 349

NAVIGATION AIDS VESSEL
5.75M TMLD LEVEL KEEL

HEADING 45 degrees
SHIP SPEED 10 knots
FLUME TANK EMPTY

WAVE		HEAVE	PITCH		ROLL		SWAY		YAW	
FREQ	AMP	AMP	AMP	PHASE	AMP	PHASE	AMP	PHASE	AMP	PHASE
1.200	0.809	0.878	0.626	97.	0.826	81.	0.801	-85.	0.000	0.
1.300	0.944	0.855	0.605	98.	0.868	79.	0.779	-84.	0.000	0.
1.400	1.021	0.829	0.581	100.	0.927	78.	0.755	-83.	0.000	0.
1.500	1.059	0.800	0.553	101.	1.021	76.	0.728	-82.	0.000	0.
1.600	1.123	0.769	0.524	103.	1.225	74.	0.698	-81.	0.000	0.
1.700	1.243	0.733	0.495	104.	1.596	70.	0.664	-80.	0.000	0.
1.800	1.292	0.693	0.466	106.	2.128	65.	0.625	-79.	0.000	0.
1.900	1.149	0.648	0.438	107.	2.038	58.	0.579	-77.	0.000	0.
2.000	1.004	0.600	0.412	108.	1.327	49.	0.527	-76.	0.000	0.
2.100	0.937	0.548	0.388	108.	1.047	38.	0.471	-75.	0.000	0.
2.200	0.905	0.493	0.368	109.	0.865	26.	0.417	-73.	0.000	0.
2.300	0.870	0.436	0.352	109.	0.726	12.	0.368	-72.	0.000	0.
2.400	0.805	0.377	0.339	109.	0.611	-3.	0.326	-71.	0.000	0.
2.500	0.717	0.317	0.329	110.	0.509	-18.	0.290	-69.	0.000	0.

DATA ARE NON-DIMENSIONALIZED AS FOLLOWS:
WAVE FREQUENCY IS MULTIPLIED BY SQRT(L/G) WHERE L IS MODEL LENGTH
WAVE AMPLITUDE IS MULTIPLIED BY 100/L
LINEAR MOTIONS ARE DIVIDED BY WAVE AMPLITUDE
ANGULAR MOTIONS ARE DIVIDED BY MAXIMUM WAVE SLOPE

TABLE 5
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LIMITED

RESULTS OF SEAKEEPING EXPERIMENTS WITH MODEL NUMBER 349

NAVIGATION AIDS VESSEL
5.75M TMLD LEVEL KEEL

HEADING 45 degrees
SHIP SPEED 10 knots
FLUME TANK OPERATING

WAVE		HEAVE	PITCH		ROLL		SWAY		YAW	
FREQ	AMP	AMP	AMP	PHASE	AMP	PHASE	AMP	PHASE	AMP	PHASE
1.200	0.000	0.872	0.579	98.	1.474	53.	0.000	-86.	0.000	0.
1.300	0.790	0.854	0.567	100.	1.245	49.	0.857	-85.	0.000	0.
1.400	0.938	0.834	0.554	101.	1.032	46.	0.818	-85.	0.000	0.
1.500	1.088	0.812	0.541	102.	0.846	42.	0.779	-85.	0.000	0.
1.600	1.188	0.788	0.528	103.	0.696	38.	0.741	-84.	0.000	0.
1.700	1.230	0.760	0.514	104.	0.594	34.	0.705	-84.	0.000	0.
1.800	1.207	0.727	0.500	104.	0.552	30.	0.668	-83.	0.000	0.
1.900	1.115	0.689	0.485	105.	0.585	25.	0.631	-83.	0.000	0.
2.000	0.982	0.644	0.470	105.	0.719	20.	0.593	-82.	0.000	0.
2.100	0.838	0.592	0.454	105.	0.698	15.	0.554	-82.	0.000	0.
2.200	0.724	0.535	0.438	104.	0.497	9.	0.513	-81.	0.000	0.
2.300	0.687	0.473	0.422	104.	0.464	3.	0.471	-80.	0.000	0.
2.400	0.709	0.408	0.406	103.	0.444	-3.	0.428	-80.	0.000	0.
2.500	0.768	0.340	0.389	103.	0.436	-10.	0.385	-79.	0.000	0.

DATA ARE NON-DIMENSIONALIZED AS FOLLOWS:
WAVE FREQUENCY IS MULTIPLIED BY SQRT(L/G) WHERE L IS MODEL LENGTH
WAVE AMPLITUDE IS MULTIPLIED BY 100/L
LINEAR MOTIONS ARE DIVIDED BY WAVE AMPLITUDE
ANGULAR MOTIONS ARE DIVIDED BY MAXIMUM WAVE SLOPE

TABLE 6
LTR-SH-342
LIMITED

MODEL 349

TYPE 1100 NAVIGATION AIDS VESSEL

SUMMARY OF TURNING CIRCLE EXPERIMENTS

APPROACH SPEED	RUDDER ANGLE	ADVANCE TO 90°	TRANSFER TO 180°	FINAL DIAM	AVE. SPEED IN TURN	AVE. YAW RATE	ROLL ANGLE	FINAL DIAM/LENGTH
13.84	10	626	783	748	12.91	0.99	0.45	9.97
13.84	20	436	564	566	11.97	1.32	1.43	7.54
13.84	30	332	409	403	11.00	1.63	3.31	5.37
8.58	10	563	722	723	7.95	0.66	0.37	9.64
8.58	20	411	510	500	7.38	0.87	0.82	6.67
8.58	30	364	440	437	7.13	0.92	1.46	5.83
3.96	10	619	732	751	3.59	0.31	0.10	10.01
3.96	20	425	531	545	3.36	0.38	0.19	7.27
3.96	30	350	418	427	3.19	0.43	0.29	5.69

TABLE 7
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M 349

BODY PLAN

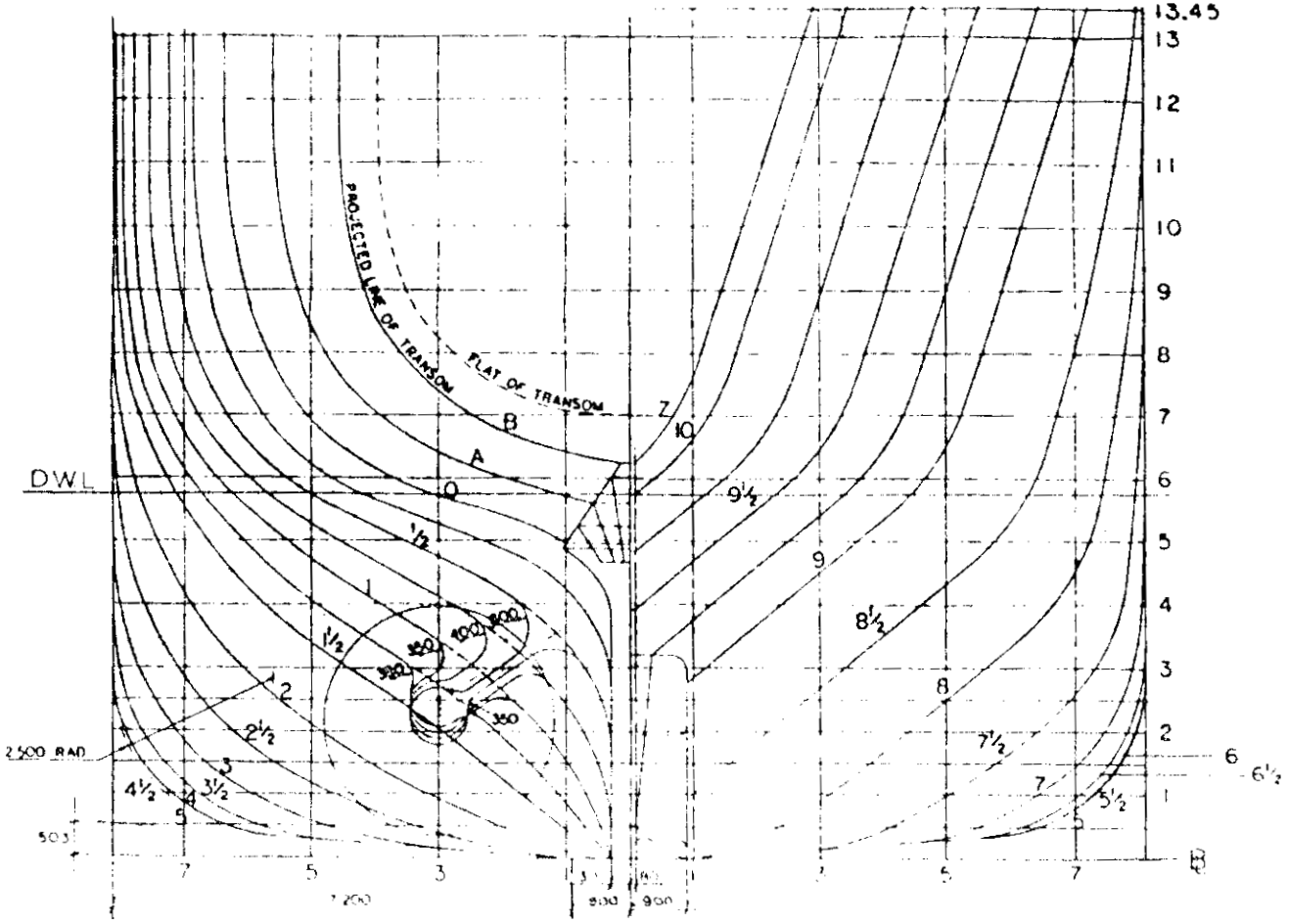


FIGURE 1
LTR-SH-342
LIMITED

M-349

FIG. 2 BOW PROFILE

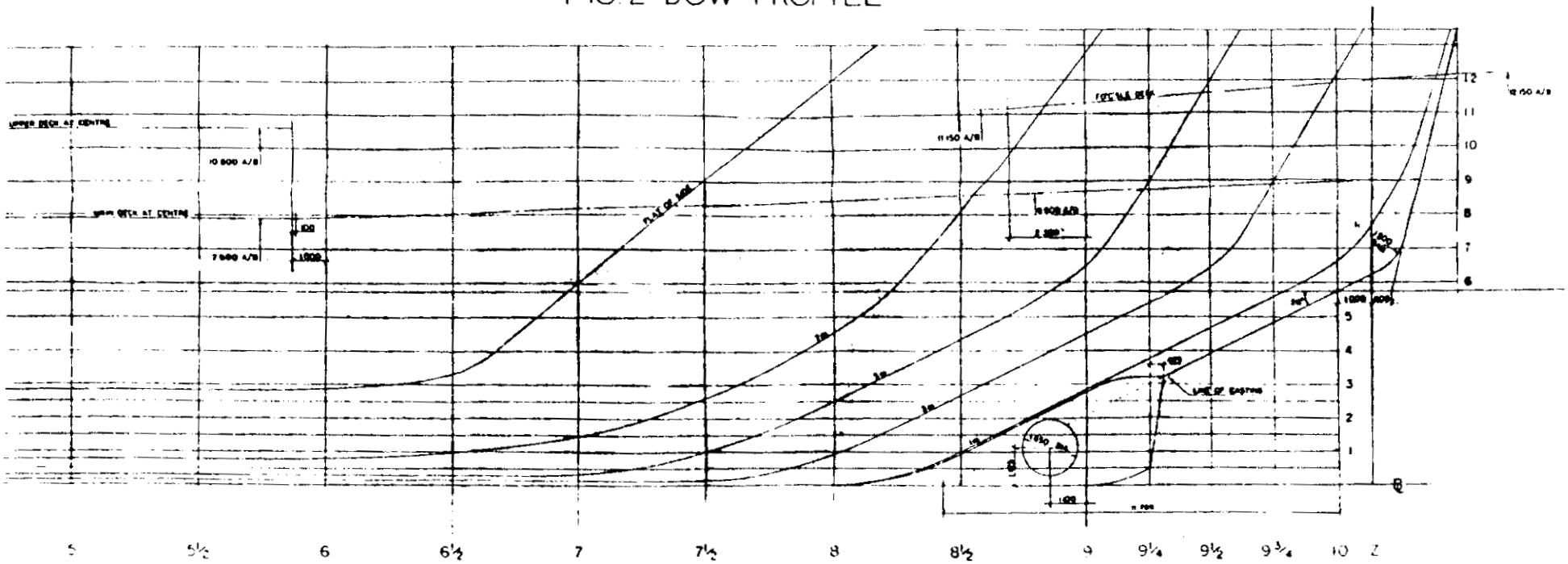
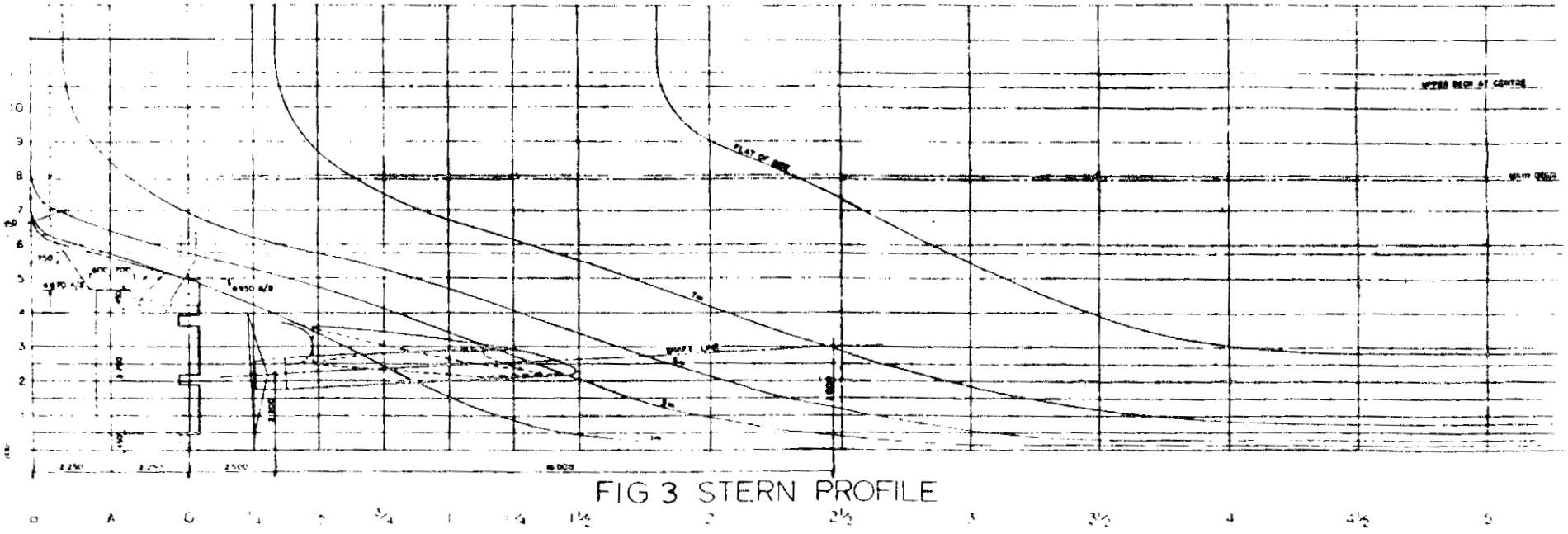


FIG 3 STERN PROFILE



FIGURES 2 & 3
LTR-SH-342
LIMITED

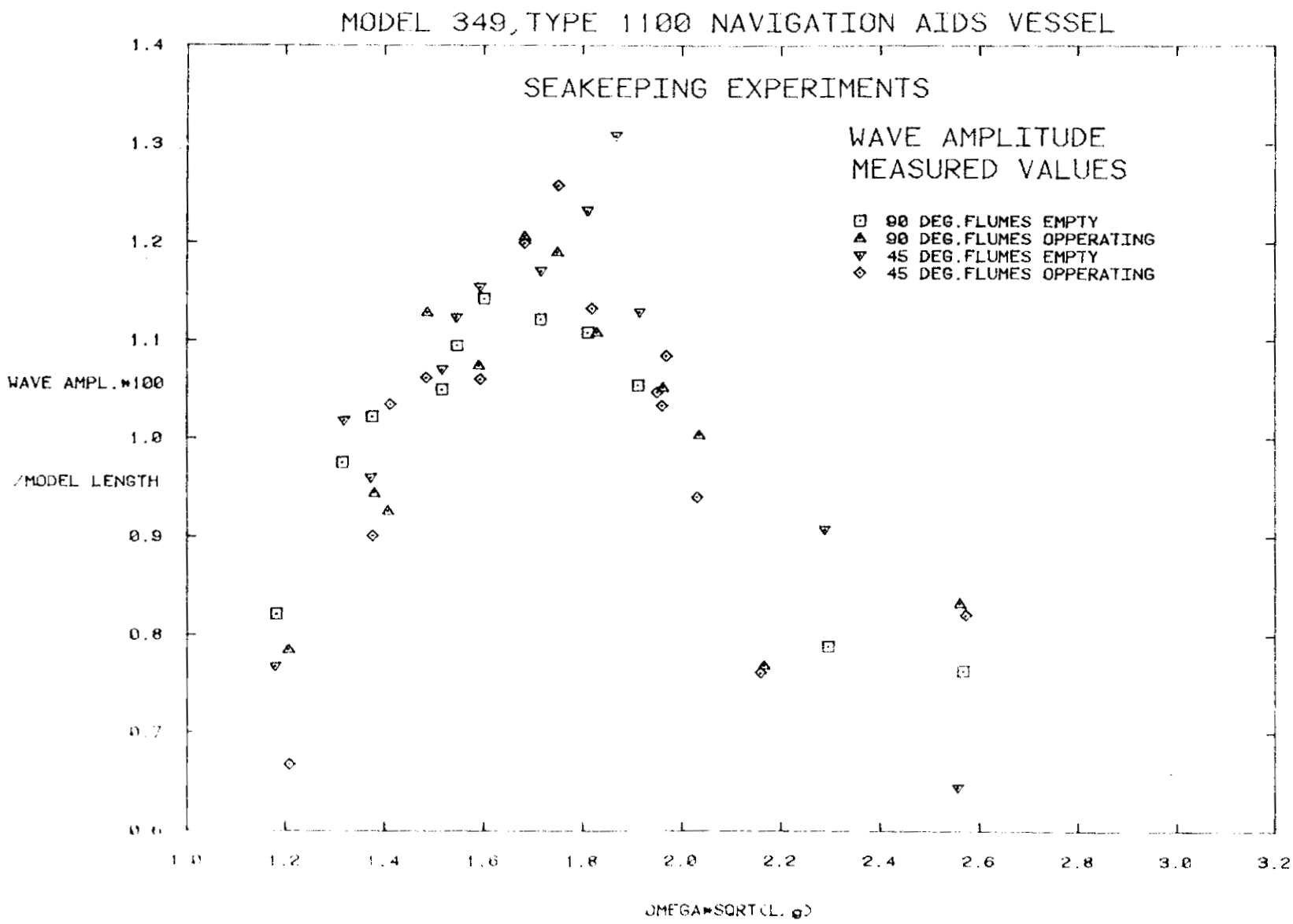


FIG. 4
FERGUSON-SHIPBUILDERS
LIMITED

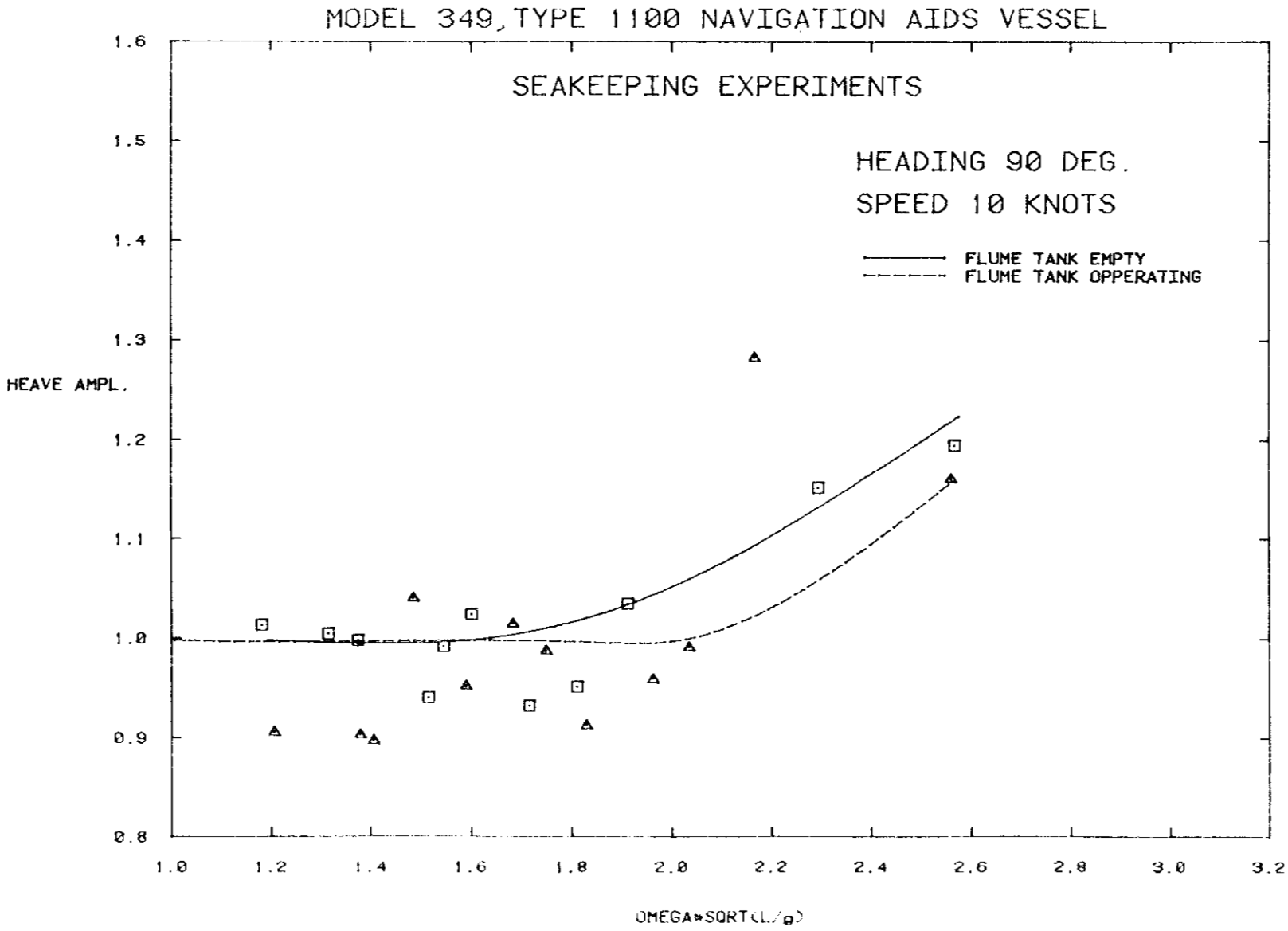
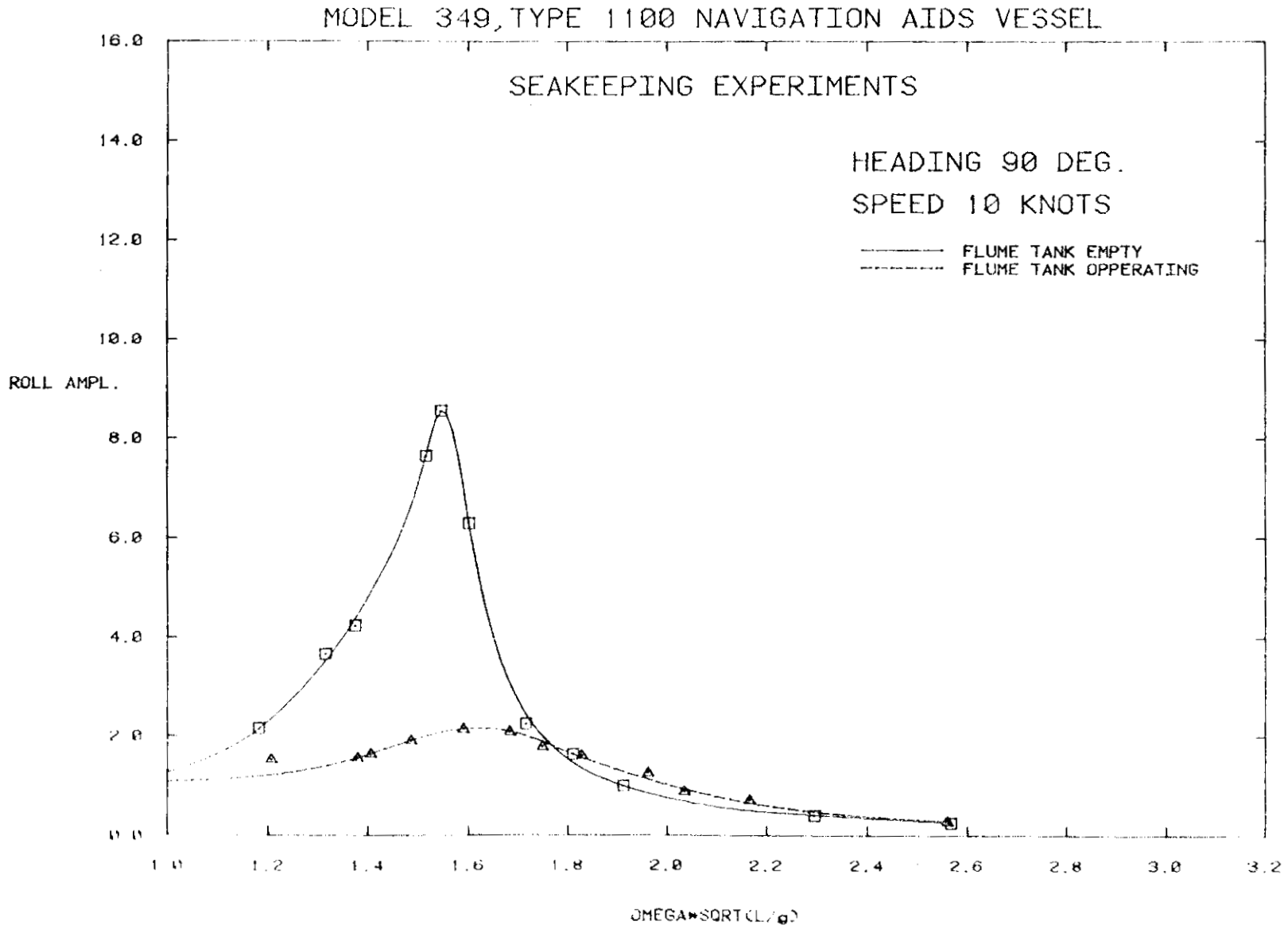


FIG. 5
LTR-SH-342
LIMITED



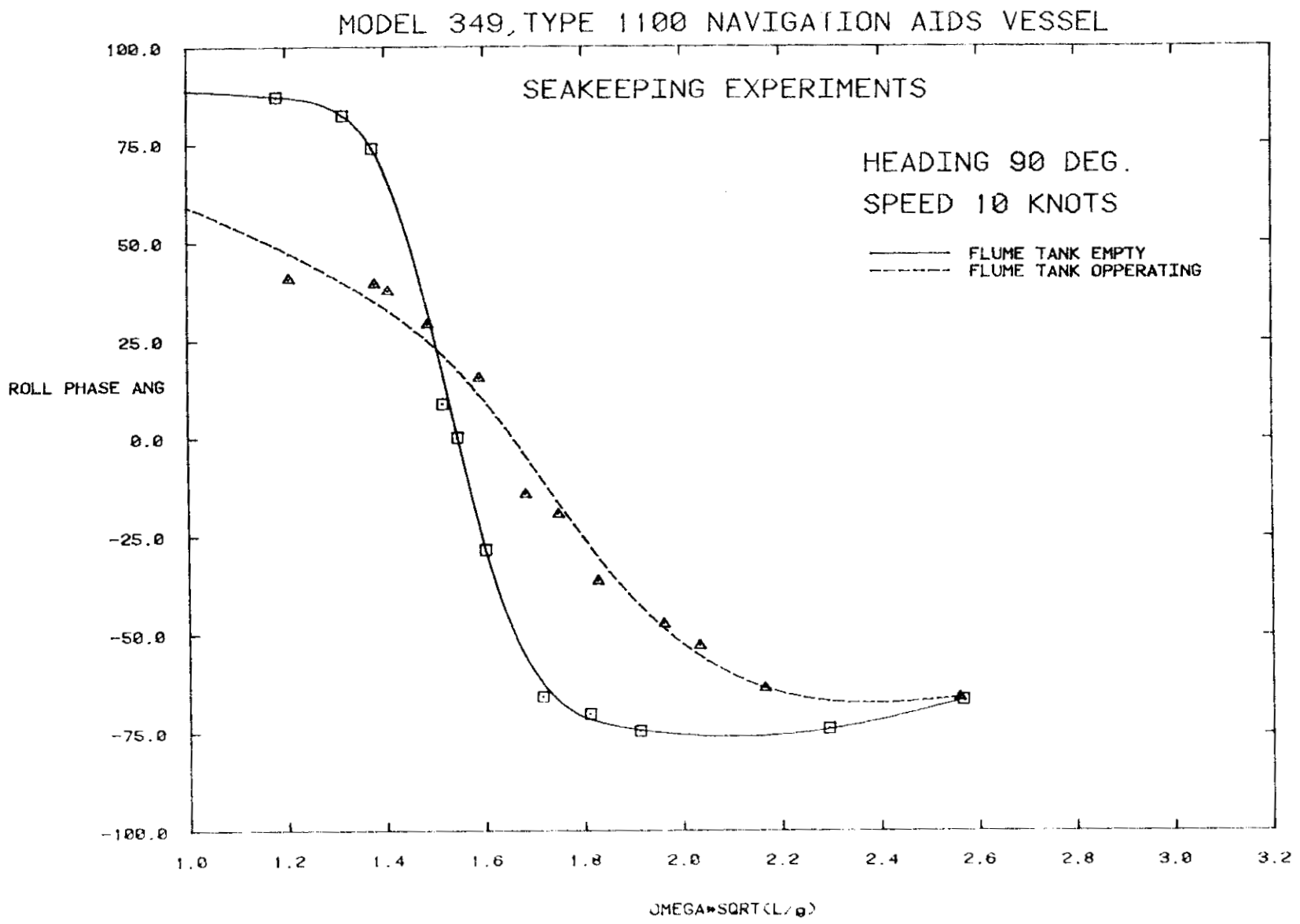
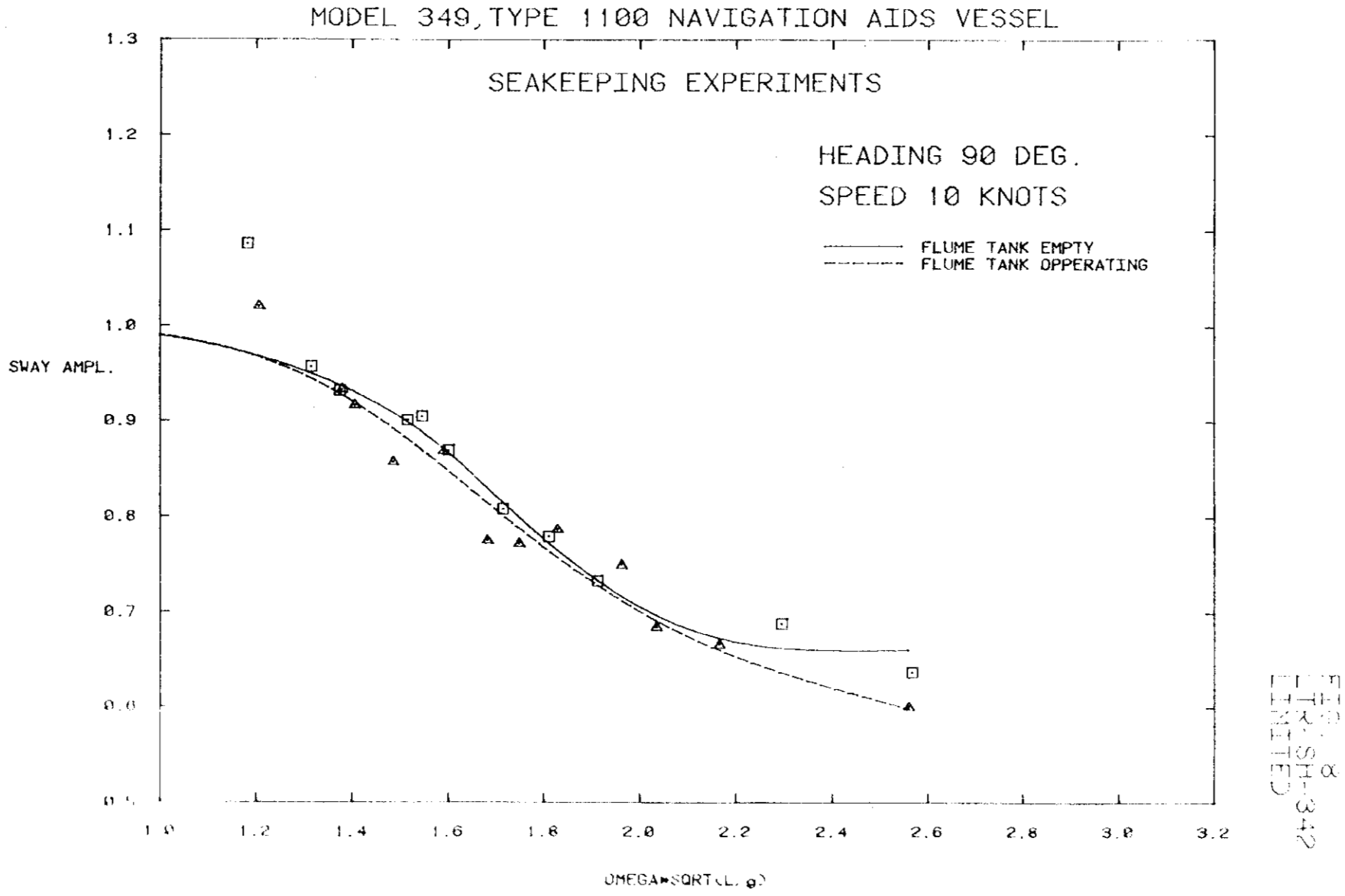


FIG. 7
ETR-SH-342
LIMITED


MODEL 349, TYPE 1100 NAVIGATION AIDS VESSEL
SEAKEEPING EXPERIMENTS
HEADING 90 DEG.
SPEED 10 KNOTS
FLUME TANK EMPTY
FLUME TANK OPPERATING
SWAY AMPL.
1.3
1.2
1.1
1.0
0.9
0.8
0.7
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
OMEGA*SQRT(L/g)

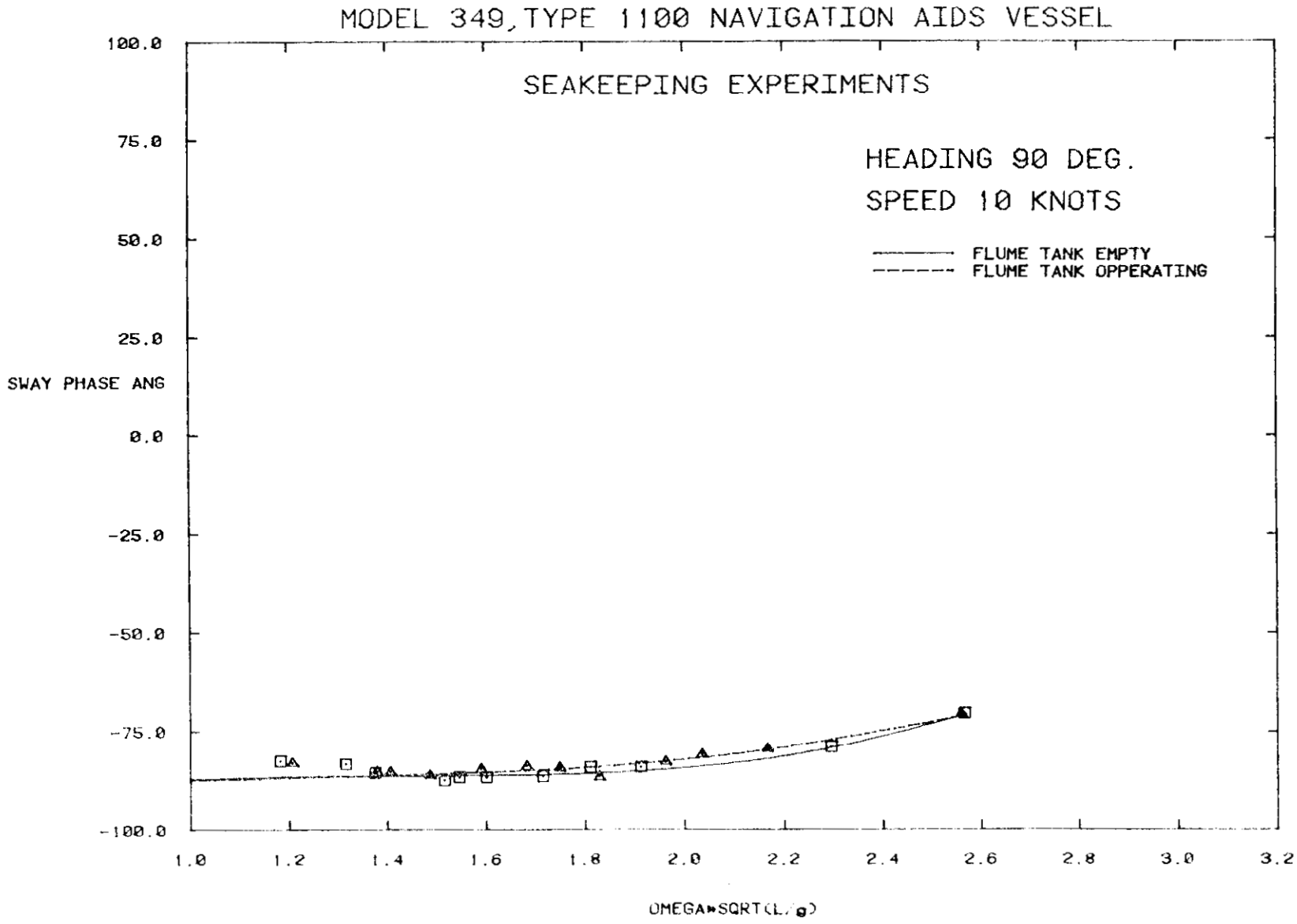
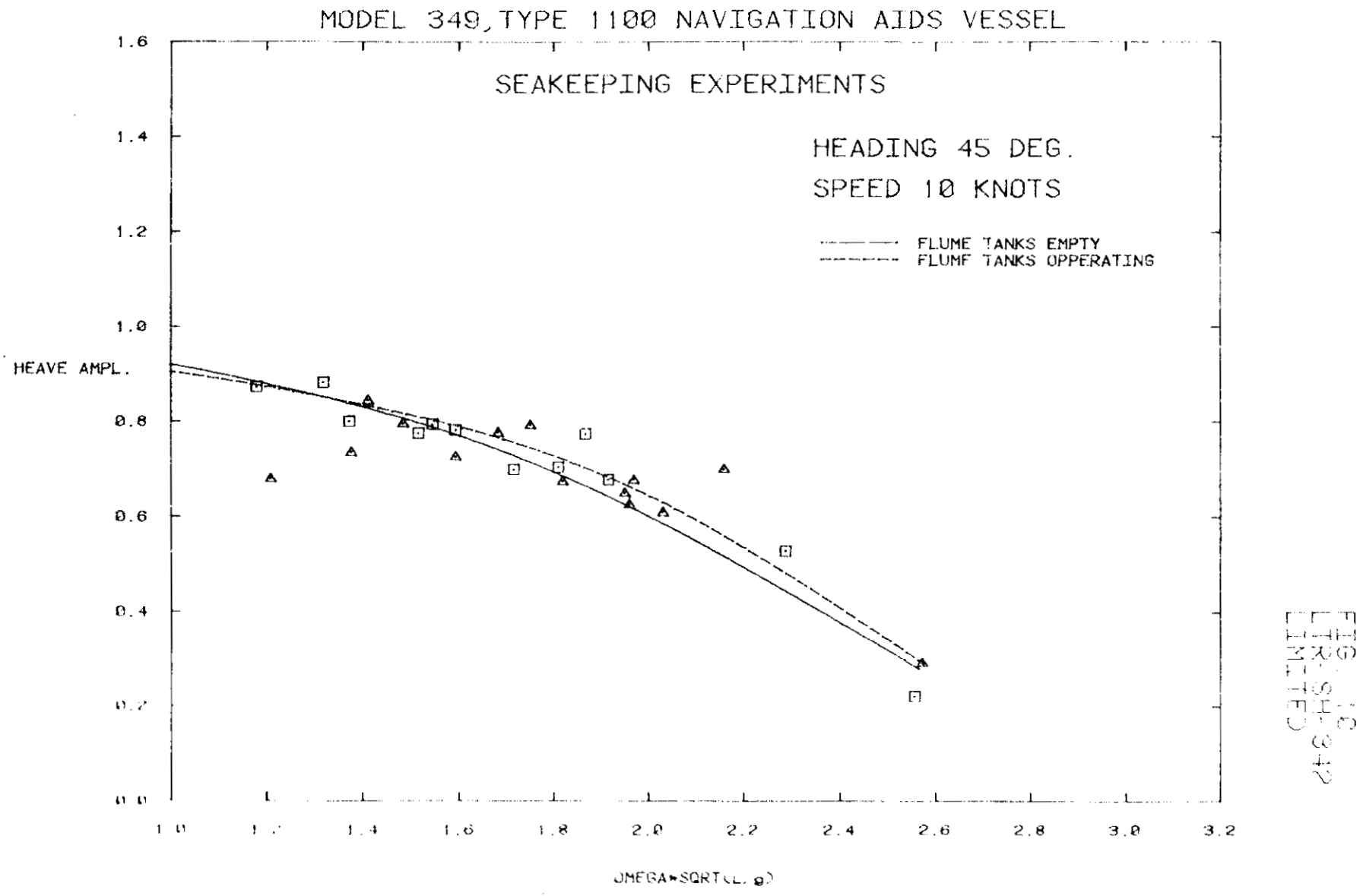


FIG. 9
ETR-SH-342
LIMITED


MODEL 349, TYPE 1100 NAVIGATION AIDS VESSEL
SEAKEEPING EXPERIMENTS
HEADING 45 DEG.
SPEED 10 KNOTS
FLUME TANKS EMPTY
FLUME TANKS OPPERATING
HEAVE AMPL.
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
OMEGA*SQRT(L/g)

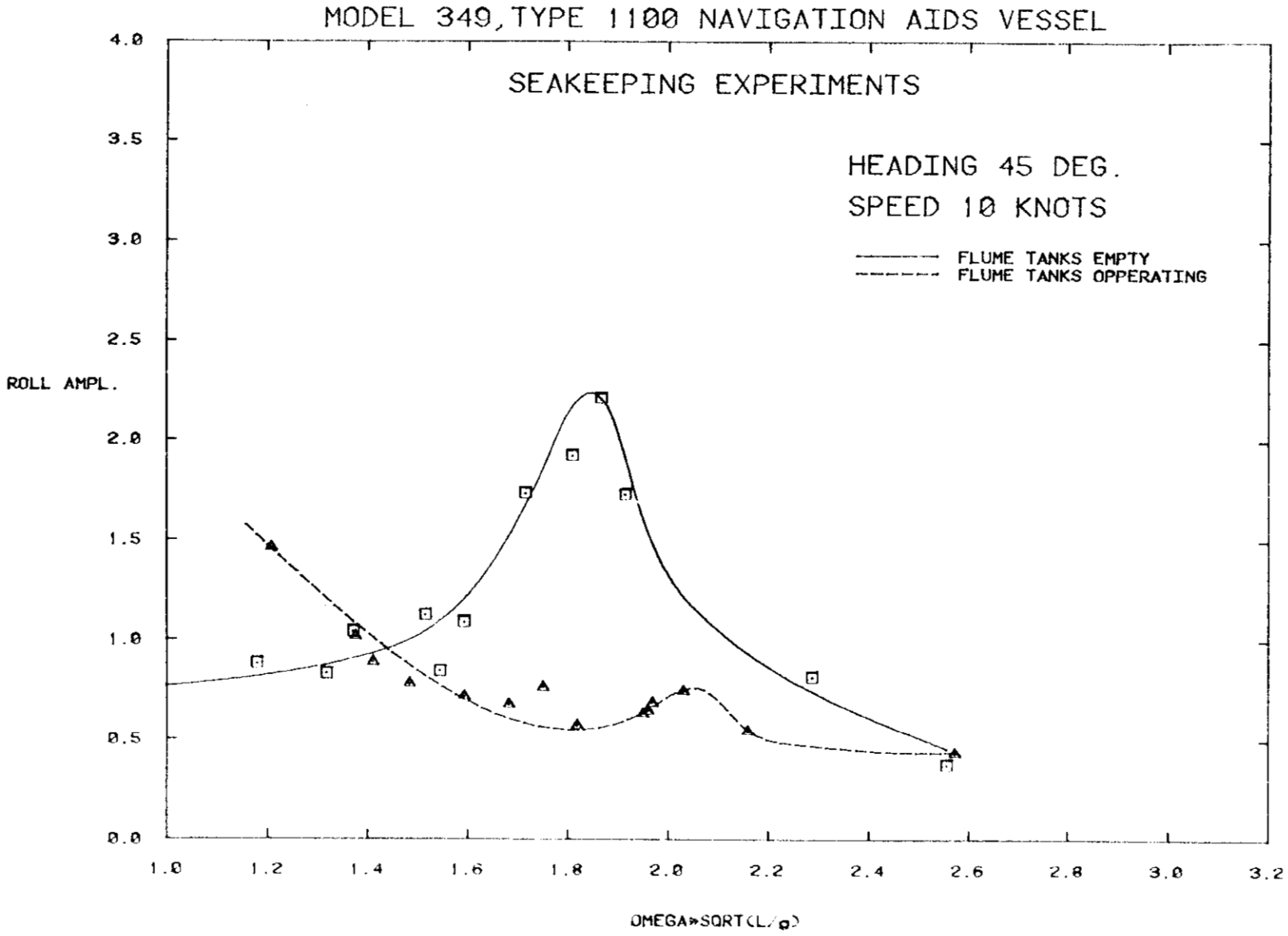


FIG. 11
ETR-SH-342
LIMITED

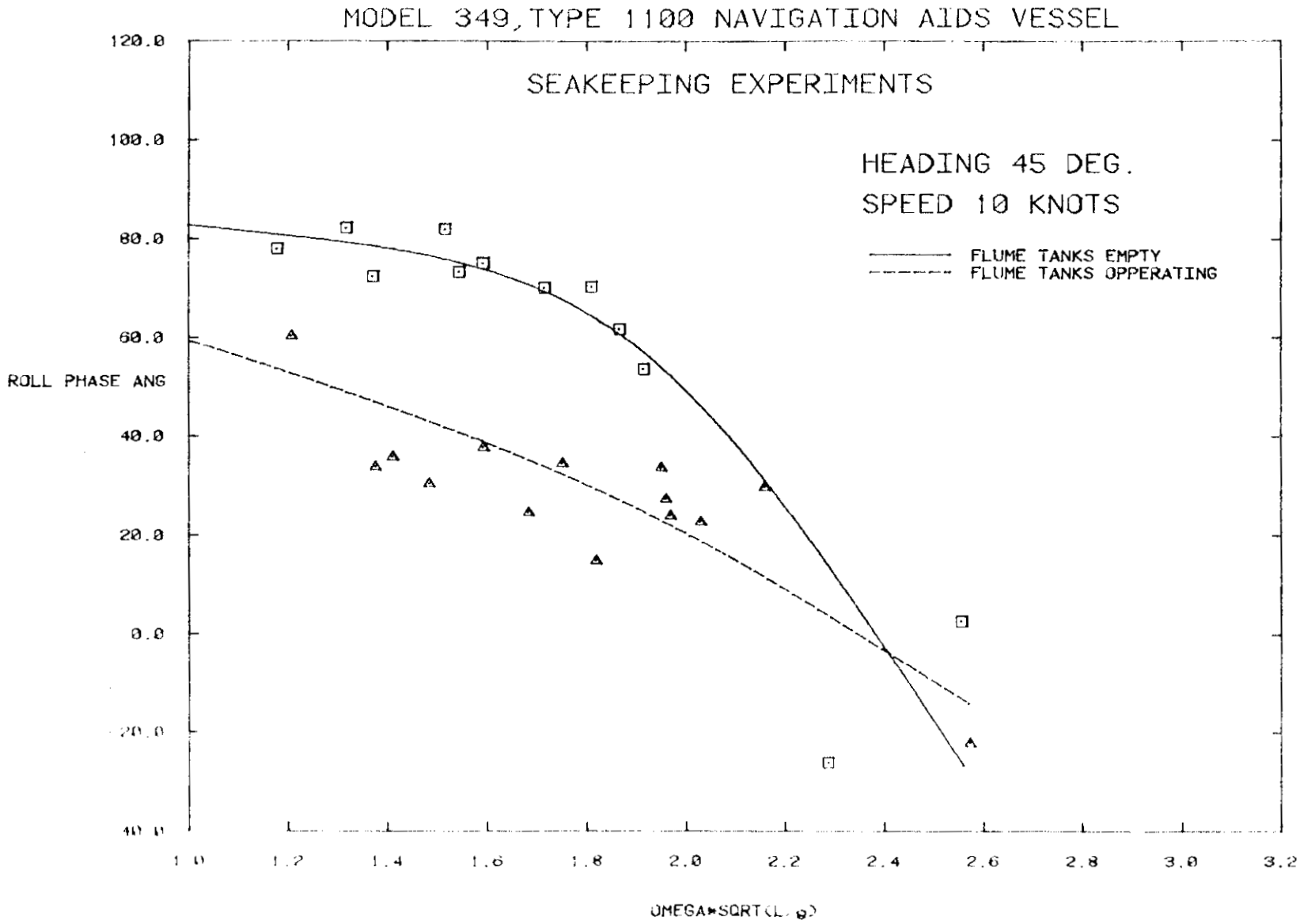


FIG. 12
TRIAL 342
FLUME

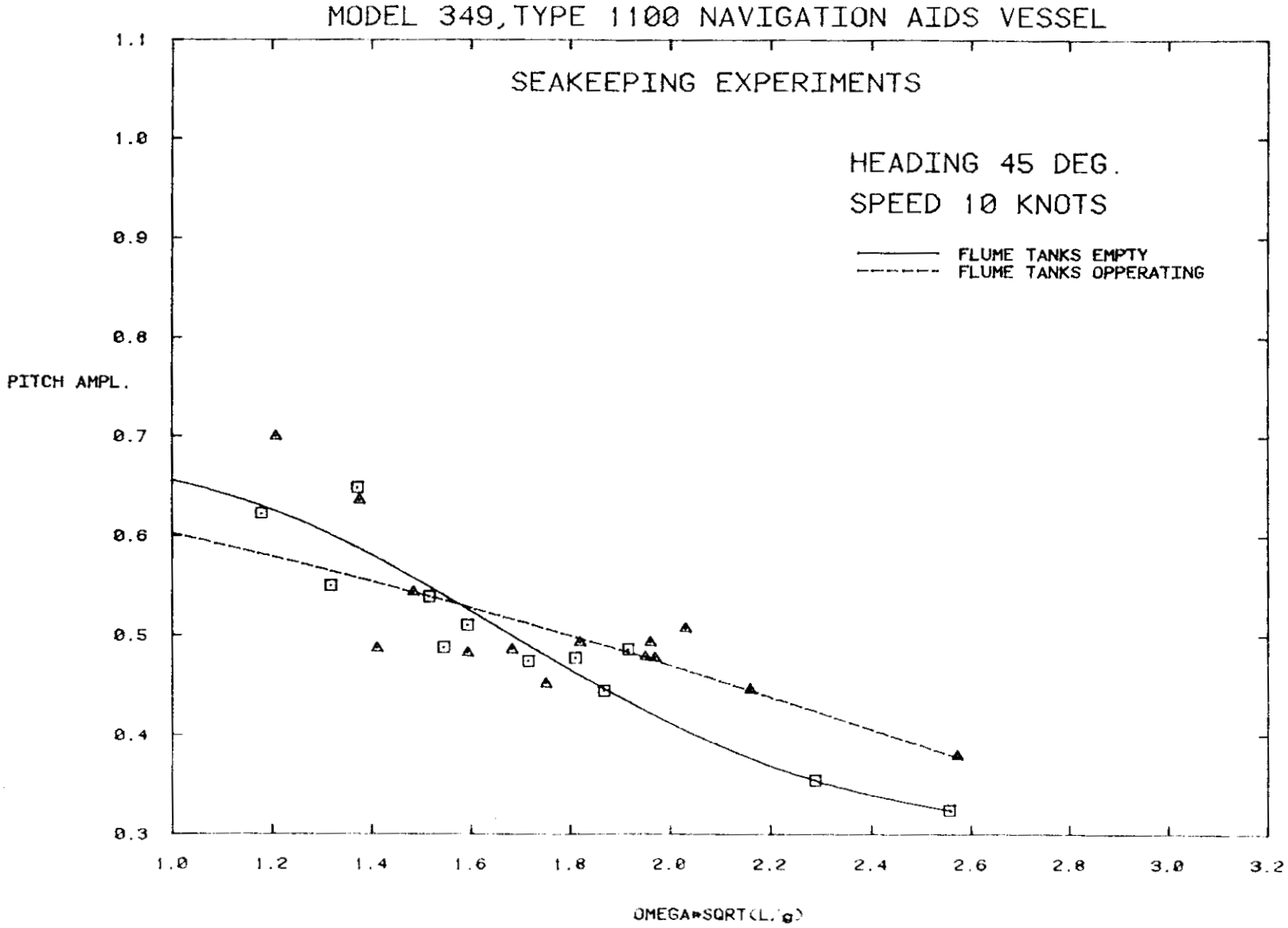
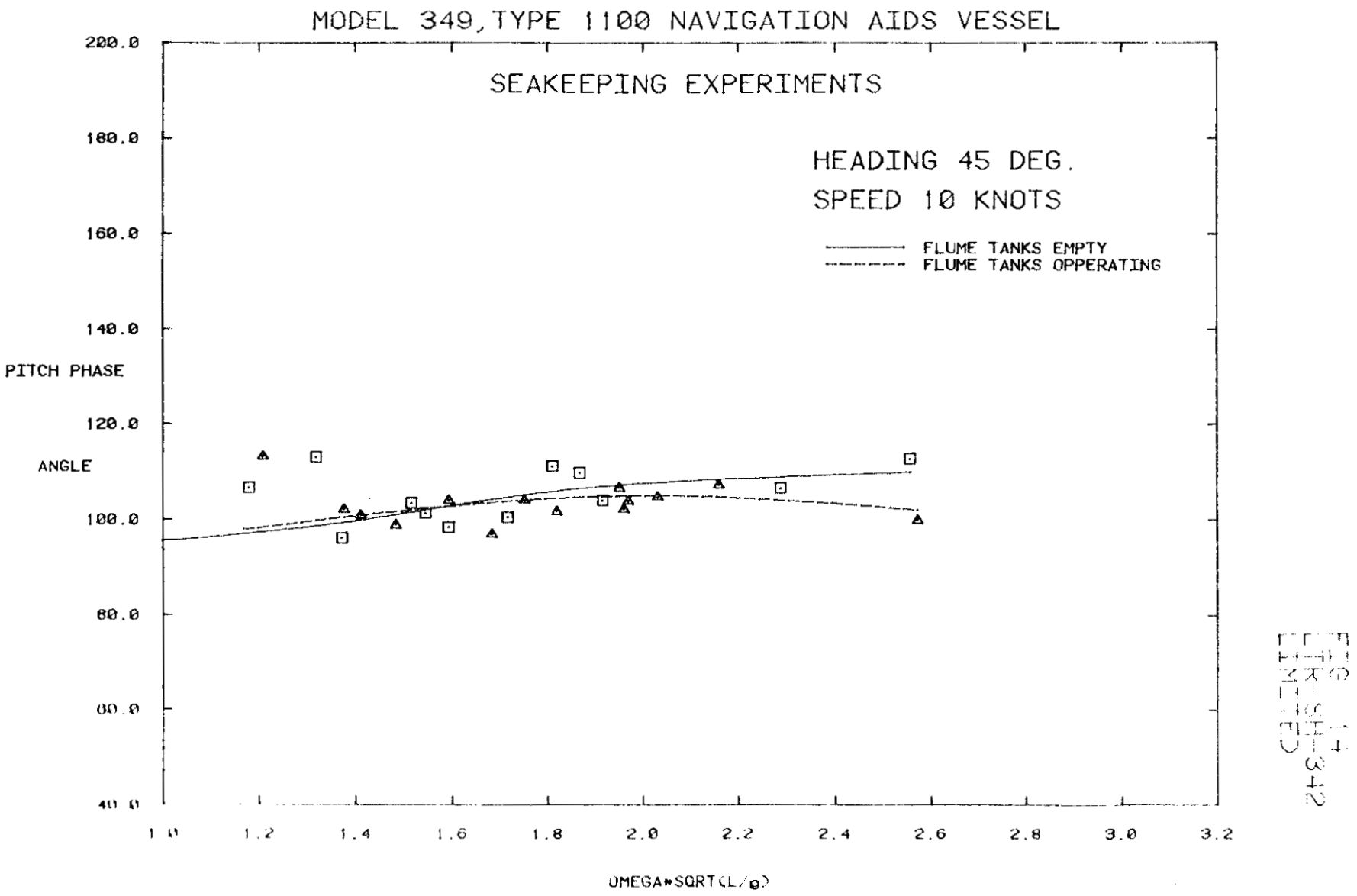


FIG. 13
ETR-SH-342
LIMITED


MODEL 349, TYPE 1100 NAVIGATION AIDS VESSEL
SEAKEEPING EXPERIMENTS
HEADING 45 DEG.
SPEED 10 KNOTS
FLUME TANKS EMPTY
FLUME TANKS OPPERATING
PITCH PHASE ANGLE
200.0
180.0
160.0
140.0
120.0
100.0
80.0
60.0
40.0
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
OMEGA*SQRT(L/g)

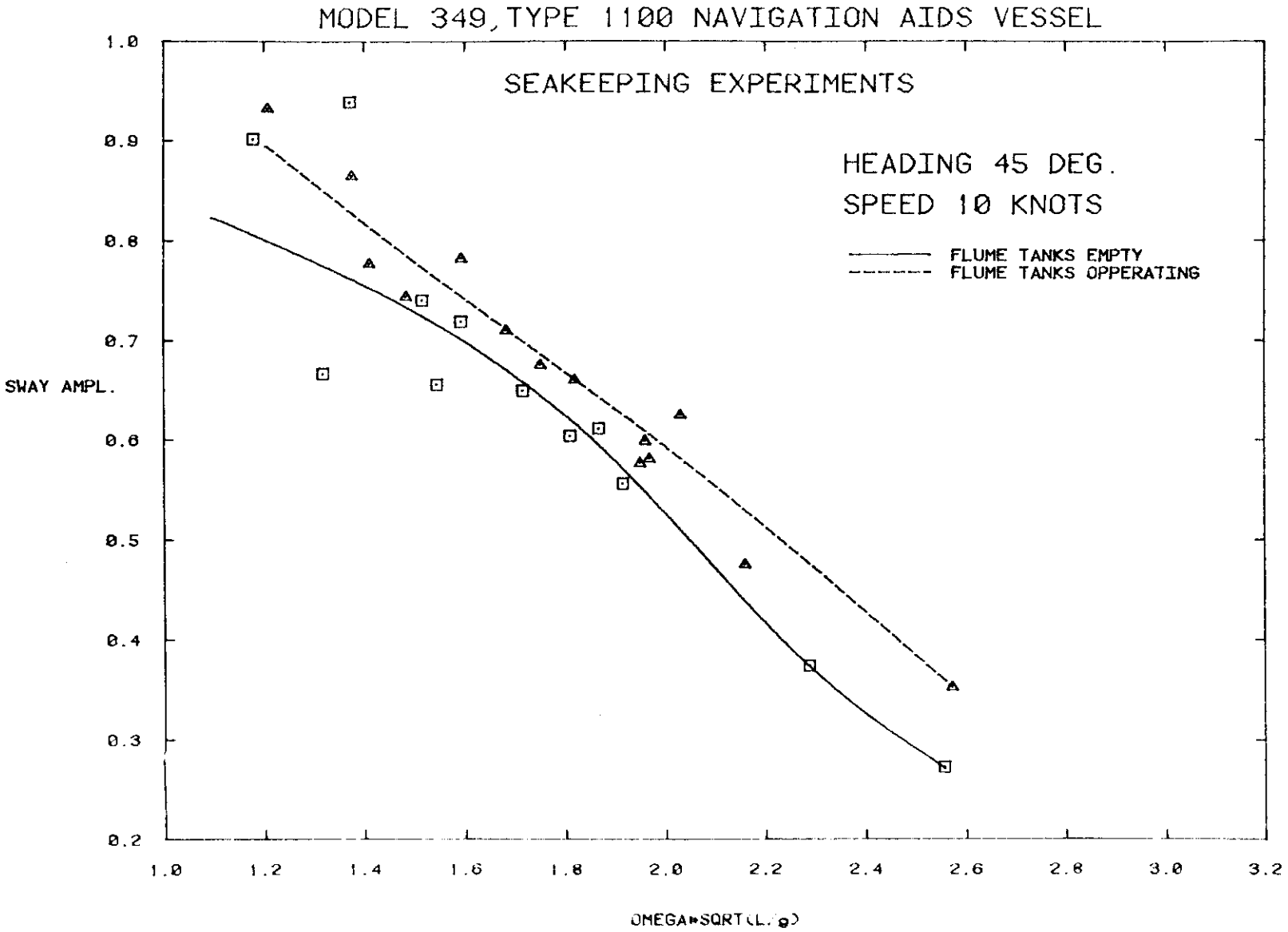
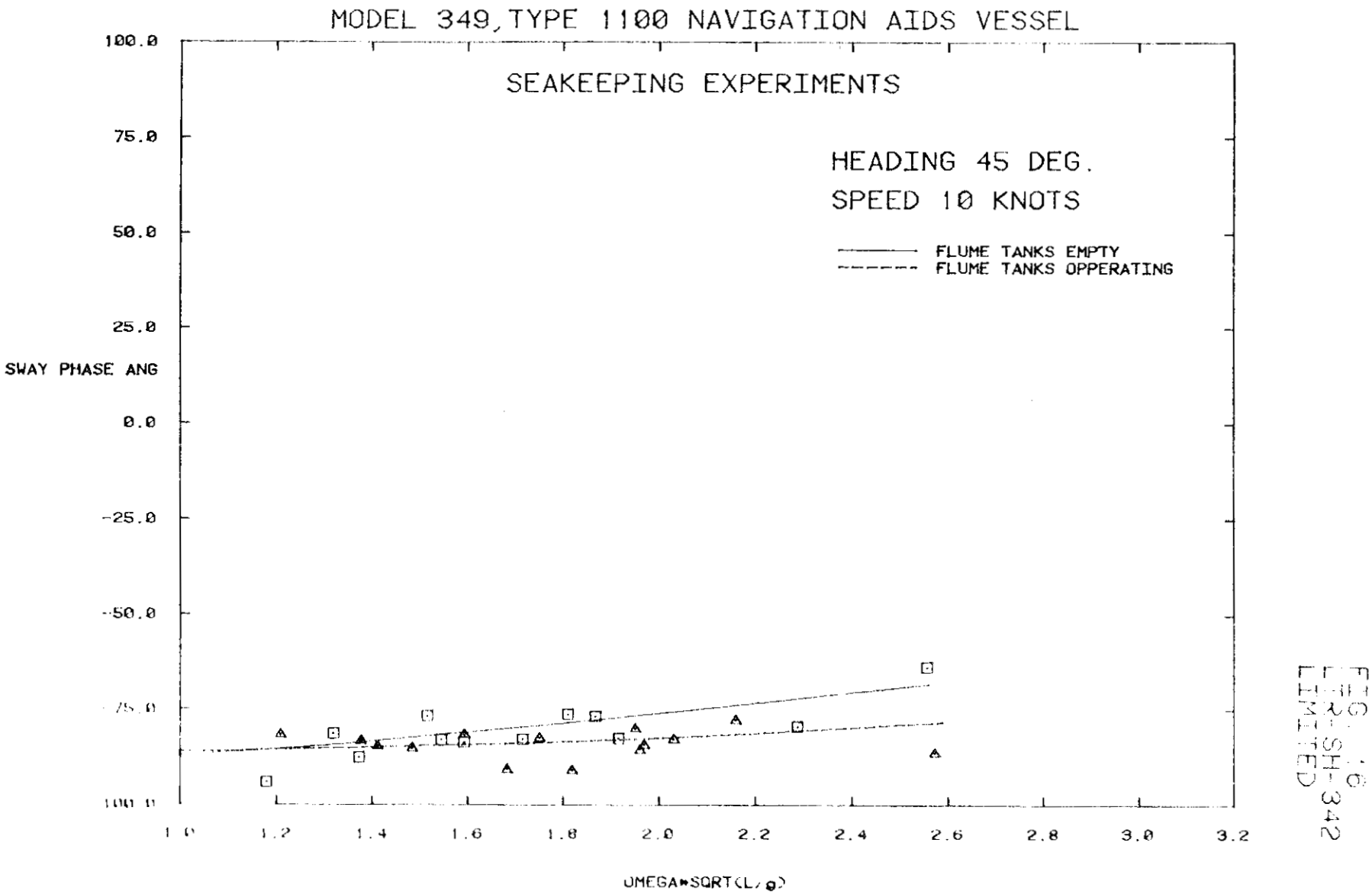


FIG. 15
LTR-SH-342
LIMITED



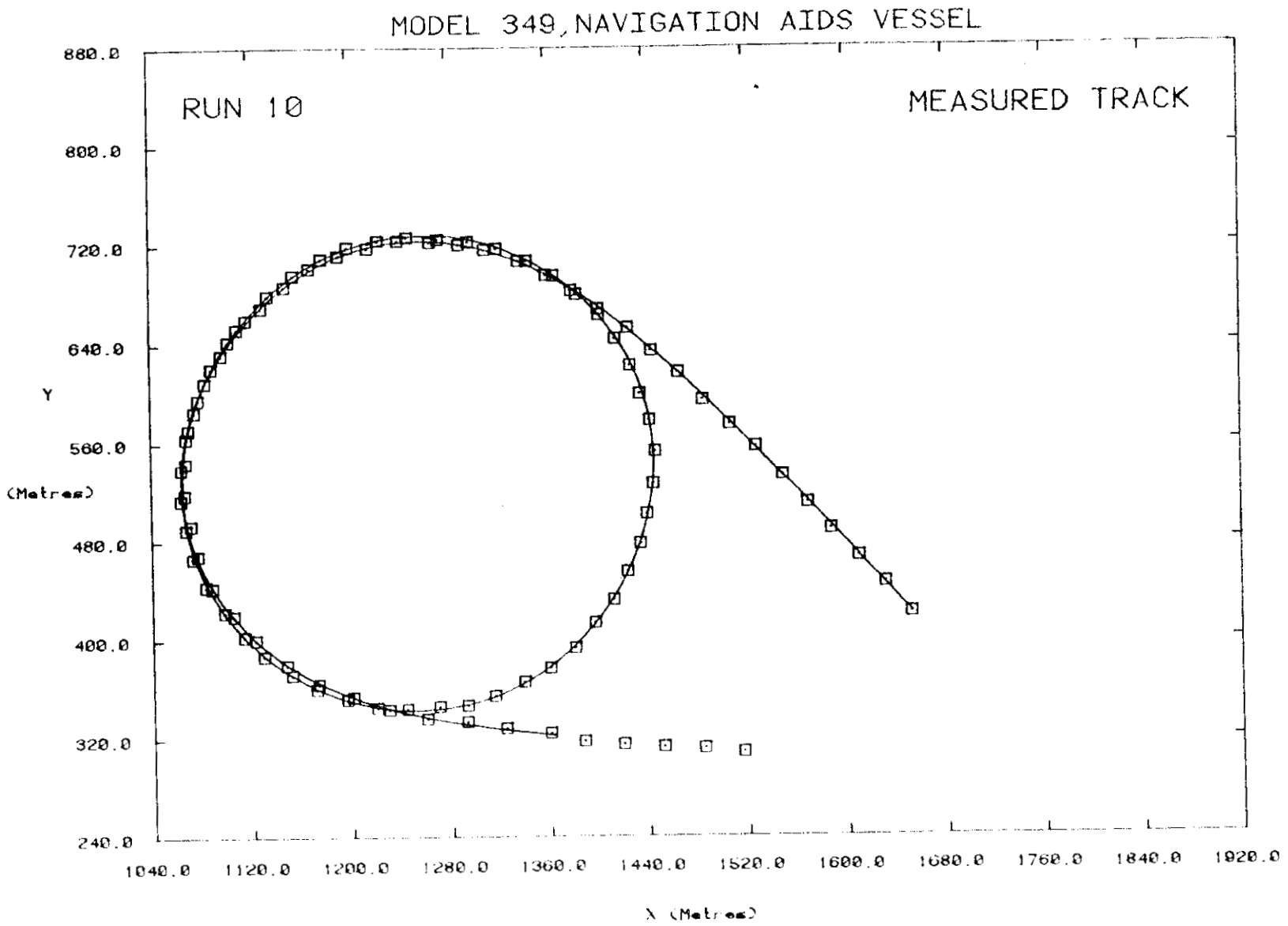
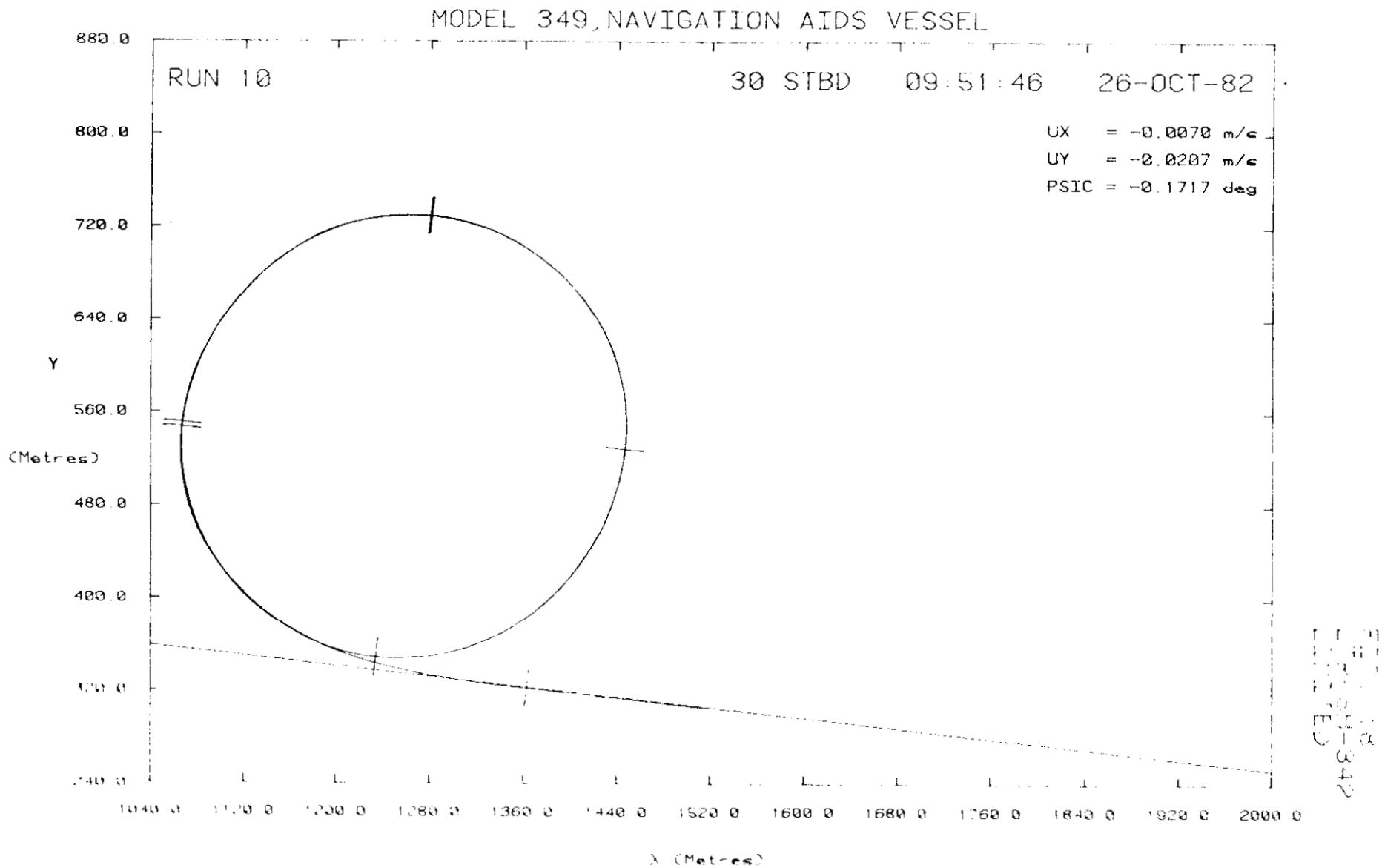


FIG. 17
LTR-SH-342
LIMITED


MODEL 349,NAVIGATION AIDS VESSEL
RUN 10
30 STBD 09:51:46 26-OCT-82
UX = -0.0070 m/s
UY = -0.0207 m/s
PSIC = -0.1717 deg
880.0
800.0
720.0
640.0
Y
560.0
(Metres)
480.0
400.0
1040.0
1200.0
1280.0
1360.0
1440.0
1520.0
1600.0
1680.0
1760.0
1840.0
1920.0
2000.0
X (Metres)

MODEL 349, TYPE 1100 NAVIGATION AIDS VESSEL

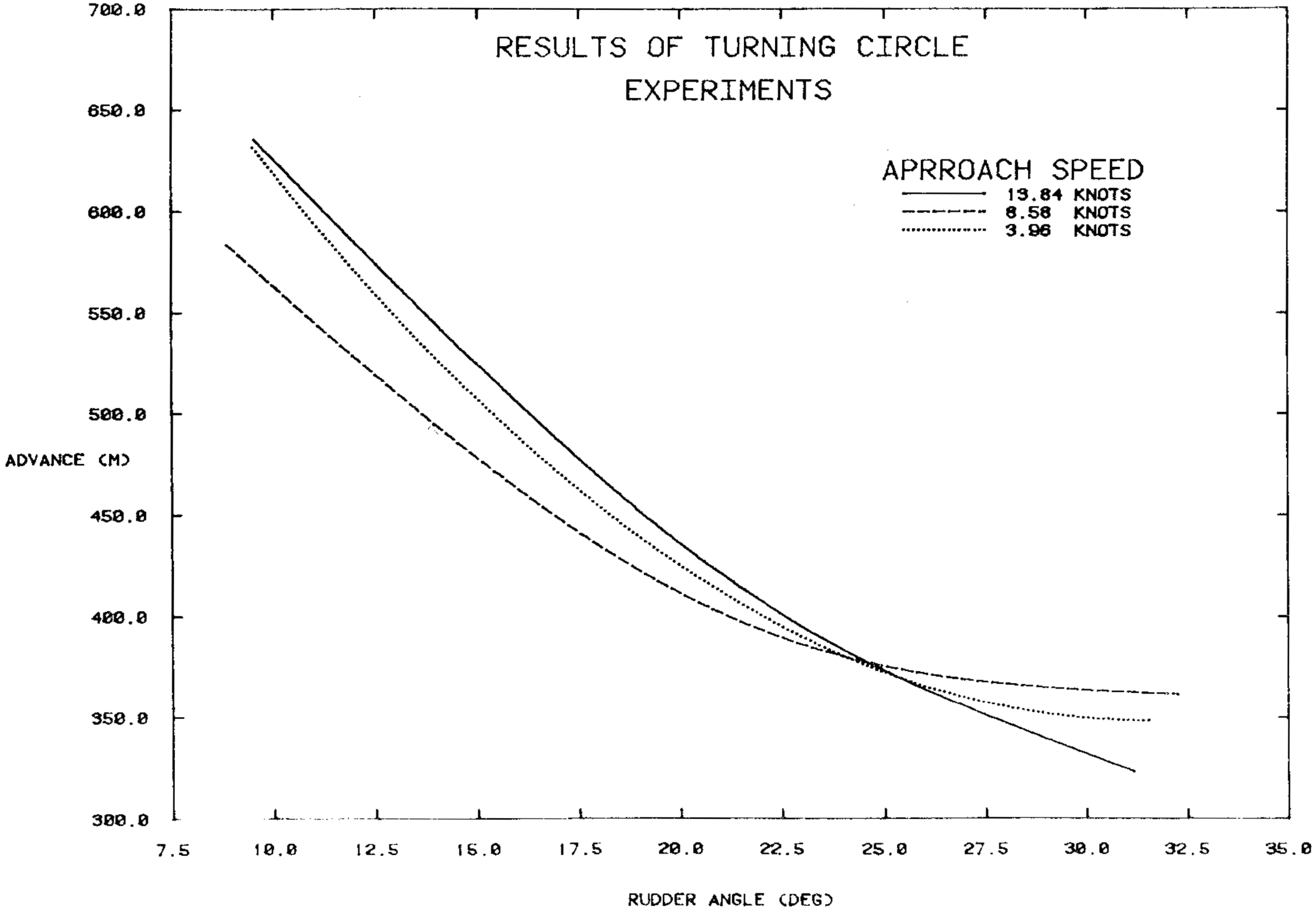


FIG. 19
LTR-SH-342
LIMITED

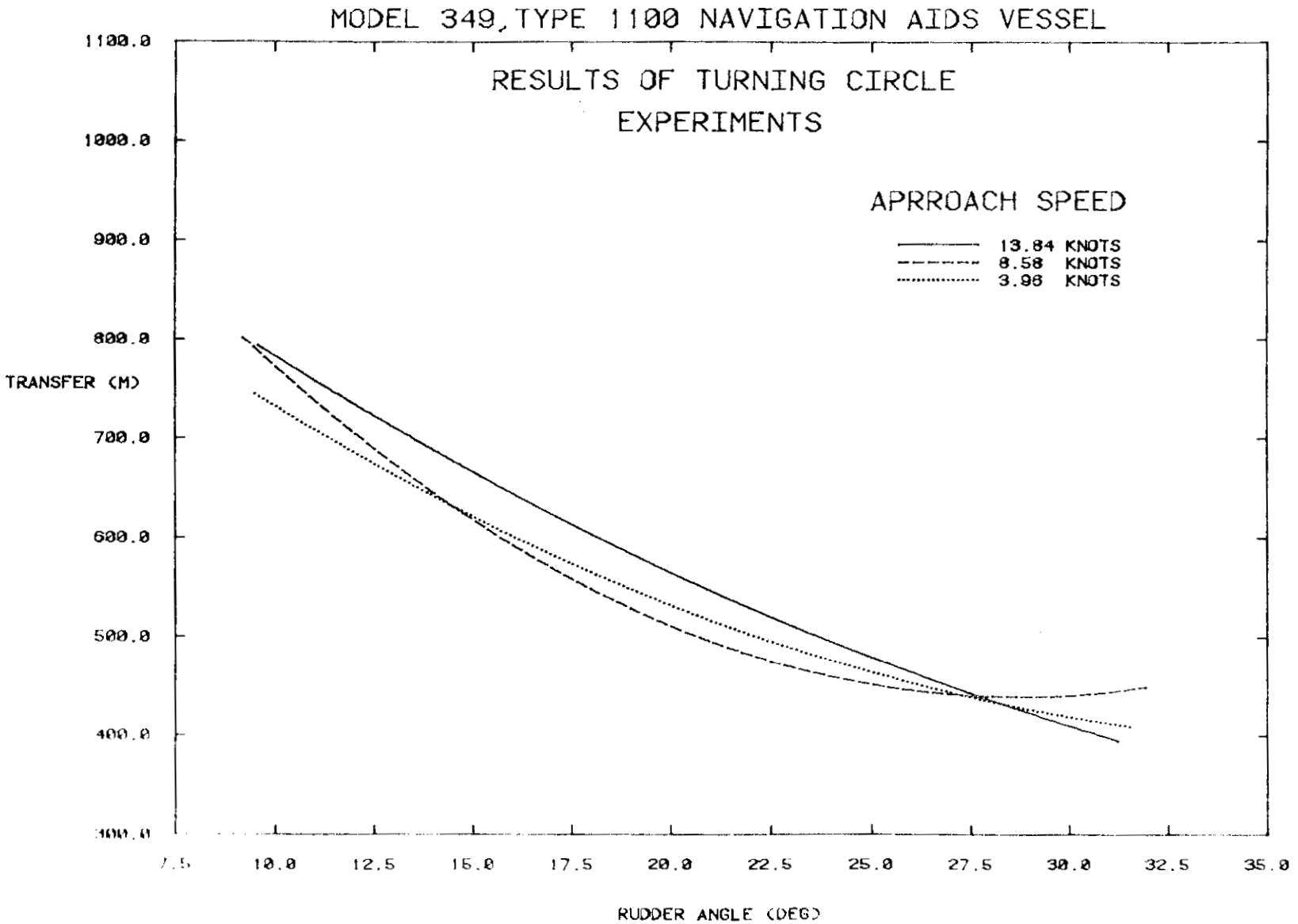


FIG. 29
CTR1-SHT-342
ENGTEC

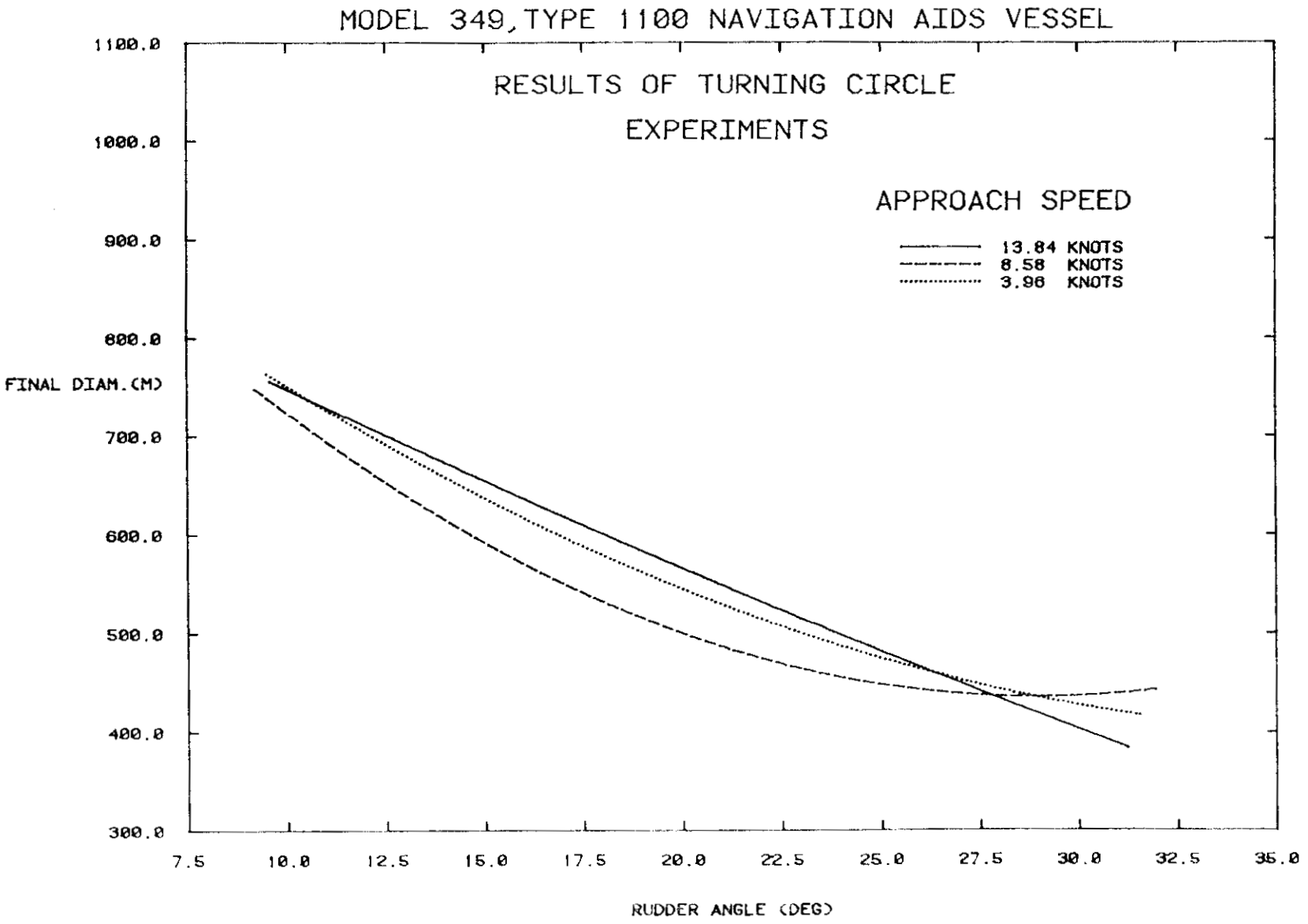


FIG. 21
TR-SH-342
LIMITED

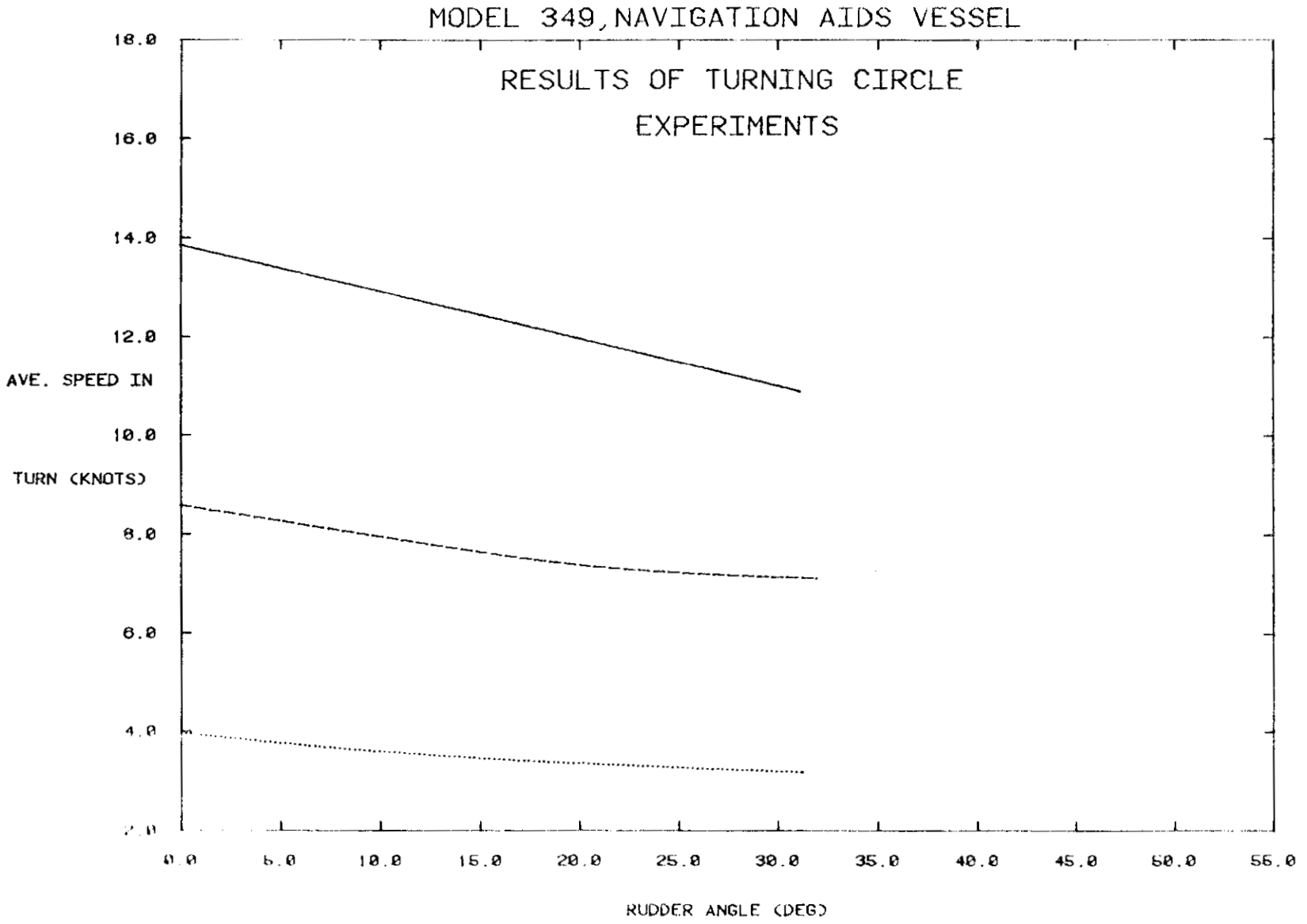


FIG. 22
SHEET 34
LENGTH

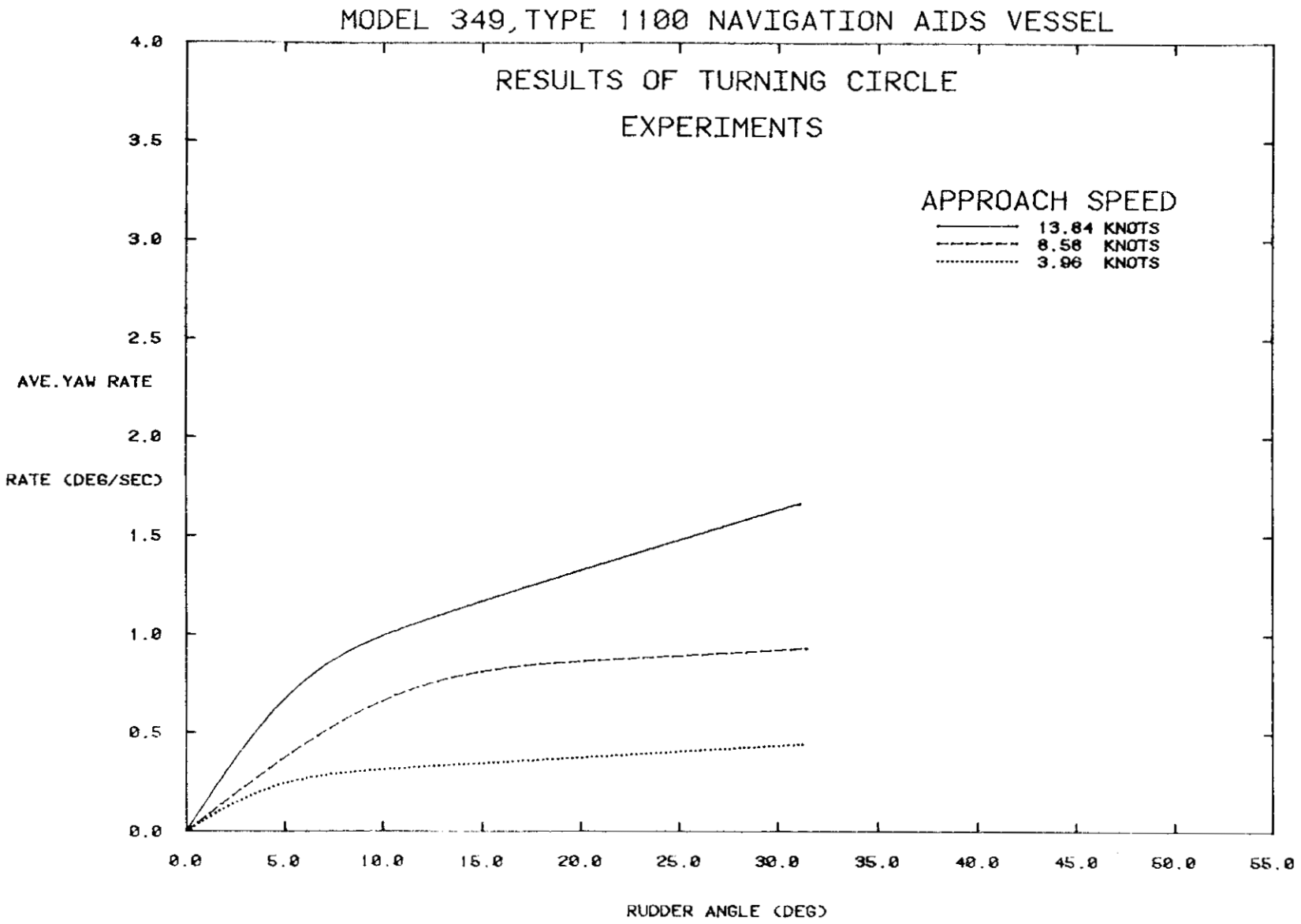
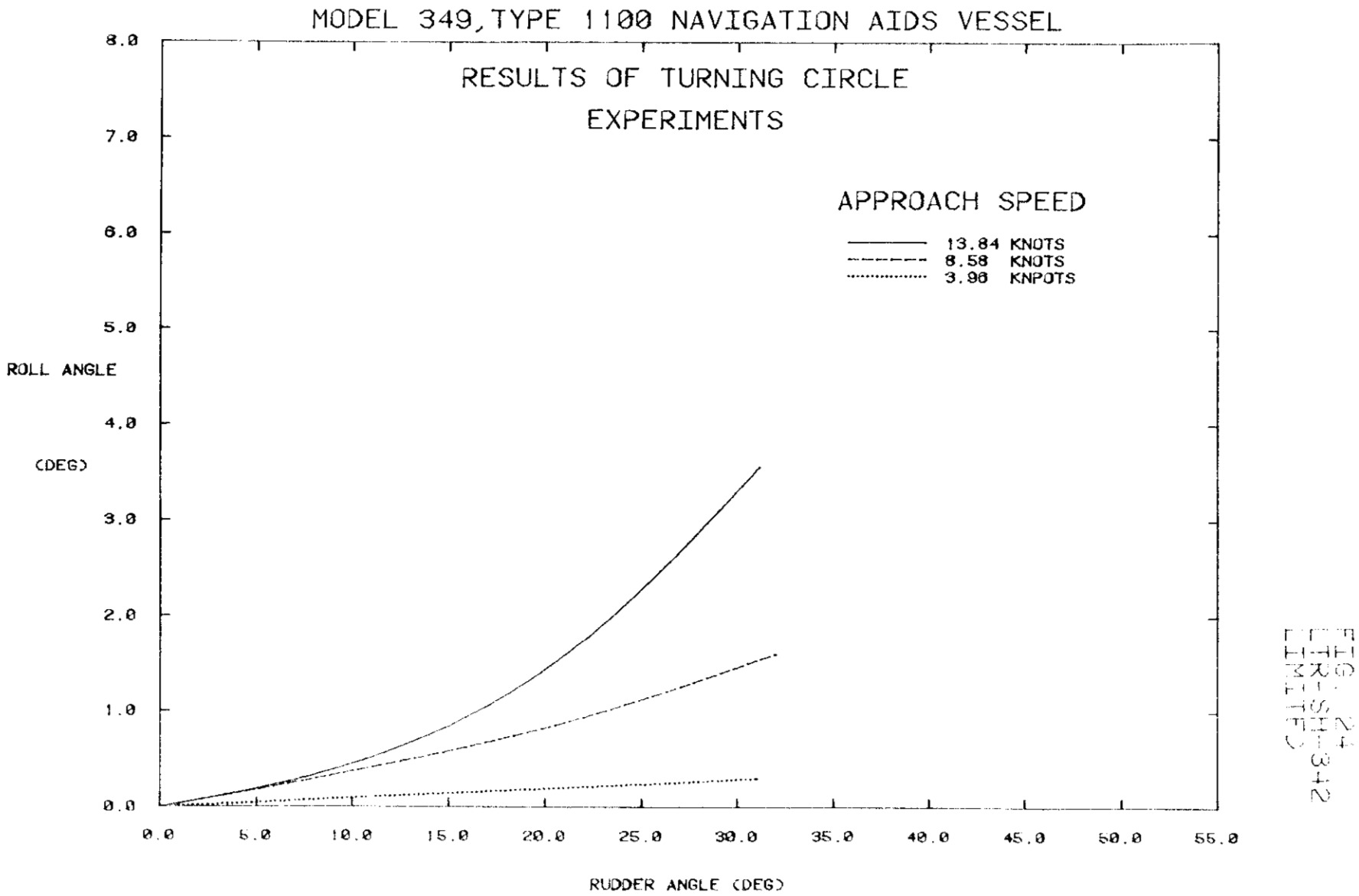


FIG. 23
FERT-SH-342
LIMITED


MODEL 349, TYPE 1100 NAVIGATION AIDS VESSEL
RESULTS OF TURNING CIRCLE EXPERIMENTS
APPROACH SPEED
13.84 KNOTS
8.58 KNOTS
3.98 KNPOTS
ROLL ANGLE (DEG)
RUDDER ANGLE (DEG)
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
40.0
45.0
50.0
55.0

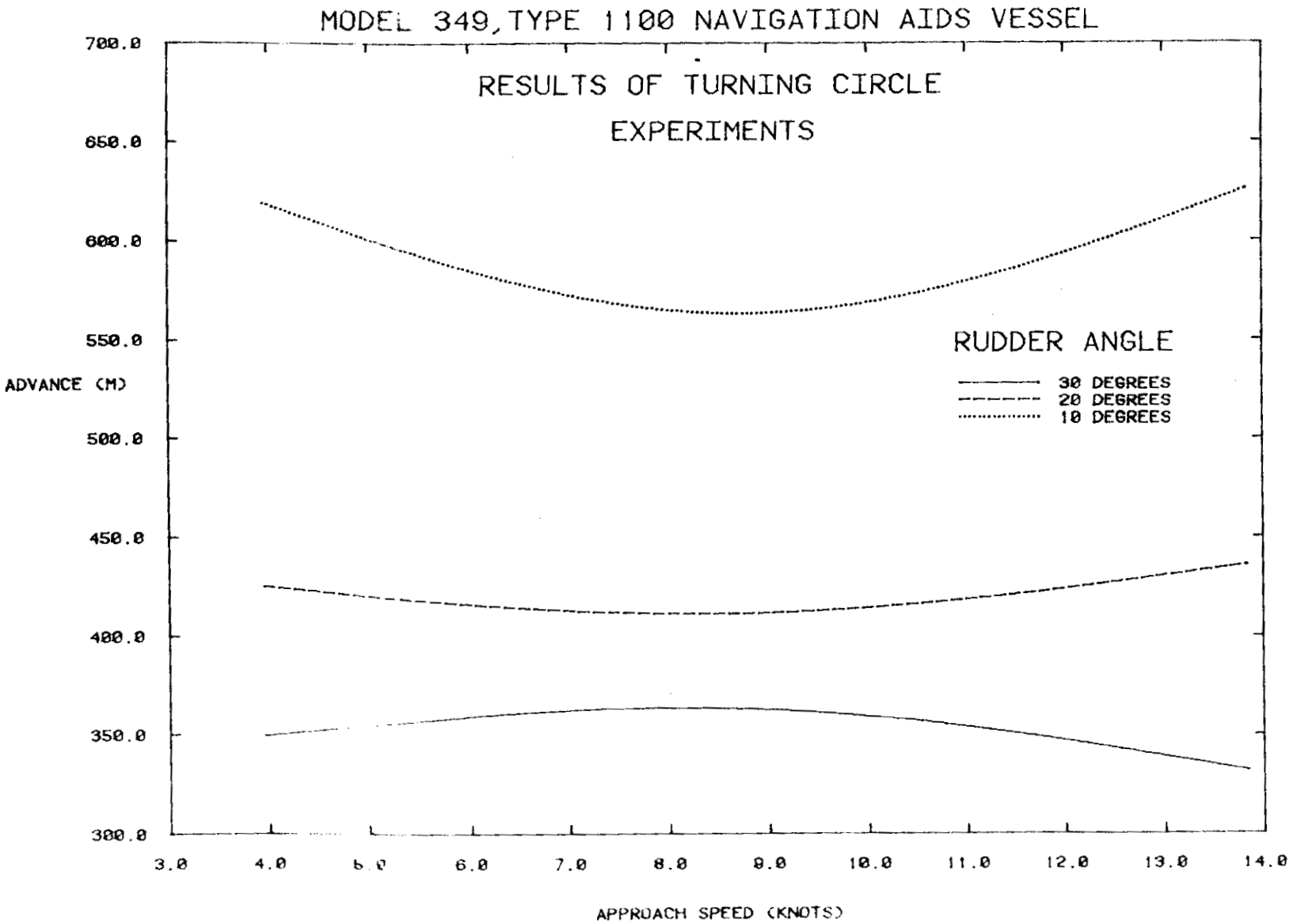


FIG 25
LTR-SHI-342
LIMITED

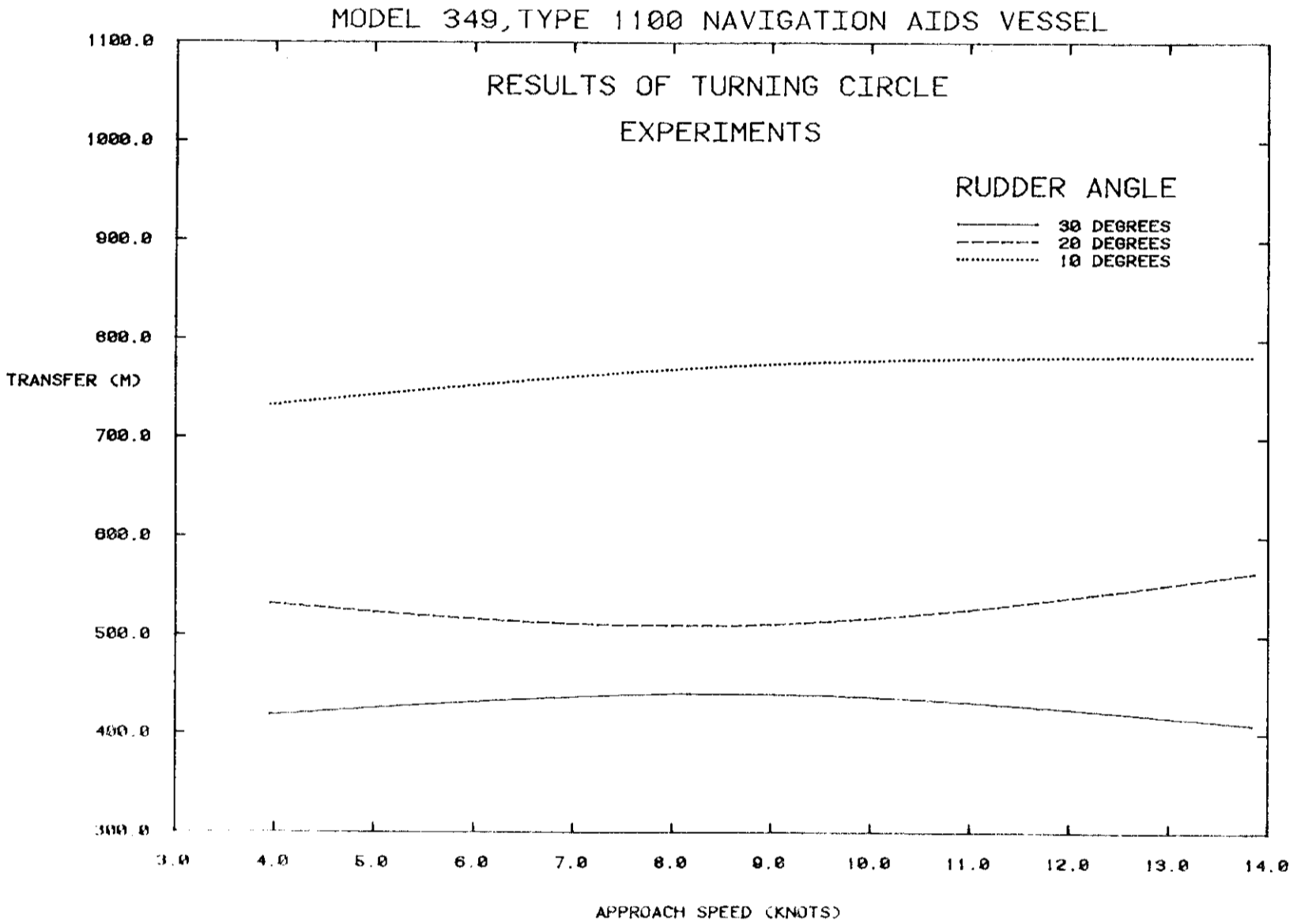


FIG. 23
ERRI-SIT-342
FEMETEC

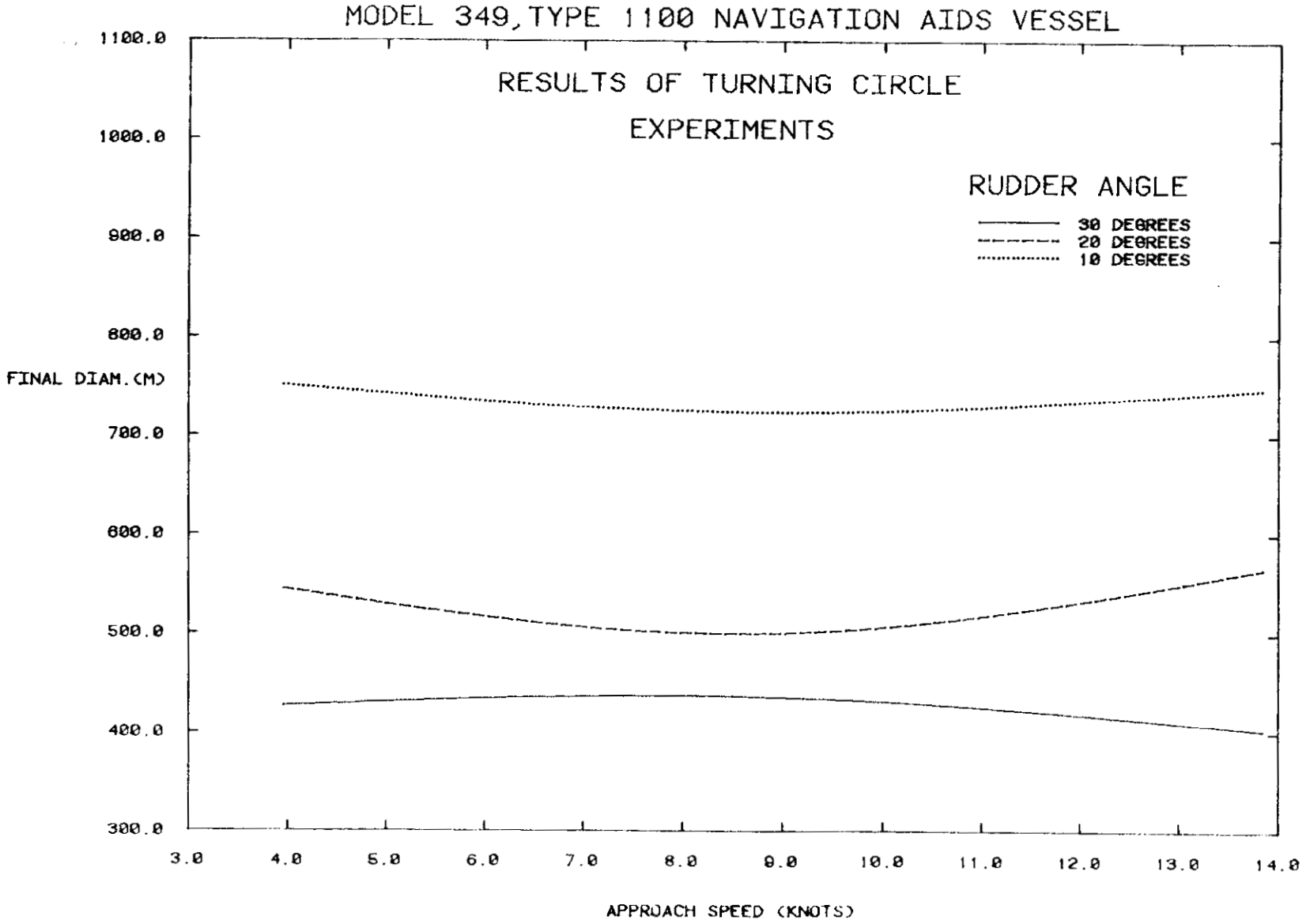
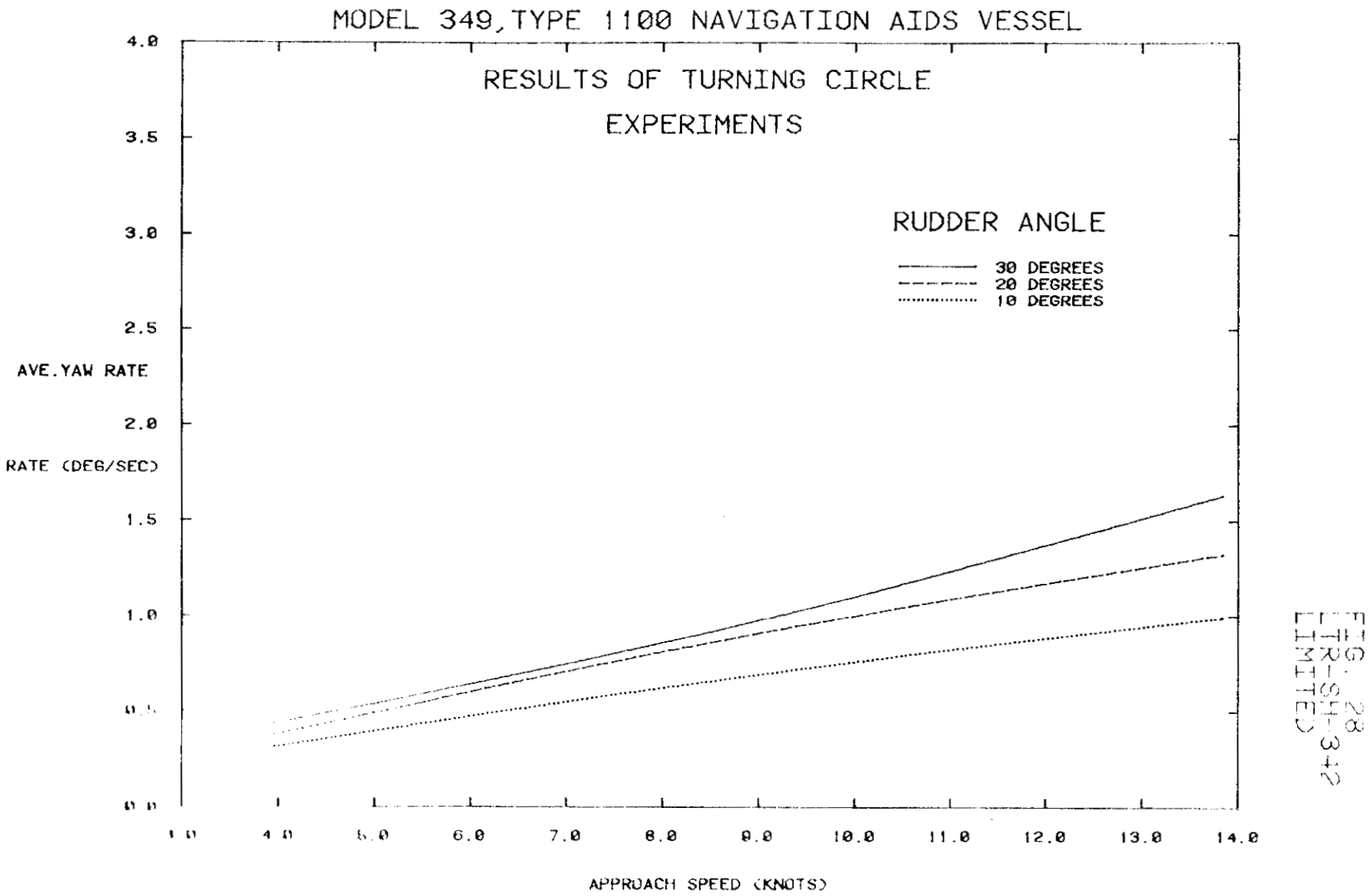


FIG. 21
LTR-SH-342
LIMITED



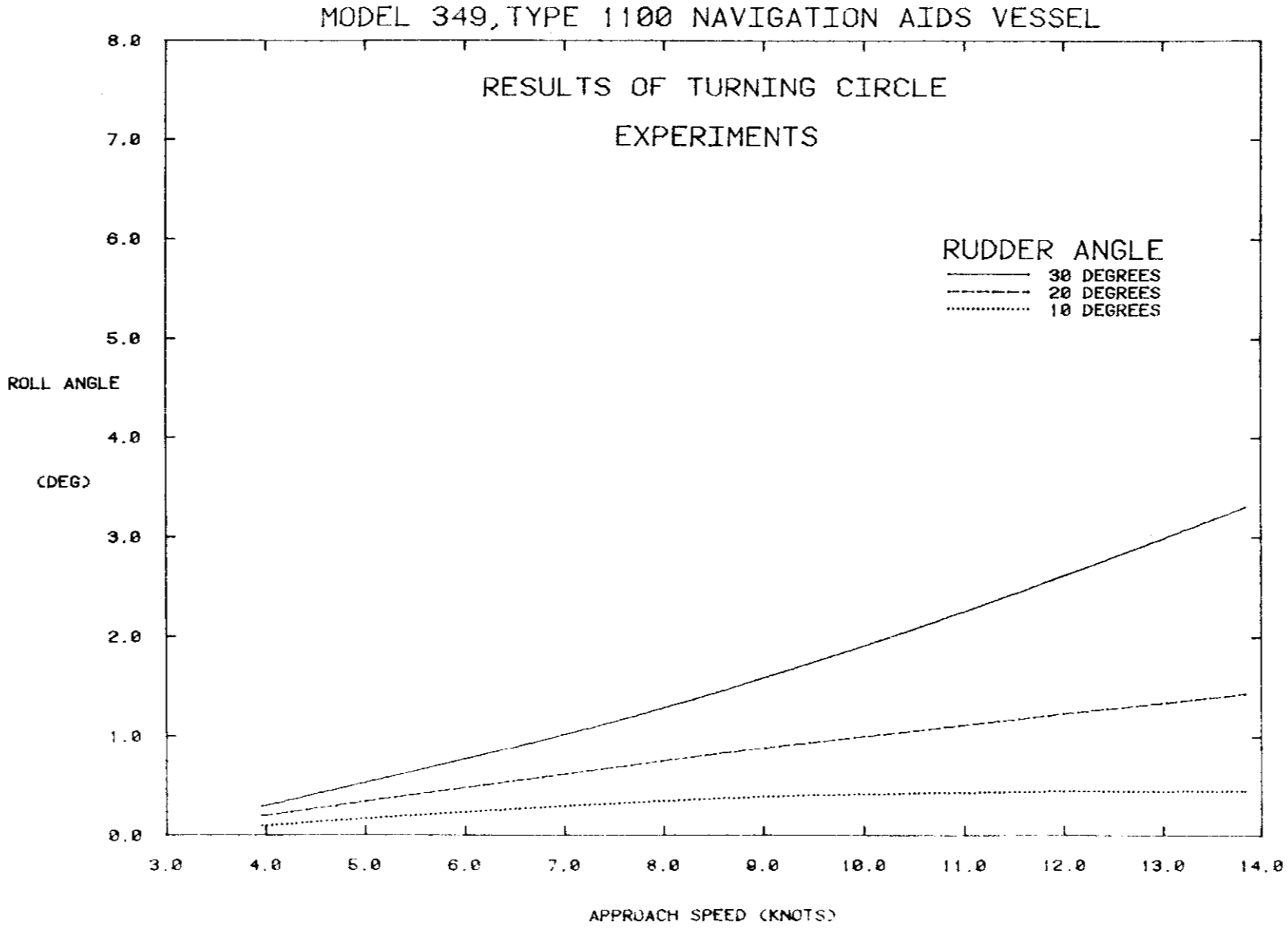


FIG 29
LTR-SH-342
LIMITED

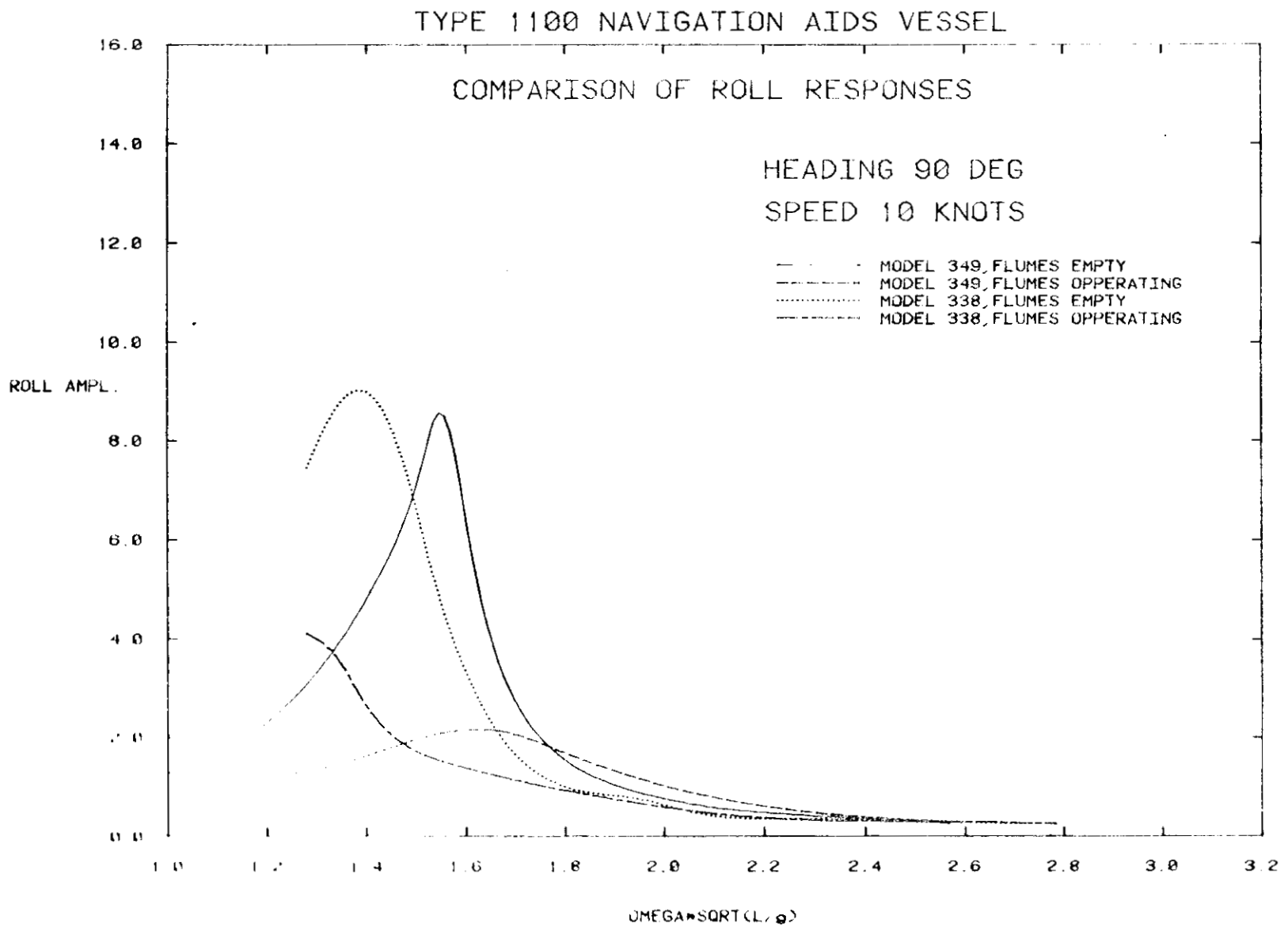


FIG. 33
BRITISH
EMITED

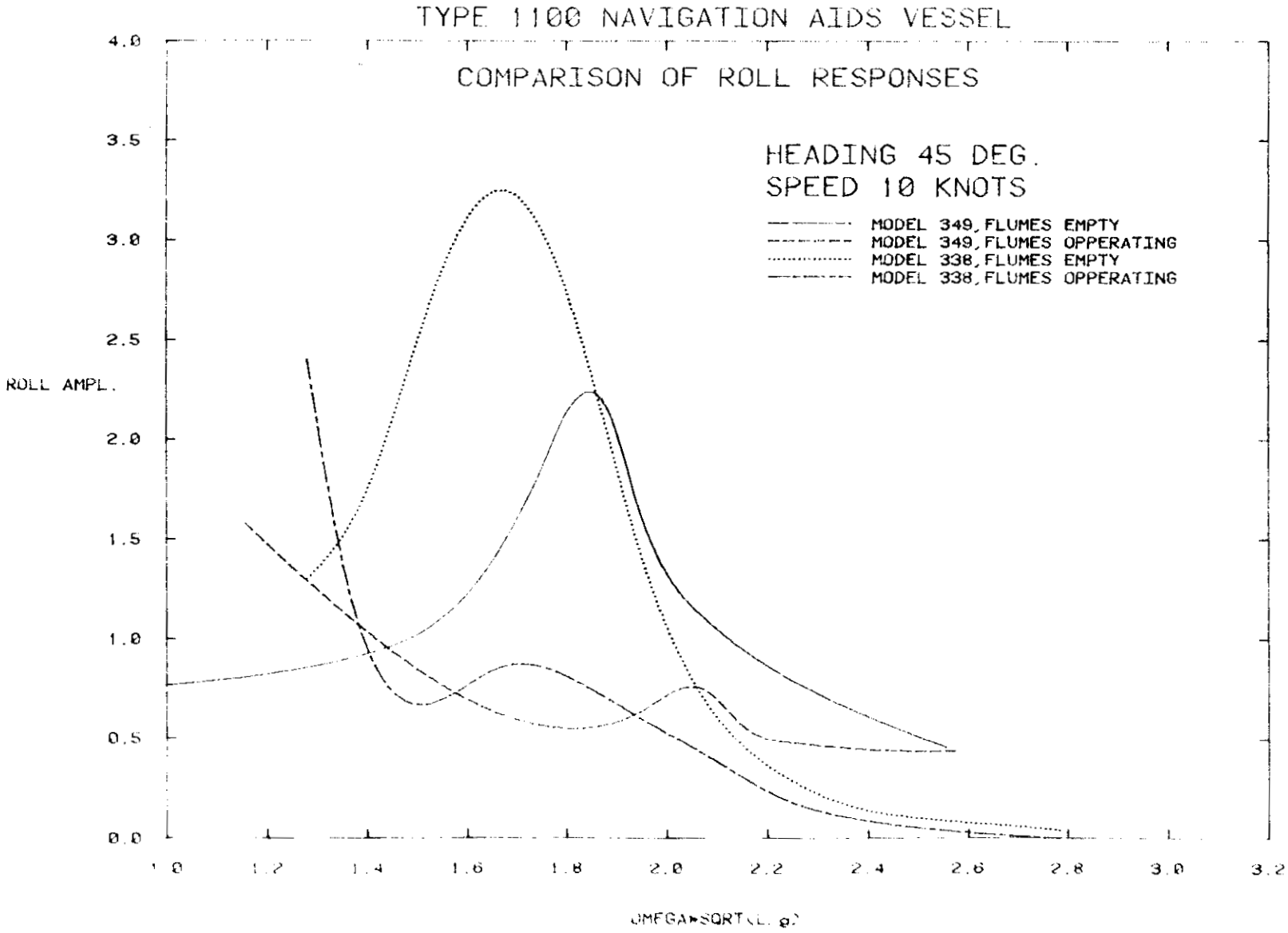
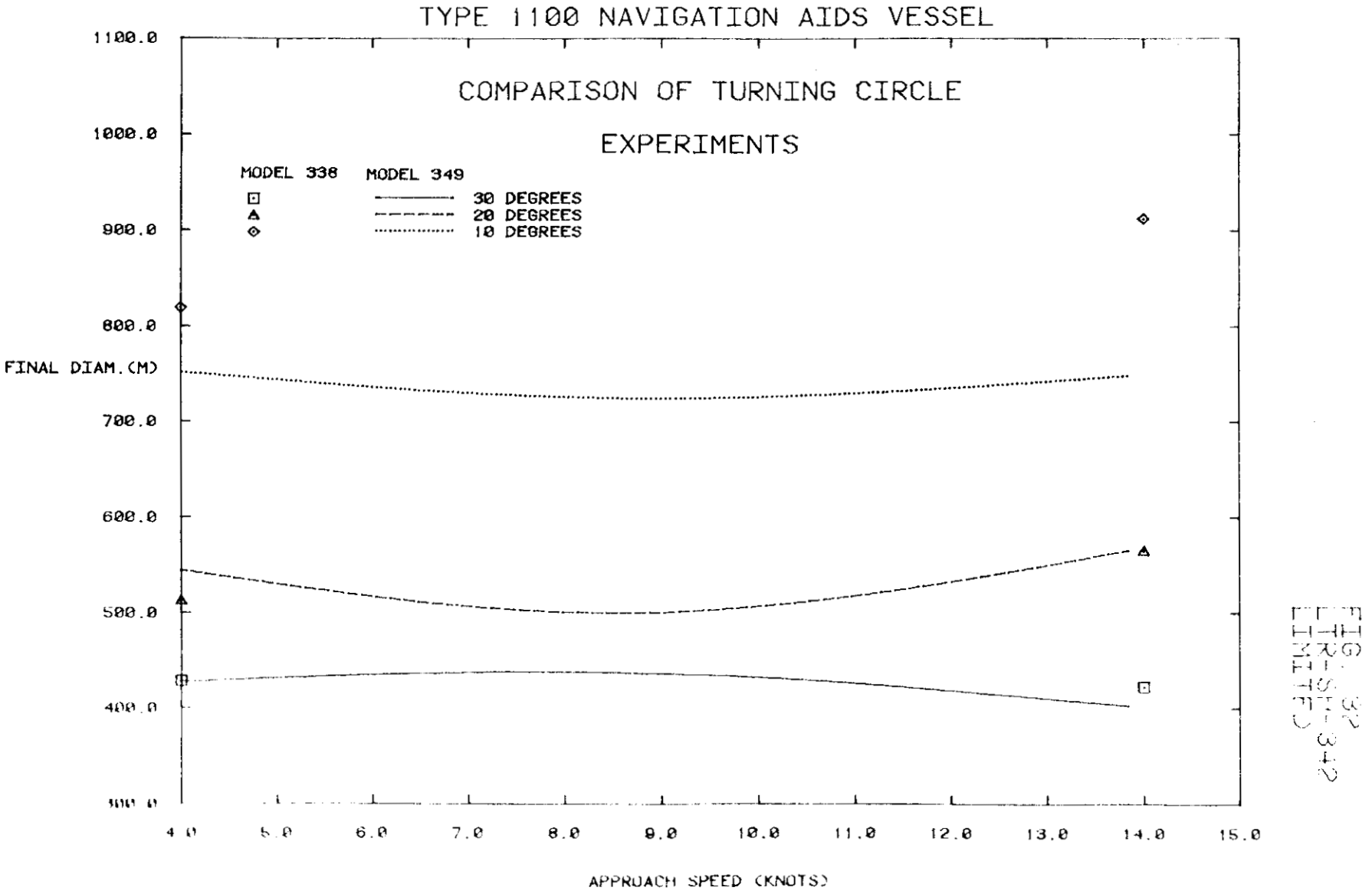


FIG. 3.1
ETR-SHI-342
LIMITED


TYPE 1100 NAVIGATION AIDS VESSEL
COMPARISON OF TURNING CIRCLE
EXPERIMENTS
MODEL 338
MODEL 349
30 DEGREES
20 DEGREES
10 DEGREES
1100.0
1000.0
900.0
800.0
700.0
600.0
500.0
400.0
FINAL DIAM.(M)
4.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0
12.0
13.0
14.0
15.0
APPROACH SPEED (KNOTS)