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NAVAL SHIP RESEARCH AND DEVELOPMENT CENTER
Bethesda, Maryland 20034

# USS EDENTON (ATS-1) TACTICAL AND MANEUVERING TRIAL RESULTS

by

Charles W. Tate, Sr.



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RESEARCH AND DEVELOPMENT REPORT

JULY 1972

Report 3961

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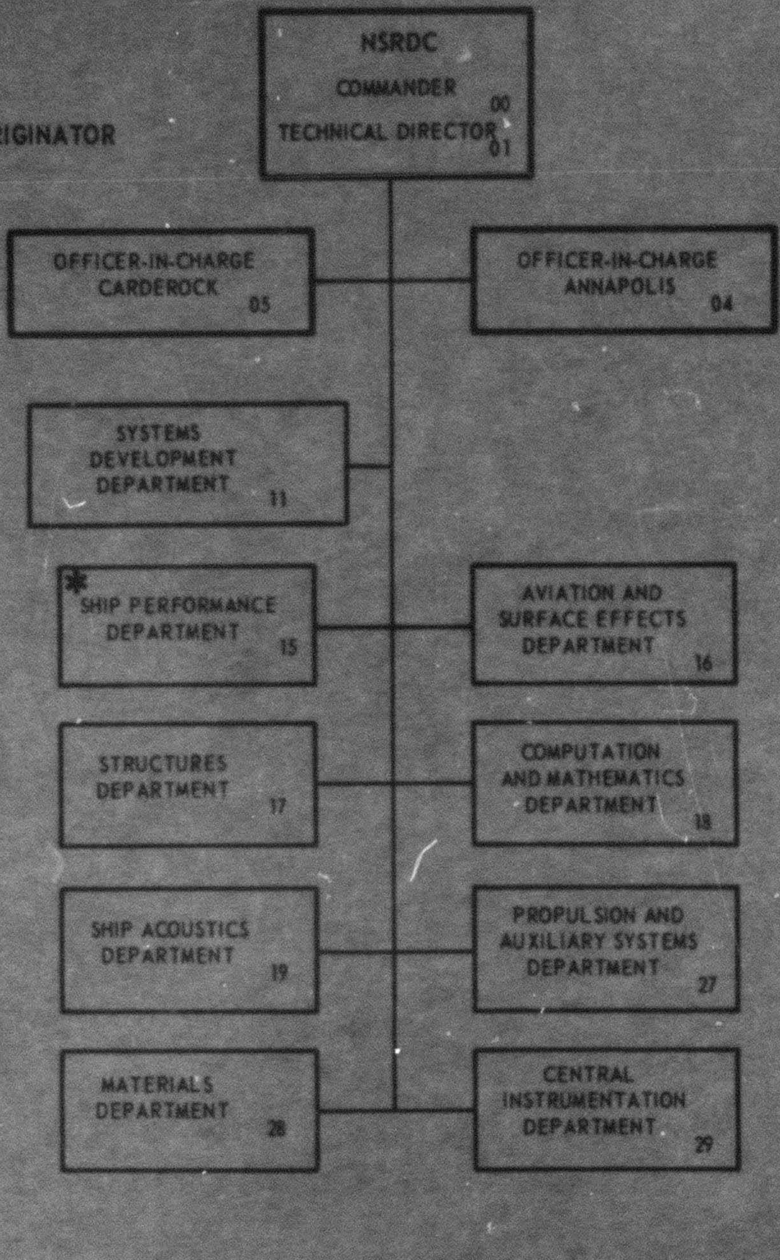

DEPARTMENT OF THE NAVY
NAVAL SHIP RESEARCH AND DEVELOPMENT CENTER
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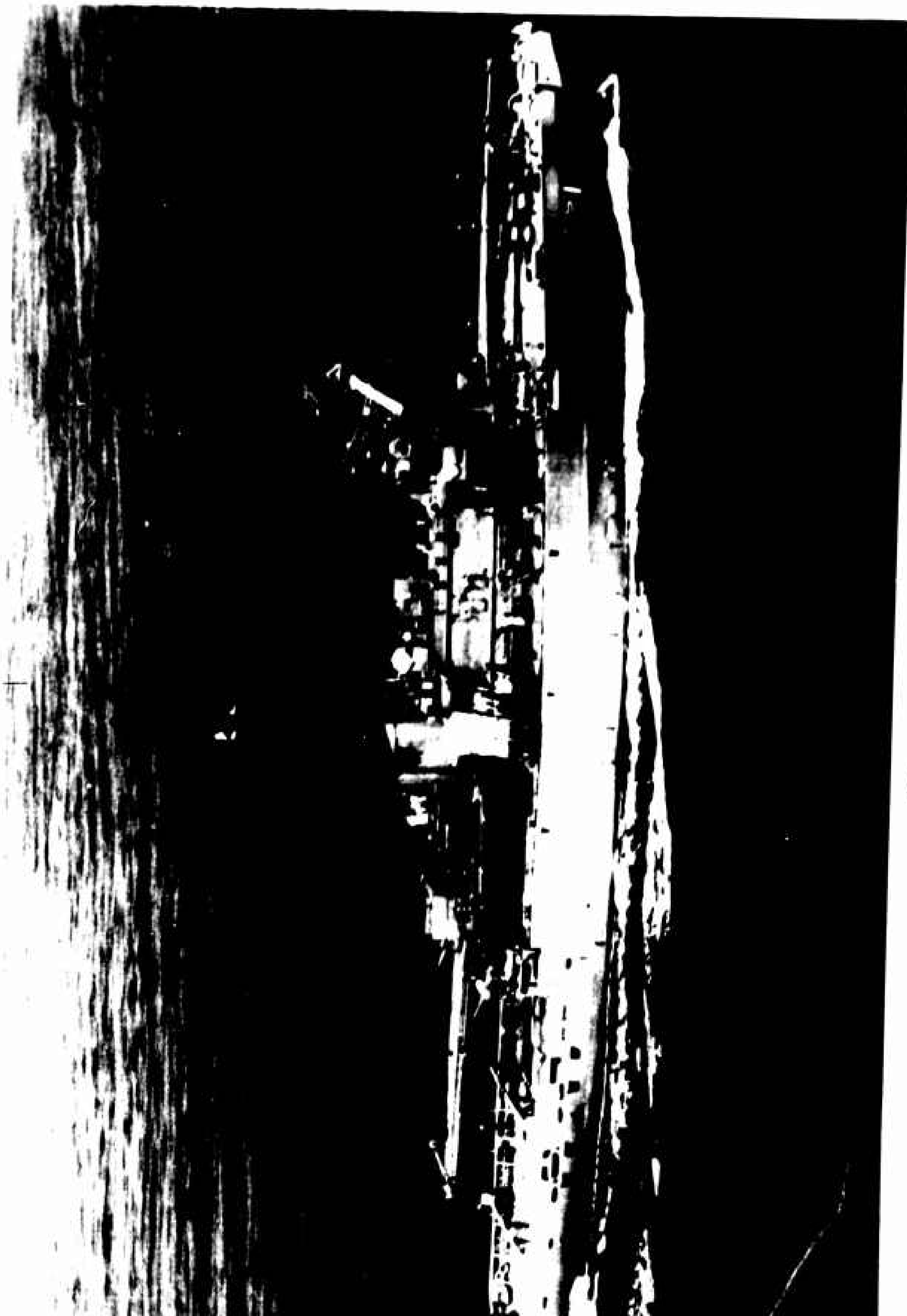
## TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES



USS EDENTON ATS-1

## ABSTRACT

This report contains the results of tactical trials conducted on USS EDENTON (ATS-1). The trials consisted of turning circles, acceleration, deceleration, spiral, swinging tests and astern controllability tests conducted at a displacement of 3,200 tons and 0 degrees trim angle. Measurements were made to determine tactical diameters, stopping distances, directional stability, controllability, and maneuvering characteristics. The results show EDENTON has normal turning characteristics, and the ship is directionally stable when operating at 11 knots. The bow thruster is effective in maneuvering the ship when operating at speeds from dead in the water to 6 knots.

## ADMINISTRATIVE INFORMATION

The trials of USS EDENTON (ATS-1), reported herein were conducted in accordance with Naval Ship Engineering Center trial agenda letter ATS-1 C1/9080, Ser 82-6144G of 3 May 1971 endorsed by Naval Ship Systems Command letter Ser 4504-391.A4 of 18 May 1971. The scope of the trials as outlined in the trial agenda was reduced by oral instructions from NAVSHIPSYSCOM and NAVSHIPENGCEN. The trial items deleted from the original agenda are listed in Naval Ship Research and Development Center Message 161508Z of June 1971.

## INTRODUCTION

USS EDENTON (ATS-1) is a diesel-powered ocean salvage towing ship equipped with two controllable pitch propellers. It is the first of its class. EDENTON was built by Brooke Marine Ltd., Lowestoft, England. Tactical and maneuvering trials were conducted off Kent Island, Maryland, during the period of 26 to 28 July 1971 by personnel of Naval Ship Research and Development Center with the assistance of ship force personnel. The objectives of these trials included the determination of tactical diameters and related parameters, rate of change of heading, speed in turns, and direction and magnitude of maximum angle of heel during turning circle maneuvers. Further objectives were to investigate the directional stability characteristics and determine if the ship as built fulfills the design requirements, to obtain performance data for use of forces afloat, and to obtain data which can be used in the design of future ships.

## SHIP CHARACTERISTICS AND TRIAL CONDITIONS

USS EDENTON (ATS-1) was designed for major towage and salvage work. The ship is equipped with two controllable pitch propellers. It also has a controllable pitch bow thruster to aid in maneuvering. The motor driving the bow thruster propeller is rated at 308 horsepower. Table 1 is a list of the principal ship and propeller characteristics. During a drydock period (7 to 16 July 1971), the underbody of EDENTON was painted with the standard Navy vinyl resin paint system and the propellers were cleaned. Photographs of the ship appendages are shown in Figure 1.

Tactical trials were conducted as near full load displacement and 0 degree trim angle as possible. The displacement maintained during the trials was 3200 tons. During the trial period sea and weather conditions were favorable and had no adverse effect on the conduct of the trials. The trials were conducted in accordance with procedures outlined in the Naval Ship Systems Command Technical Manual, Chapter 9080. Pertinent data concerning conditions during the trials are listed in Table 2.

## TURNING CIRCLES

Fourteen 540-degree turning circles were conducted at various approach speeds and rudder angle settings. However, data reported herein consists of ten turning circles. The two left turn check tests are not included since the results of these turns agreed with corresponding right turns. Two right turning circles (15 degrees rudder at full power and 45 degrees rudder at 11 knots) are omitted because the data could not be analyzed with normal consistency.

Data were obtained from two shore stations and shipboard instrumentation during these maneuvers. The two shore stations, located 2460.5 yards apart, sighted on the mainmast of the ship. The mainmast was located 5.75 feet forward of amidship. Radio communication from ship to shore was established to coordinate the data-taking sequence of each run, and bearings were recorded at predetermined change of heading increments. By means of triangulation of bearings taken from the two shore stations the path and speed of the ship were determined. Change of heading was determined by means of a digital recorder electrically connected to the ship's gyro-compass circuit. Angle of heel data were obtained from the ship's inclinometer.

## TABLE 1 - SHIP AND PROPELLER CHARACTERISTICS

### Ship Characteristics

| | |
|---|---|
| Length Overall (LOA), feet | 282.67 |
| Length between Perpendiculars (LBP), feet | 264 |
| Breadth, Extreme, feet | 50 |
| Number of Rudders | 2 |

### Propeller Characteristics

| | |
|---|---|
| Number of Propellers | 2 |
| Number of Blades | 4 |
| Rotation | Outboard |
| Diameter, feet | 11.75 |
| Design Pitch at 0.7 Radius, feet | 14.14 |
| Mean Width Ratio (MWR) | 0.24 |
| Disc Area, square feet ($A_o$) | 108.4 |
| Developed Area, square feet ($A_D$) | 47.34 |
| Projected Area, square feet ($A_p$) | 41.31 |

PORT PROPELLER AND RUDDER

STERN QUARTER VIEW


STERN VIEW

STARBOARD PROPELLER AND RUDDER

BOW VIEW

Figure 1 - Ship Appendages

TABLE 2 - TRIAL CONDITIONS

| | |
|---|---|
| Displacement, tons | 3,200 |
| Draft | |
| Forward, feet-inches | 15-5 |
| Aft, feet-inches | 15-5 |
| Days out of Drydock | 10-12 |
| Water Temperature, degrees F | 77 |
| Water Specific Gravity | 1.0063 |
| Air Temperature, degrees F | 72-88 |
| Sea Conditions, Beaufort Scale | 2-3 |
| True Wind Velocity, knots | 4-10 |
| True Wind Direction, degrees | 000-[illegible]00 |

The results of the turning circle trials, referred to the mainmast, are presented graphically in Figure 2. This figure shows advance, transfer, and tactical diameter plotted against ship speed. A diagram in Appendix A shows the definition of these terms. The curves are extrapolated in the areas where data points are missing, and these areas are shown as dashed lines. A tabulation of tactical data is presented in Table 3. These data have been corrected for drift due to wind and current. Figures 3, 4, and 5 are faired change of heading curves plotted against time for the tactical turns. During the full power, 45-degree right rudder turning circle shaft torque and RPM data were recorded and are shown plotted against time in Figure 6.

The results of the turning circles for EDENTON indicate normal turning characteristics in that advance, transfer, and tactical diameter increase with increasing speed and decrease with increasing rudder angle.

ACCELERATION RUN

One acceleration run was conducted from dead in the water to full power ahead. During this run the two shore stations tracked the ship to determine its speed and reach. These data, plotted against time, are shown in Figure 7. The speed and reach data have been corrected for drift due to wind and current. The results reveal that the ship accelerated from dead in the water to 16 knots in 160 seconds over a distance of 960 yards. During the last minute of the run the ship reached a speed of 16.15 knots while traveling an additional distance of 535 yards. Figure 8 presents the machinery data recorded on board the ship during this maneuver. Data pertinent to the conduct of the acceleration run are listed in Table 4.

DECELERATION RUNS

Four deceleration runs were made at various operating conditions: half power ahead to half power astern, half power ahead to full power astern, full power ahead to half power astern, and full power ahead to full power astern. The ahead and astern power designations for these runs represent requested propulsion plant operating conditions rather than measured values. The rudder was used in an attempt to keep the ship on the proper heading during these runs. The tracking results of the deceleration runs are presented in Figures 9, 10 and 11 which show speed, reach, and ship path plotted against time. The speed and reach data for the deceleration run conducted from full

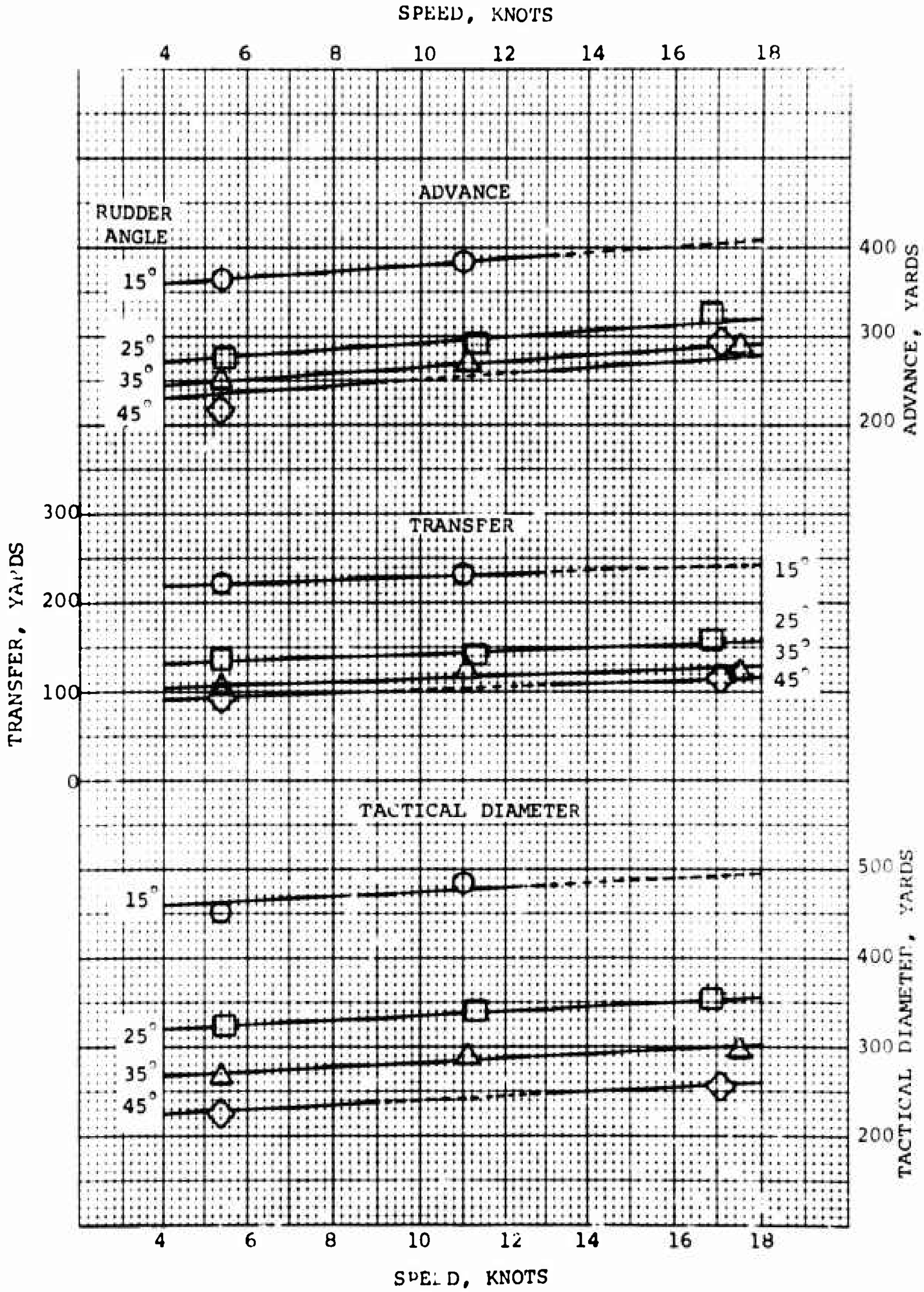



Figure 2 - Advance, Transfer and Tactical Diameter Using Right Rudder Angles at Various Approach Speeds

TABLE 3 - OBSERVED TACTICAL DATA CORRECTED FOR DRIFT

| Rudder Angle Degrees | Approach Speed Knots | Speed in turn Knots | Advance Yards | Transfer Yards | Tactical Diameter Yards | Maximum* Angle of Heel Degrees | Average Angle of Heel on the Approach |
|---|---|---|---|---|---|---|---|
| 15°R | 5.4 | 4.2 | 365 | 222 | 450 | .2P | 1.2P |
| 25°R | 5.5 | 3.7 | 276 | 137 | 324 | 1.8P | 0.8S |
| 35°R | 5.4 | 3.3 | 251 | 108 | 267 | 1.3P | 0.5S |
| 45°R | 5.4 | 2.9 | 220 | 92 | 224 | 1.3P | 0.4S |
| 15°R | 11.0 | 8.6 | 385 | 231 | 486 | 4.1P | 0.5S |
| 25°R | 11.3 | 7.6 | 291 | 140 | 338 | 3.8P | 0.6P |
| 35°R | 11.1 | 6.5 | 270 | 122 | 290 | 4.0P | 0.2P |
| 25°R | 16.9 | 11.9 | 327 | 158 | 352 | 8.7P | 0.6P |
| 35°R | 17.5 | 9.8 | 291 | 127 | 296 | 9.4P | 1.1P |
| 45°R | 17.1 | 8.2 | 294 | 116 | 258 | 8.6P | 0.9P |

*Values represent the change from the average heel angle recorded on the approach to each run.

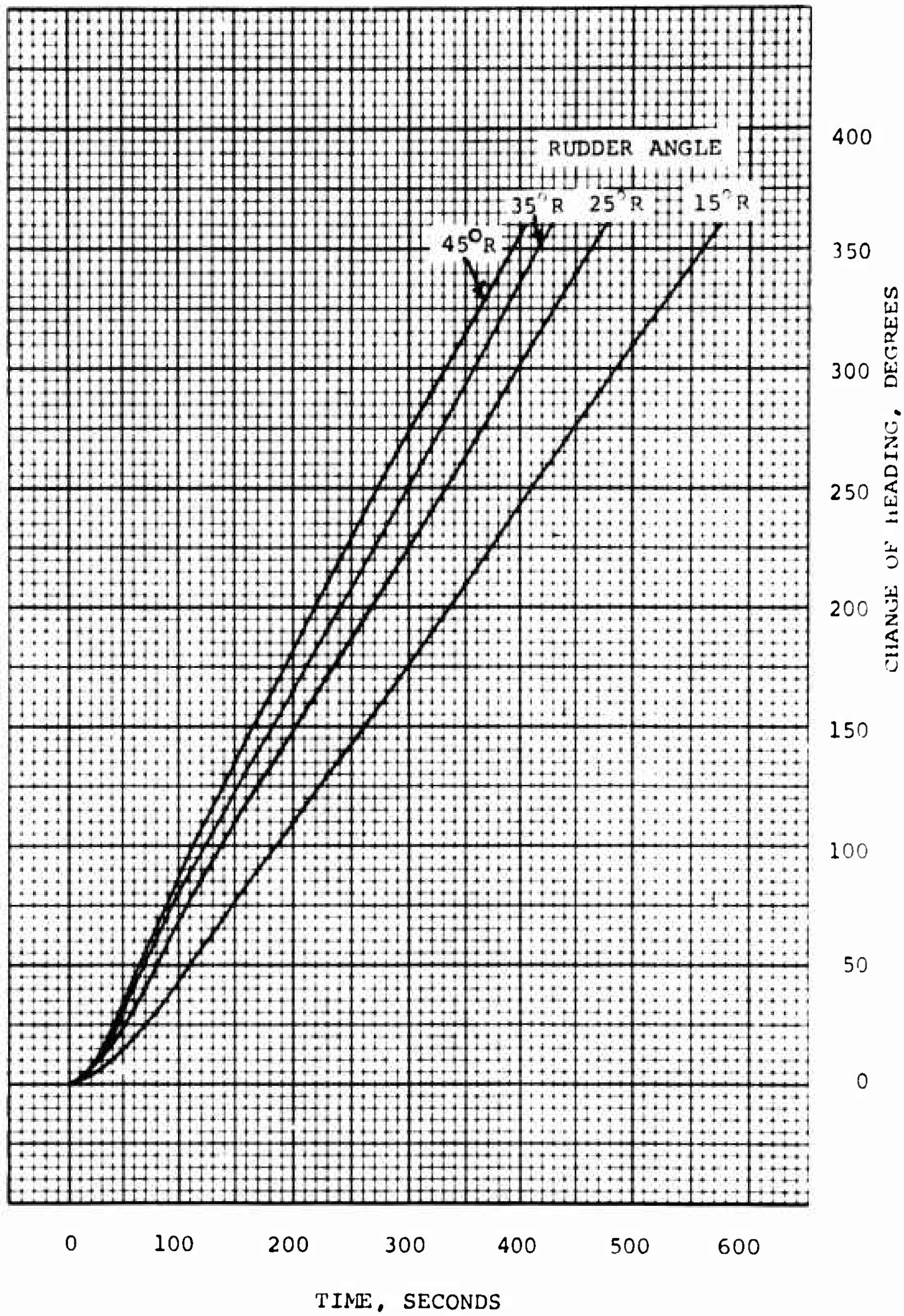



Figure 3 - Curves of Change of Heading Against Time, ominal Approach Speed 5.5 Knots

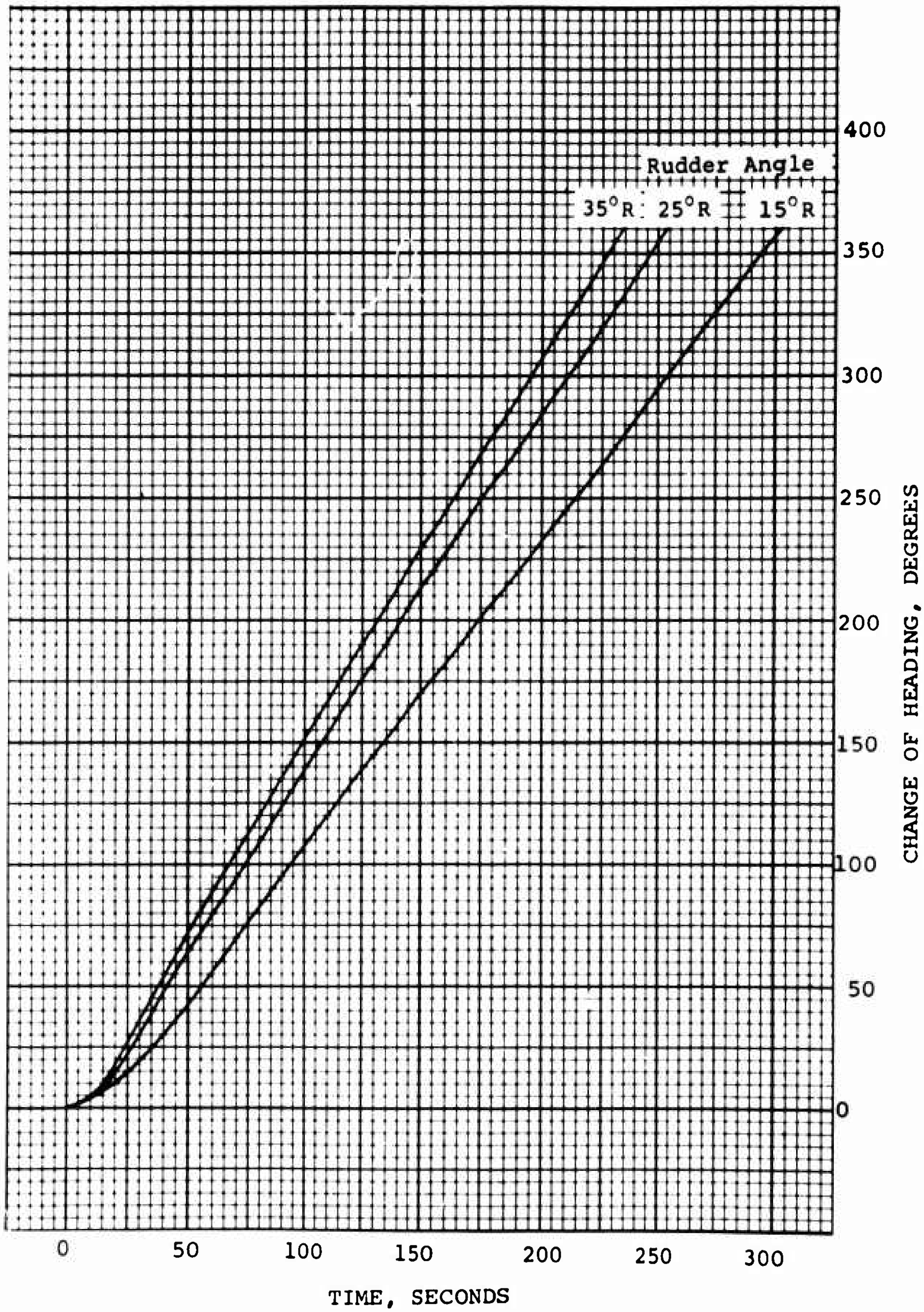



Figure 4 - Curves of Change of Heading Against Time, Nominal Approach Speed 11.0 Knots

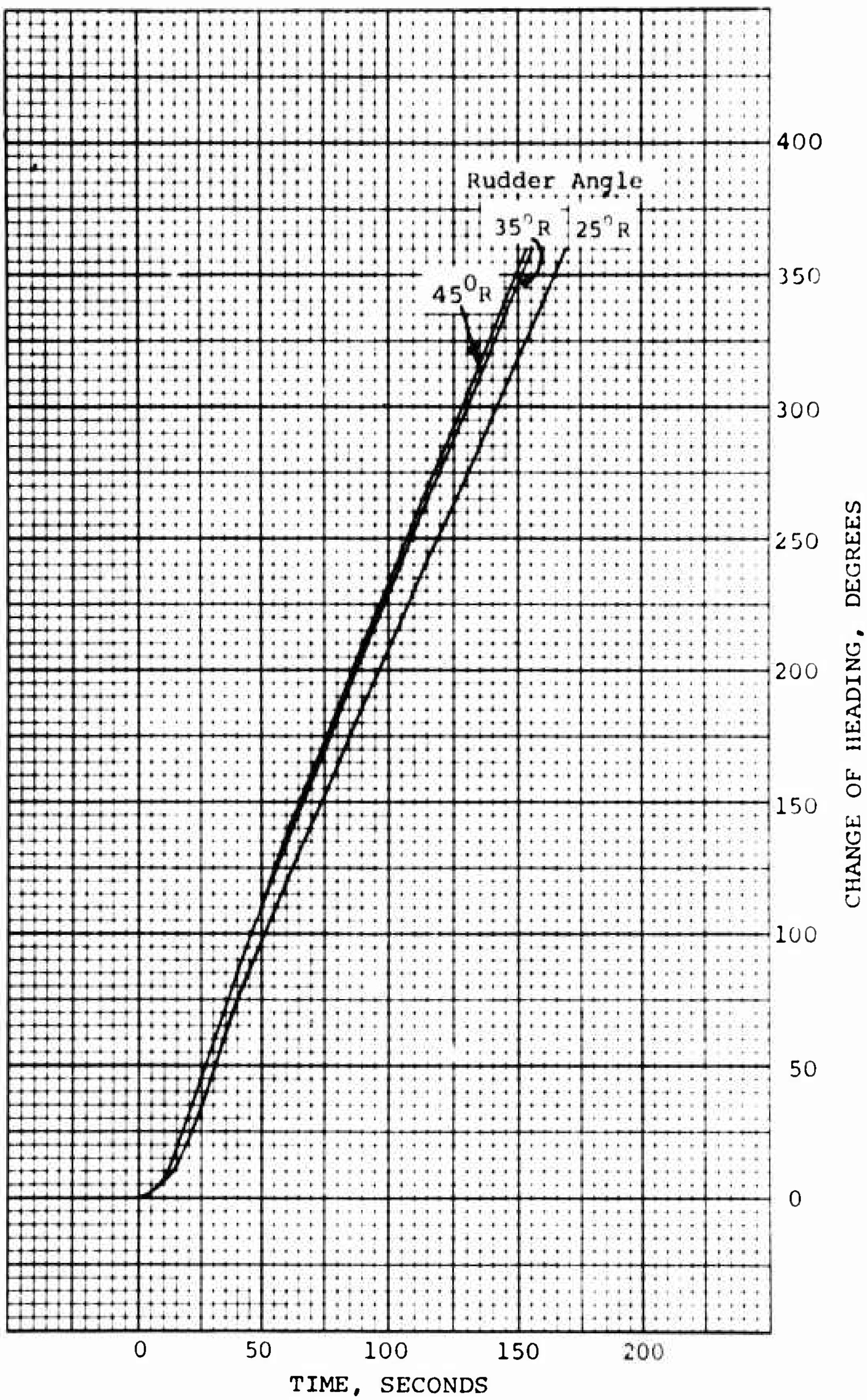



Figure 5 - Curves of Change of Heading Against Time, Nominal Approach Speed 17 Knots

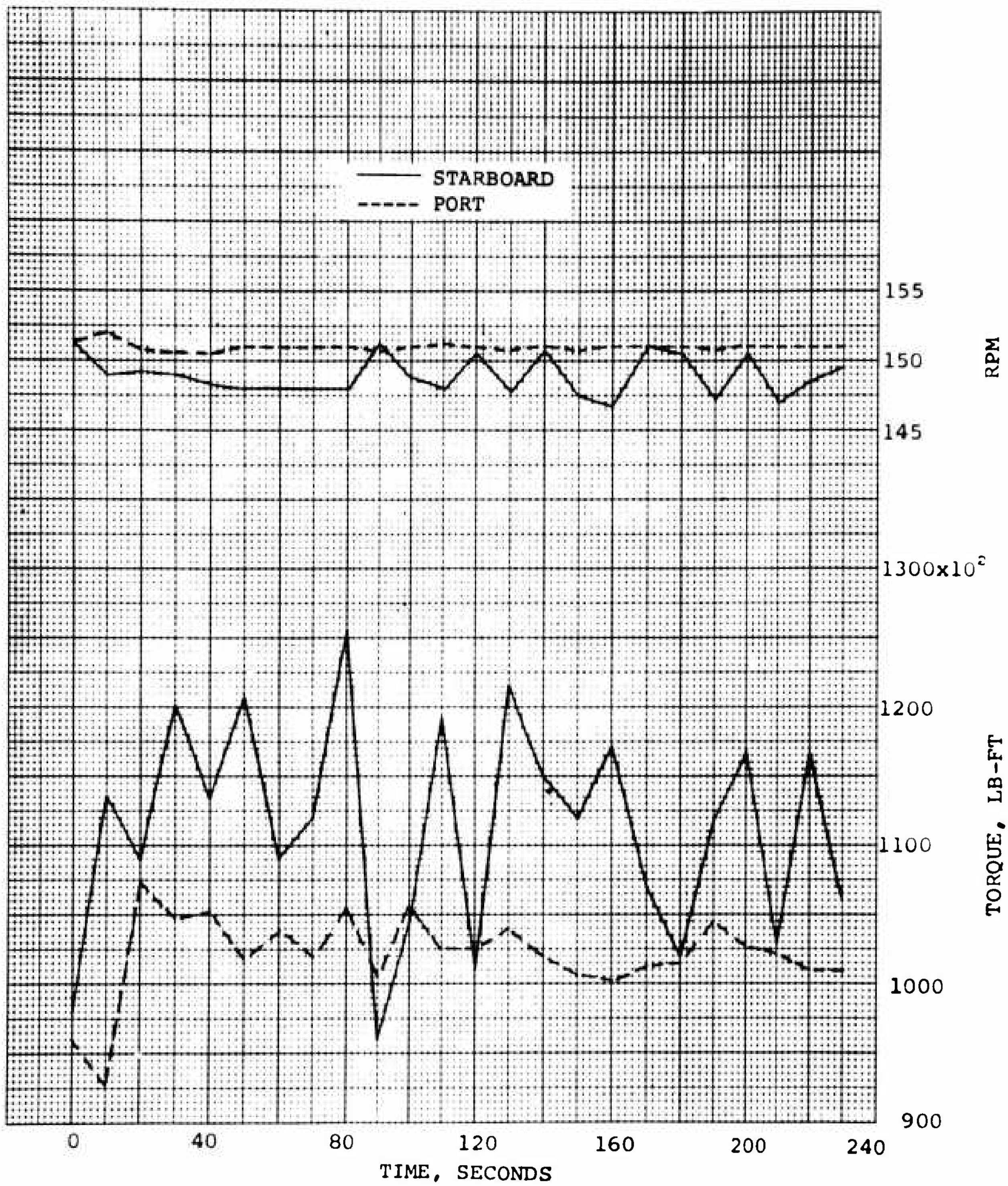



Figure 6 - Machinery Data Recorded During the Full Power Turning Circle Using 45 Degrees Right Rudder

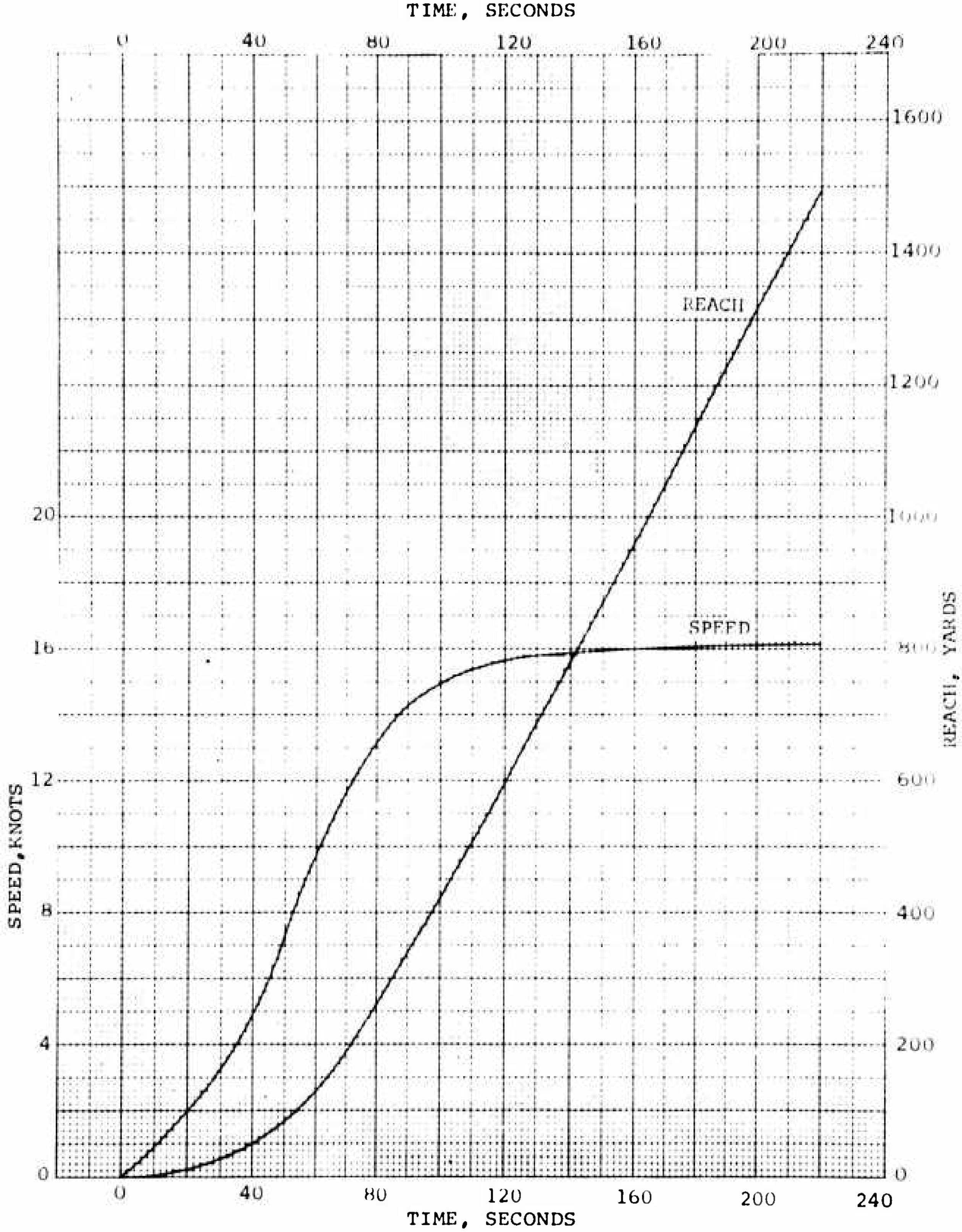



Figure 7 - Acceleration Run - Dead in the Water to Full Power Ahead

TABLE 4 - ACCELERATION AND DECELERATION DATA SUMMARY

Acceleration Run

| Approach Speed Knots | Approach RPM Port/STBD | Duration of Run Sec | Ahead Power | Maximum Speed Knots | Distance Traveled Yards |
|---|---|---|---|---|---|
| 0 | 0 | 220 | Full | 16.15 | 1495 |

Deceleration Run

| Approach Speed Knots | Approach RPM Port/STBD | Duration of Run Sec | Ahead Power | Astern Power | Reach Yards |
|---|---|---|---|---|---|
| 14.6 | 120/120 | 80 | Half | Half | 325 |
| 14.1 | 120.3/120.3 | 70 | Half | Full | 280 |
| 16.1 | 150.4/150.2 | 67 | Full | Full | 290 |

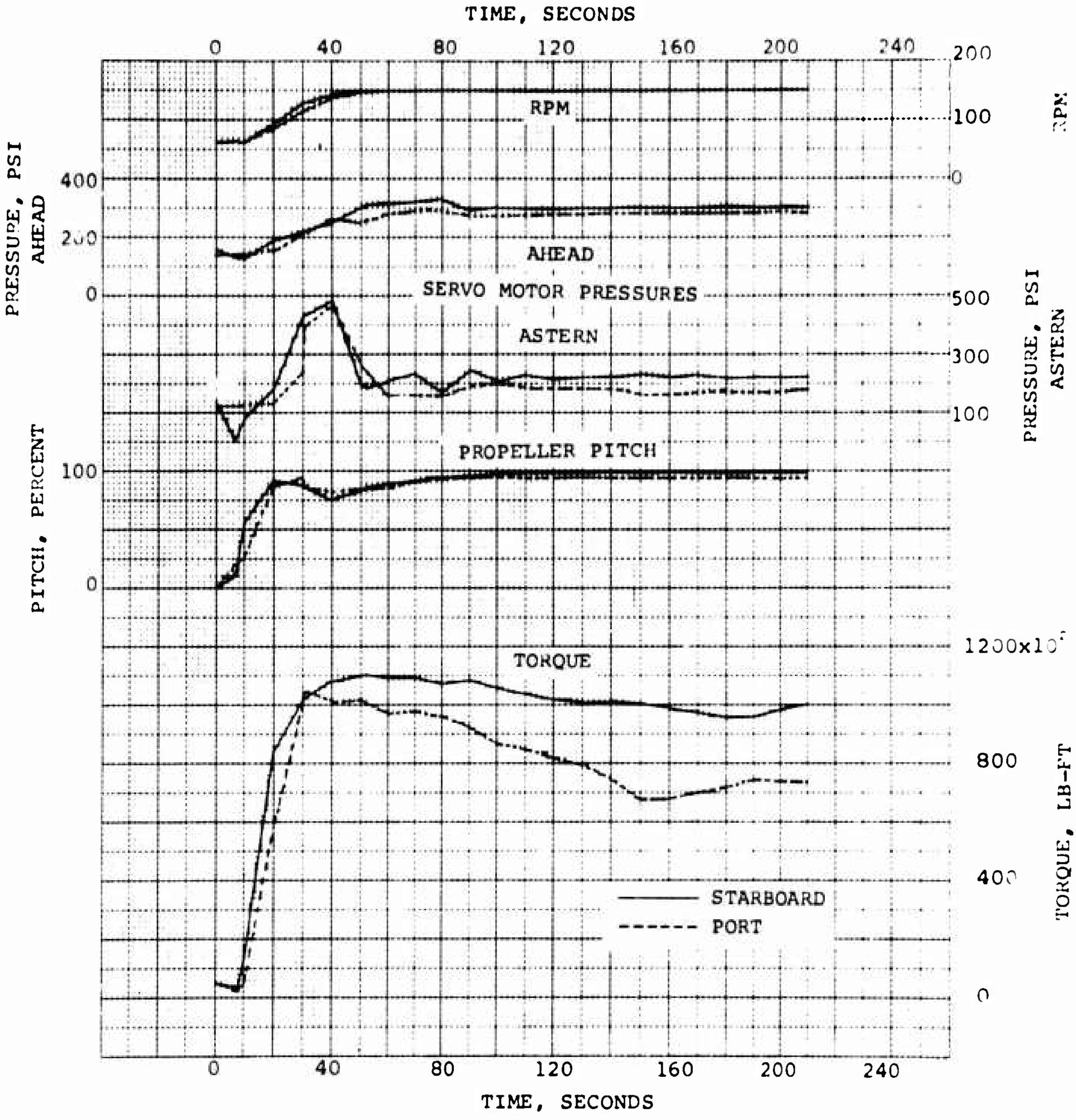



Figure 8 - Machinery Data Recorded During the Acceleration Run From Dead in the Water to Full Power Ahead

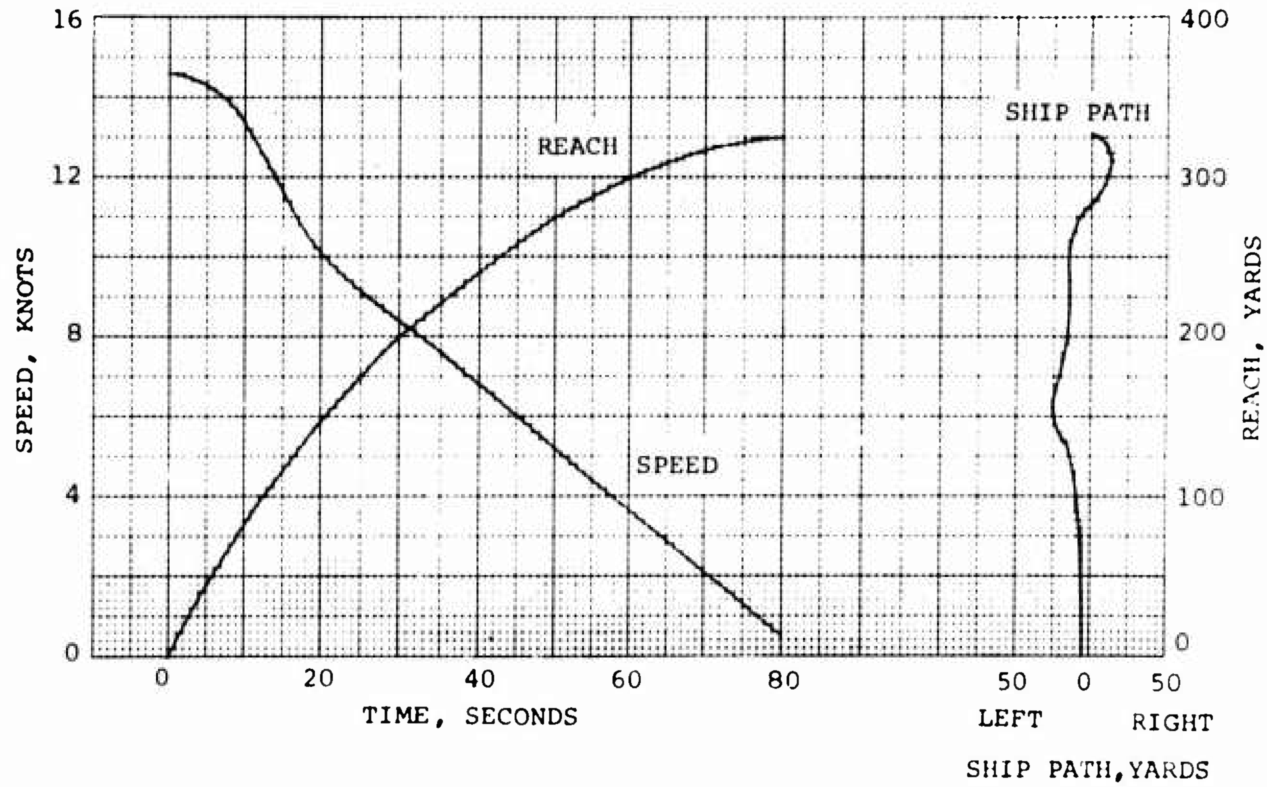



Figure 9 - Deceleration Run - Half Power Ahead to Half Power Astern, Approach Speed 14.6 Knots

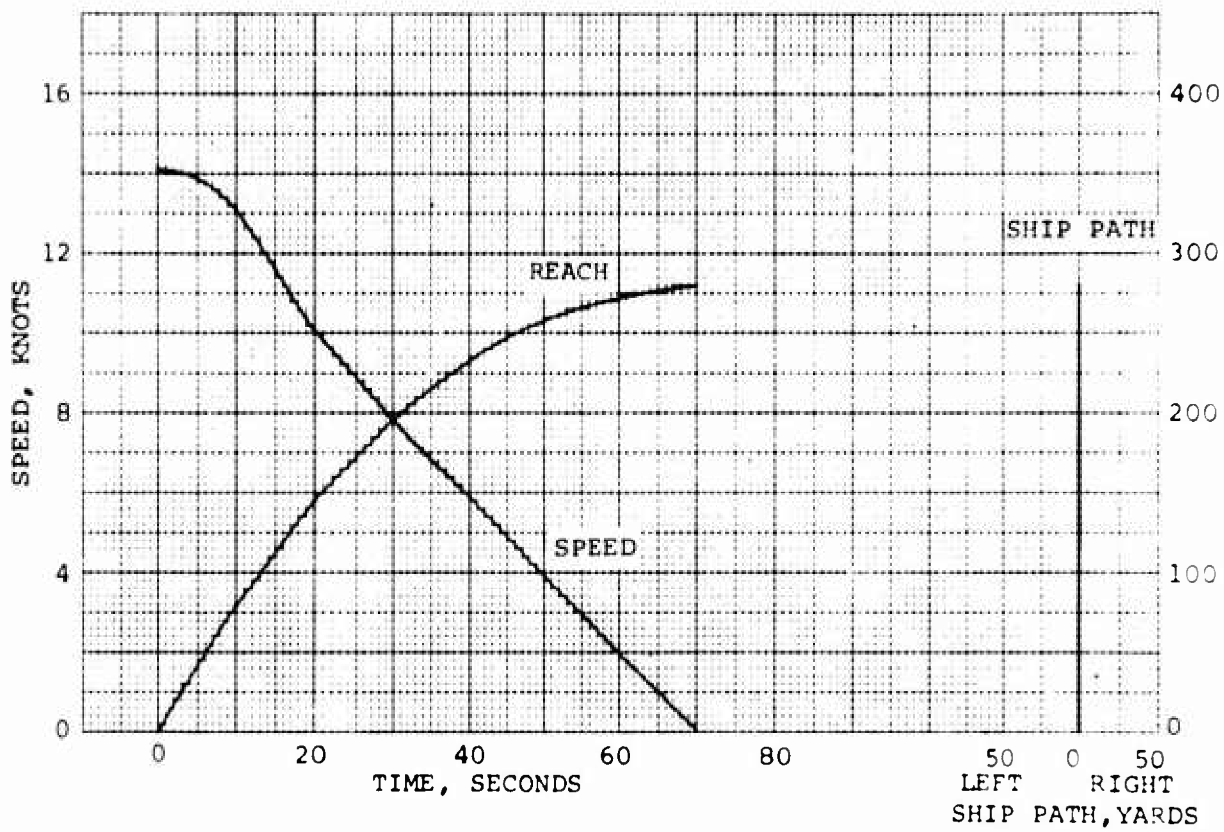



Figure 10 - Deceleration Run - Half Power Ahead to Full Power Astern, Approach Speed 14.1 Knots

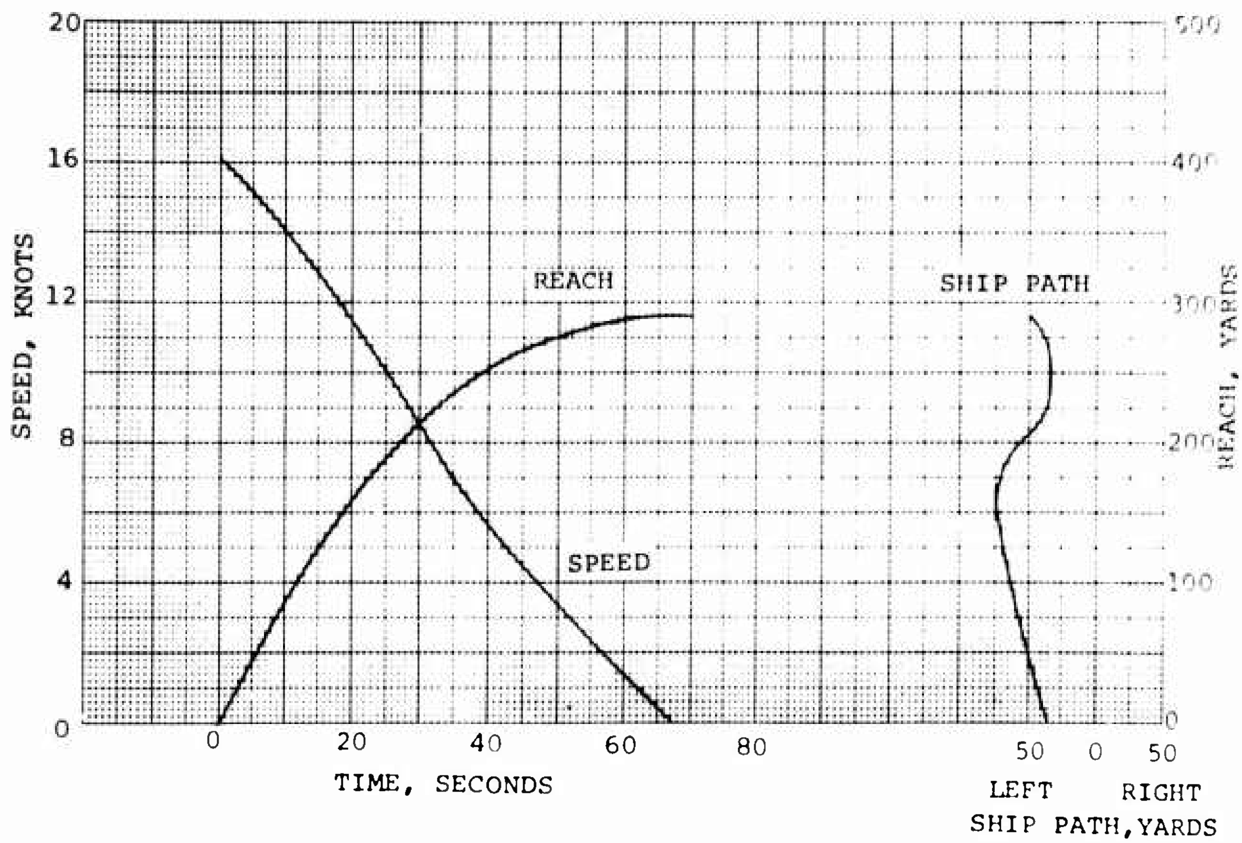



Figure 11 - Deceleration Run - Full Power Ahead to Full Power Astern, Approach Speed 16.1 Knots

power ahead to half power astern have not been plotted because the data were erratic and did not yield meaningful results. The reach data shown on the curves were determined by projecting the ships path to the corrected base course. The reach is the distance the ship travels from execute time to the time it becomes dead in the water as measured along the base course. The total distance traveled by the ship may be determined from the actual path of the ship as shown in Figures 9, 10 and 11. Table 4 presents information regarding measurements derived from these maneuvers. Measurements of RPM, torque, propeller pitch, and ahead and astern servo motor pressures were recorded during the deceleration runs. Figures 12 through 15 present the results of these recordings plotted against time for each shaft. The port shaft is indicated by dashed lines and the starboard shaft is indicated by solid lines.

## SPIRAL MANEUVERS

A spiral maneuver was conducted at 11 knots ahead. An astern spiral was attempted at 2/3 astern, but the ship failed to respond to rudder movement and the astern spiral was discontinued.

The ahead spiral maneuver was started after the ship was steady on course at the scheduled speed; throttle settings were not changed during the run. At execute the rudder was moved to 15 degrees right and held until the rate of change of heading became constant. The rudder was then eased to 10 degrees right and held until the rate of change of heading was again constant. This procedure was repeated for subsequent rudder angles of 7°R, 5°R, 2°R, 0°, 2°L, 5°L, 7°L, 10°L, 15°L, and back to 15°R in the reverse order.

The results of the spiral maneuver are plotted as rate of change of heading versus rudder angle in Figure 16. At 11 knots EDENTON is directionally stable as indicated in Figure 16.

## SWINGING TESTS

The main purpose of these tests was to determine the turning rates when using the bow thruster and to demonstrate the capability of the bow thruster to initiate, maintain, and reverse swings. Turning moments were created by using the bow thruster only, the main propulsion engines only, and a combination of both so that a comparison of the turning rates could be made.

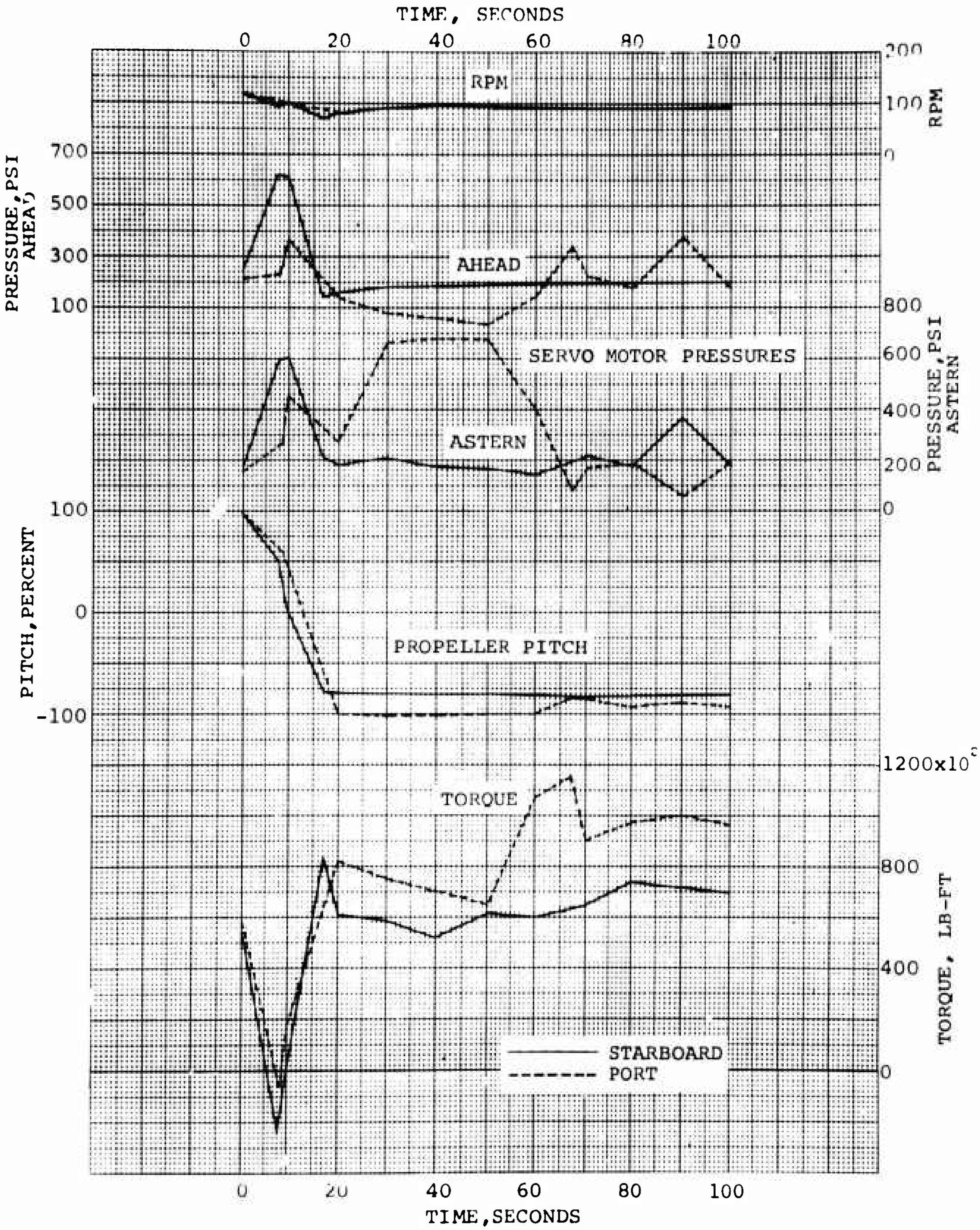



Figure 12 - Machinery Data Recorded During the Deceleration Run From Half Power Ahead to Half Power Astern, Approach Speed 14.6 Knots

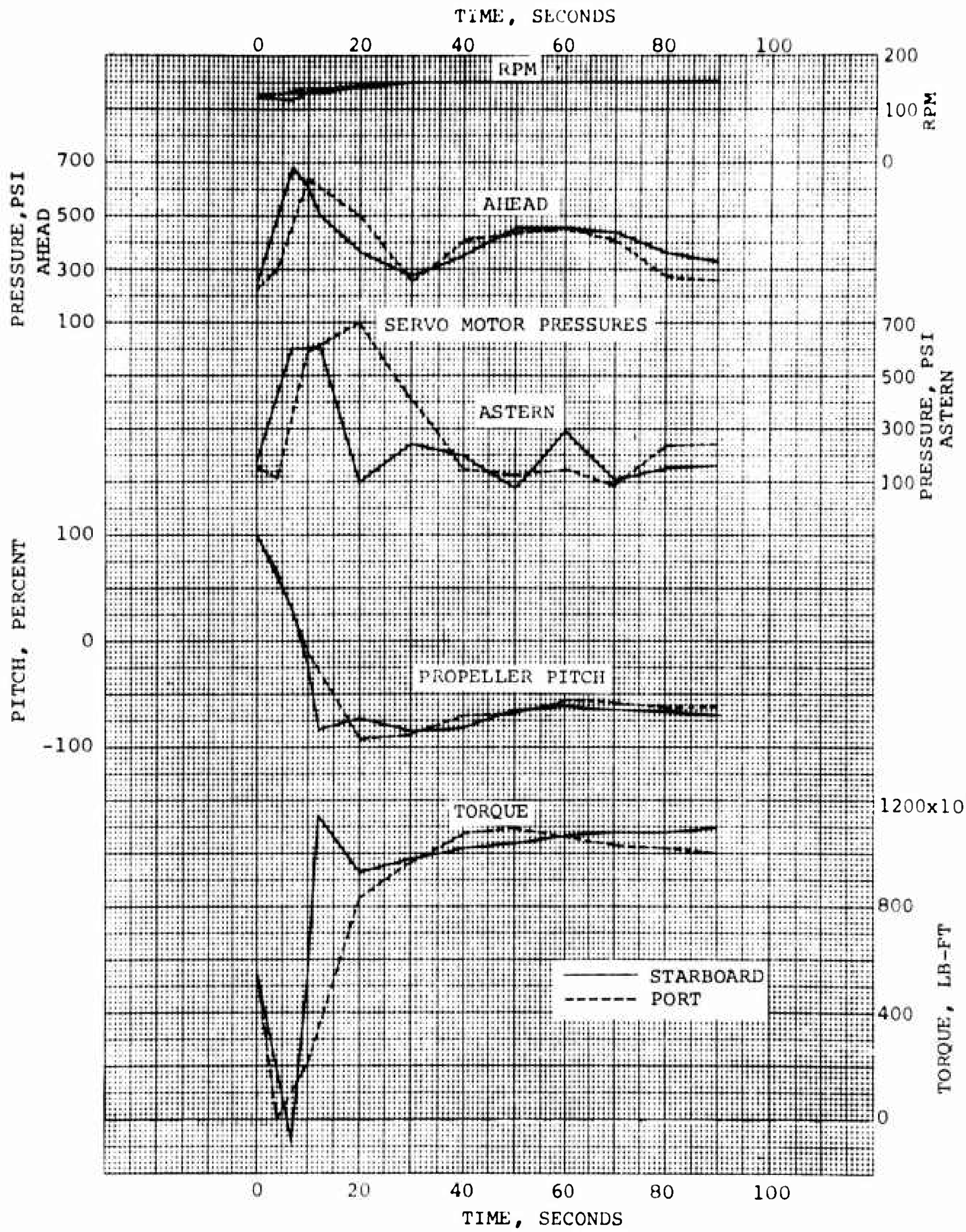



Figure 13 - Machinery Data Recorded During the Deceleration Run From Half Power Ahead to Full Power Astern, Approach Speed 14.1 Knots

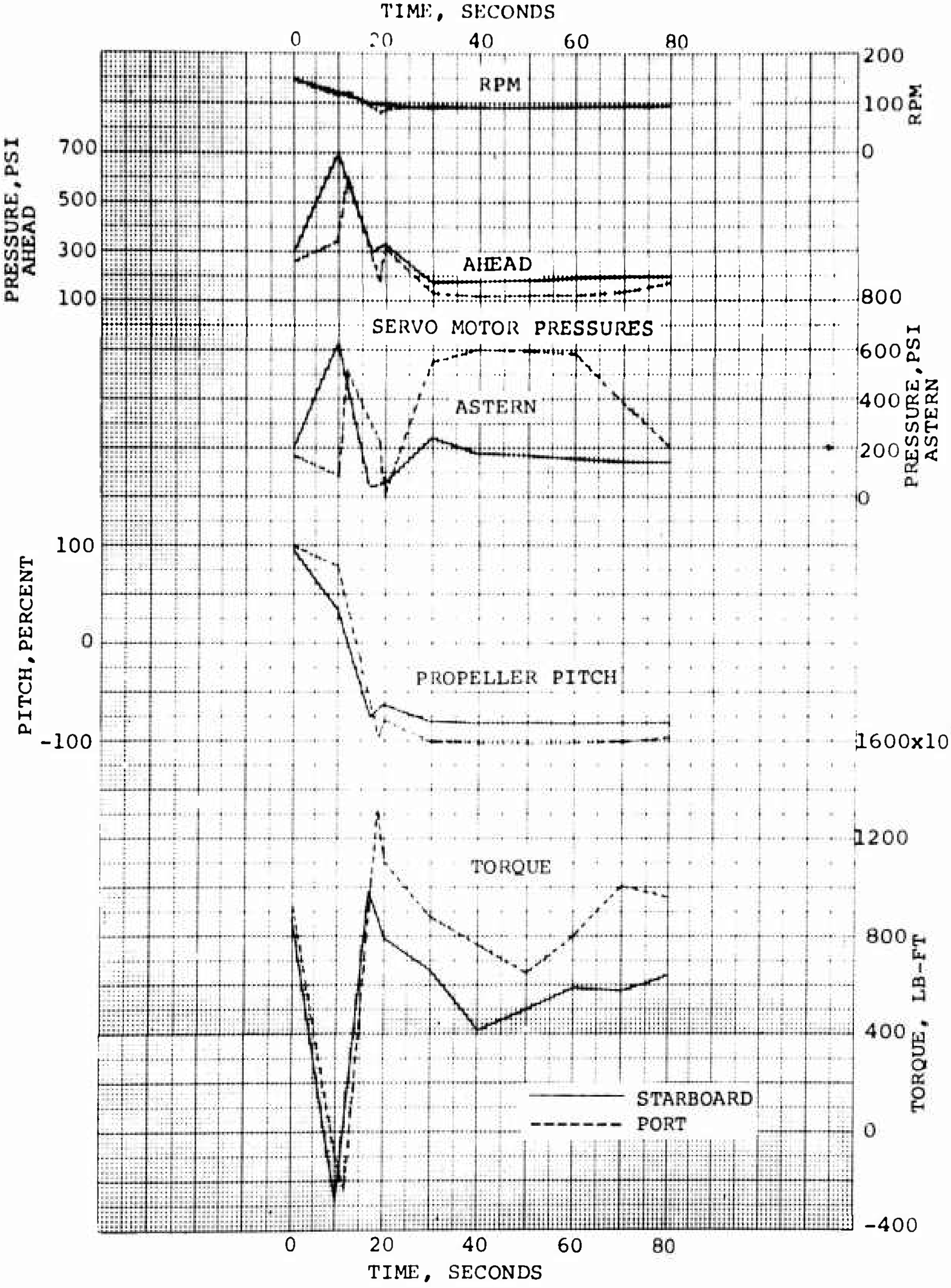



Figure 14 - Machinery Data Recorded During the Deceleration Run From Full Power Ahead to Half Power Astern, Approach Speed 17 Knots

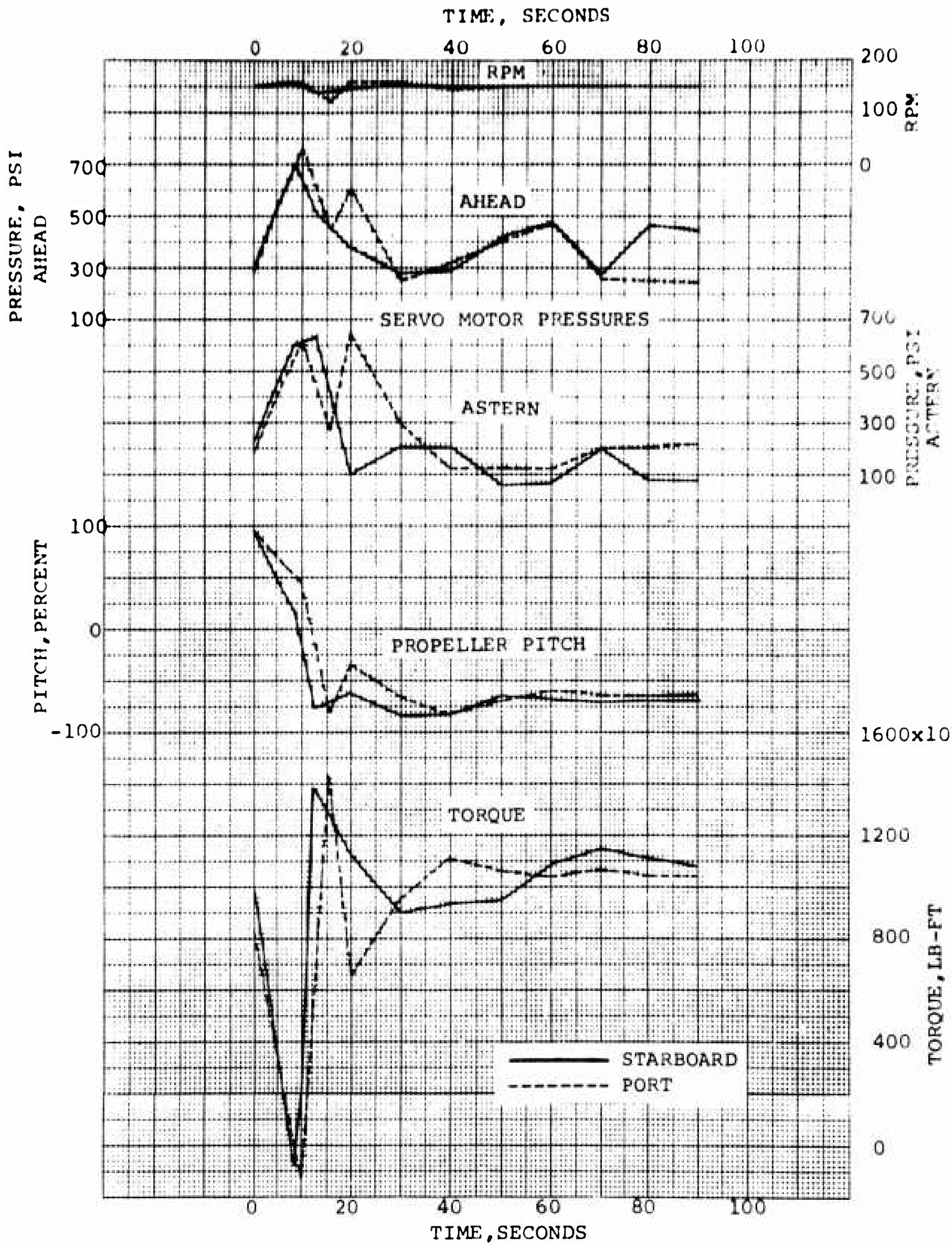



Figure 15 - Machinery Data Recorded During the Deceleration Run From Full Power Ahead to Full Power Astern, Approach Speed 16.1 Knots

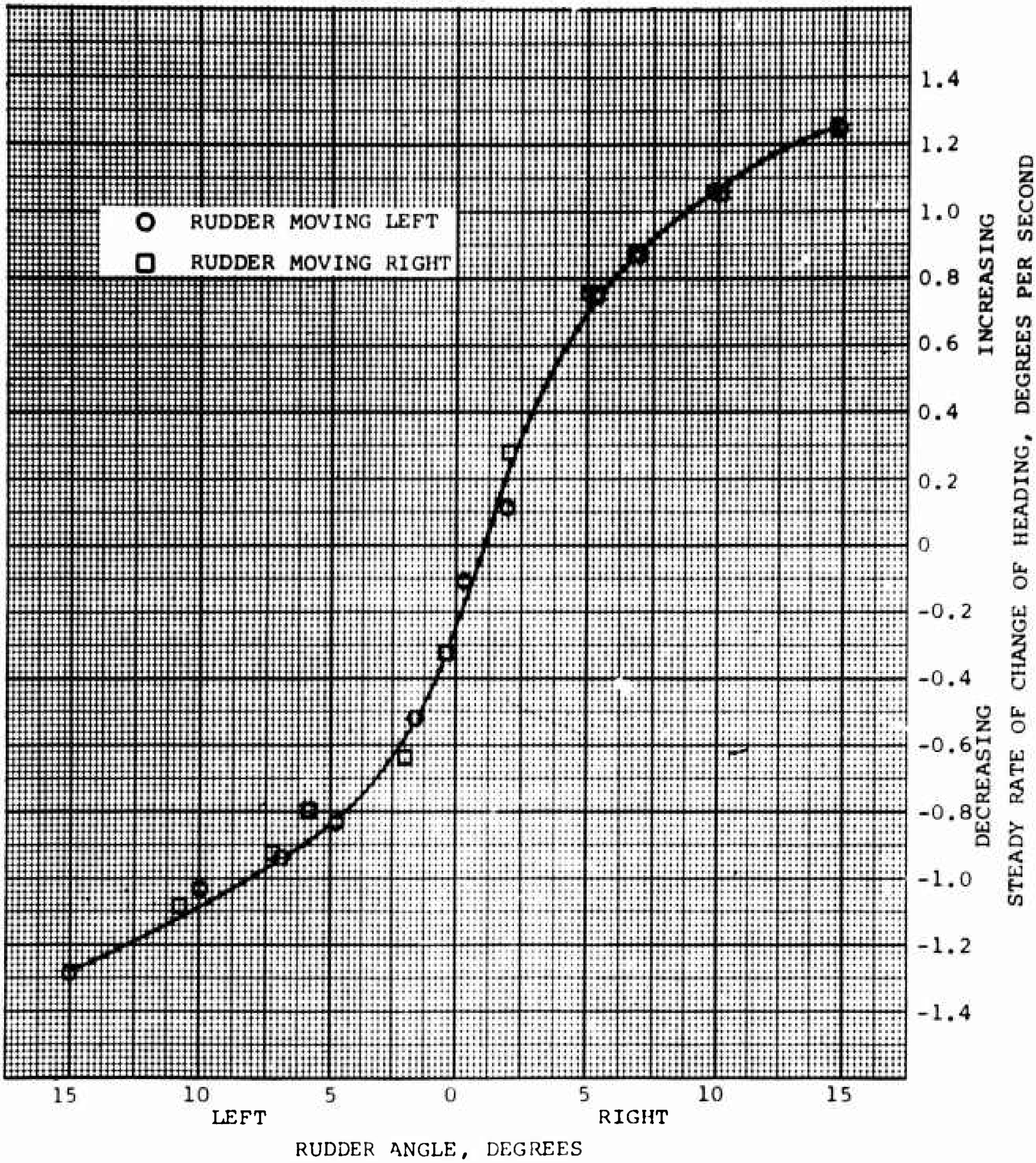



Figure 16 - Ahead Spiral Maneuver - Nominal Approach Speed 11.0 Knots

Ten swinging maneuvers were conducted with the ship at 3200 tons displacement and 0 degrees trim angle. The draft of the ship was 15 feet - 5 inches, and the bow thruster tunnel was submerged 6 feet - 9 inches. The tests were conducted in water having an average depth of 113 feet. Wind and current were negligible and had no adverse effect on the operation of the ship during the maneuvers.

The tests were conducted with the ship dead in the water and underway at various speeds with the rudder held at 0 degrees. A turning moment was applied initially for a period of 240 seconds to swing the ship, then the turning moment was reversed for 480 seconds. The turning moment was reversed again and held 240 seconds. Full bow thruster power, as indicated by the bridge control unit, was applied when the bow thruster was used. When the main engines were used, full ahead power was ordered on one shaft and full astern power was ordered on the other shaft to create the turning moments. Table 5 is a list of the swinging tests and the corresponding figure numbers used to present the results.

Figure 17 presents the results of swinging tests using the bow thruster only with the ship operating at speeds of 0, 3, 6, and 8 knots. These curves show that the bow thruster can be used to swing the ship and to reverse the direction of swing when the ship is dead in the water and underway at speeds up to 6 knots. The effectiveness of the bow thruster is reduced considerably when the ship is operating at 8 knots. The 8-knot curve of Figure 17 shows that during the first 240 seconds of the run, the heading changed about 45 degrees. During the next 480 seconds, the heading was reversed with the thruster, and the ship swung at a steady rate of approximately 0.6 degrees per second. After the third execute of the thruster at 720 seconds, the rate of change of heading was reduced, but the ship continued to swing in the same direction during the last 240 seconds of the maneuver. The shape of the curve, however, indicates that a course reversal would have been accomplished had the thruster power been applied for a longer period of time.

The results of swinging tests using propulsion engine reversals to create the swinging moment are shown in Figure 18. These tests were run at the same initial ship speeds as the bow thruster tests. A comparison of Figures 17 and 18 shows that at 0 knots, a slightly higher turning rate was obtained with the main engines between 240 and 720 seconds as compared to that when using the bow thruster. During the initial swing (0-240 seconds) and the final swing

TABLE 5 - LIST OF SWINGING TESTS

| Figure No. | Speed Knots | Rudder Angle | Thruster* Power | STBD Engine | Port Engine | Time of Swing-sec |
|---|---|---|---|---|---|---|
| 17 | 0 | 0 | FP-Stbd | Stopped | Stopped | 240 |
| | | | FP-Port | Stopped | Stopped | 480 |
| | | | FP-Stbd | Stopped | Stopped | 240 |
| 18 | 0 | 0 | 0 | Full Astern | Full Ahead | 240 |
| | | | 0 | Full Ahead | Full Astern | 480 |
| | | | 0 | Full Astern | Full Ahead | 240 |
| 19 | 0 | 0 | FP-Stbd | Full Astern | Full Ahead | 240 |
| | | | FP-Port | Full Ahead | Full Astern | 480 |
| | | | FP-Stbd | Full Astern | Full Ahead | 240 |
| | | | | (Approach RPM) | | |
| 17 | 3 | 0 | FP-Stbd | 64 Shaft RPM | | 240 |
| | | | FP-Port | | | 480 |
| | | | FP-Stbd | | | 240 |
| 17 | 6 | 0 | FP-Stbd | 67 Shaft RPM | | 240 |
| | | | FP-Port | | | 480 |
| | | | FP-Stbd | | | 240 |
| 17 | 8 | 0 | FP-Stbd | 69 Shaft RPM | | 240 |
| | | | FP-Port | | | 480 |
| | | | FP-Stbd | | | 240 |
| 18 | 3 | 0 | 0 | Full Astern | Full Ahead | 240 |
| | | | 0 | Full Ahead | Full Astern | 480 |
| | | | 0 | Full Astern | Full Ahead | 240 |
| 18 | 6 | 0 | 0 | Full Astern | Full Ahead | 240 |
| | | | 0 | Full Ahead | Full Astern | 480 |
| | | | 0 | Full Astern | Full Ahead | 240 |
| 18 | 8 | 0 | 0 | Full Astern | Full Ahead | 240 |
| | | | 0 | Full Ahead | Full Astern | 480 |
| | | | 0 | Full Astern | Full Ahead | 240 |
| 19 | 3 | 0 | FP-Stbd | Full Astern | Full Ahead | 240 |
| | | | FP-Port | Full Ahead | Full Astern | 480 |
| | | | FP-Stbd | Full Astern | Full Ahead | 240 |

*Stbd indicates thrust to move bow to the right; port indicates thrust to move bow to the left.

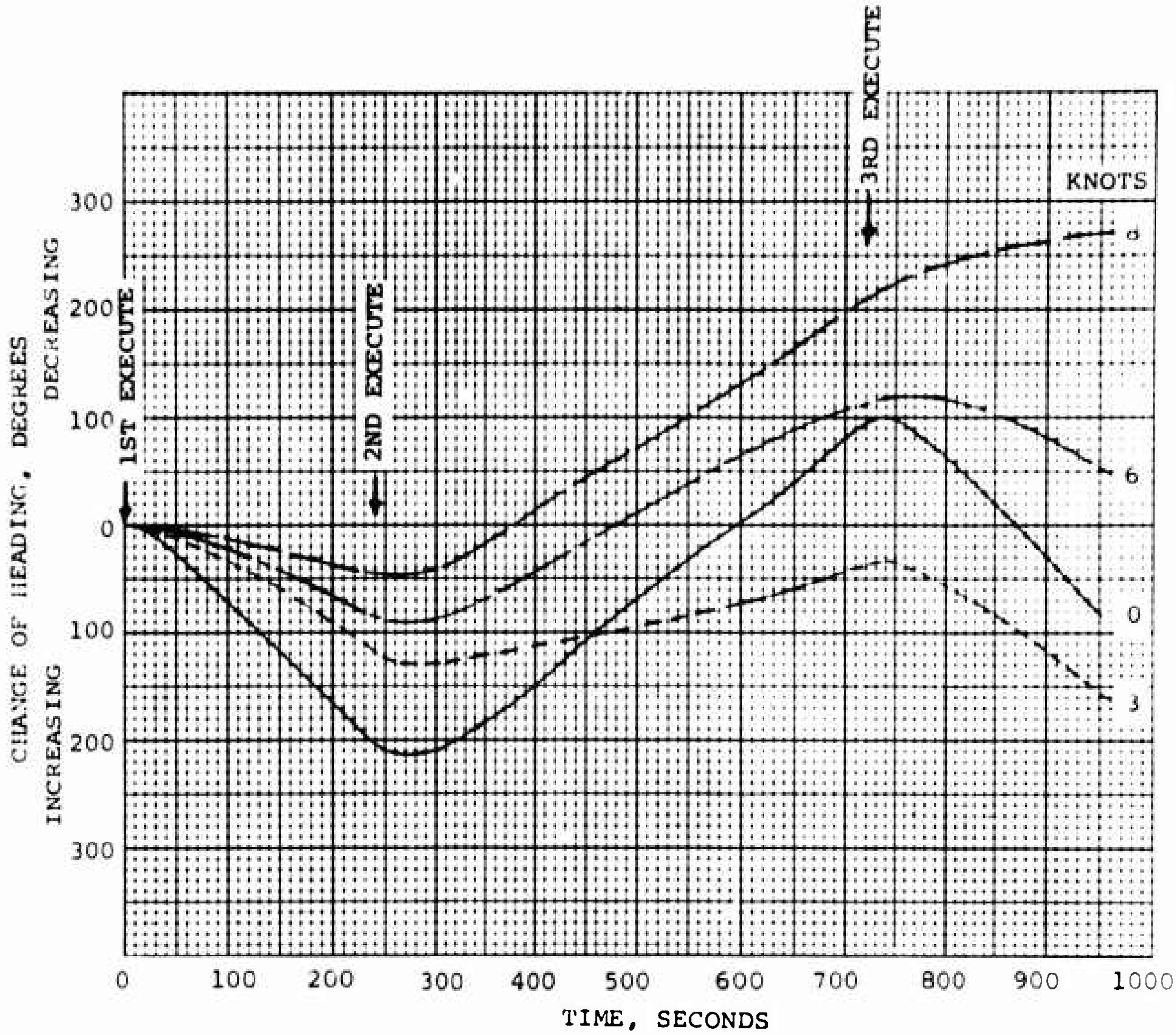



Figure 17 - Change of Heading versus Time Recorded During Swinging Maneuvers Using Bow Thruster Only at Various Ship Speeds

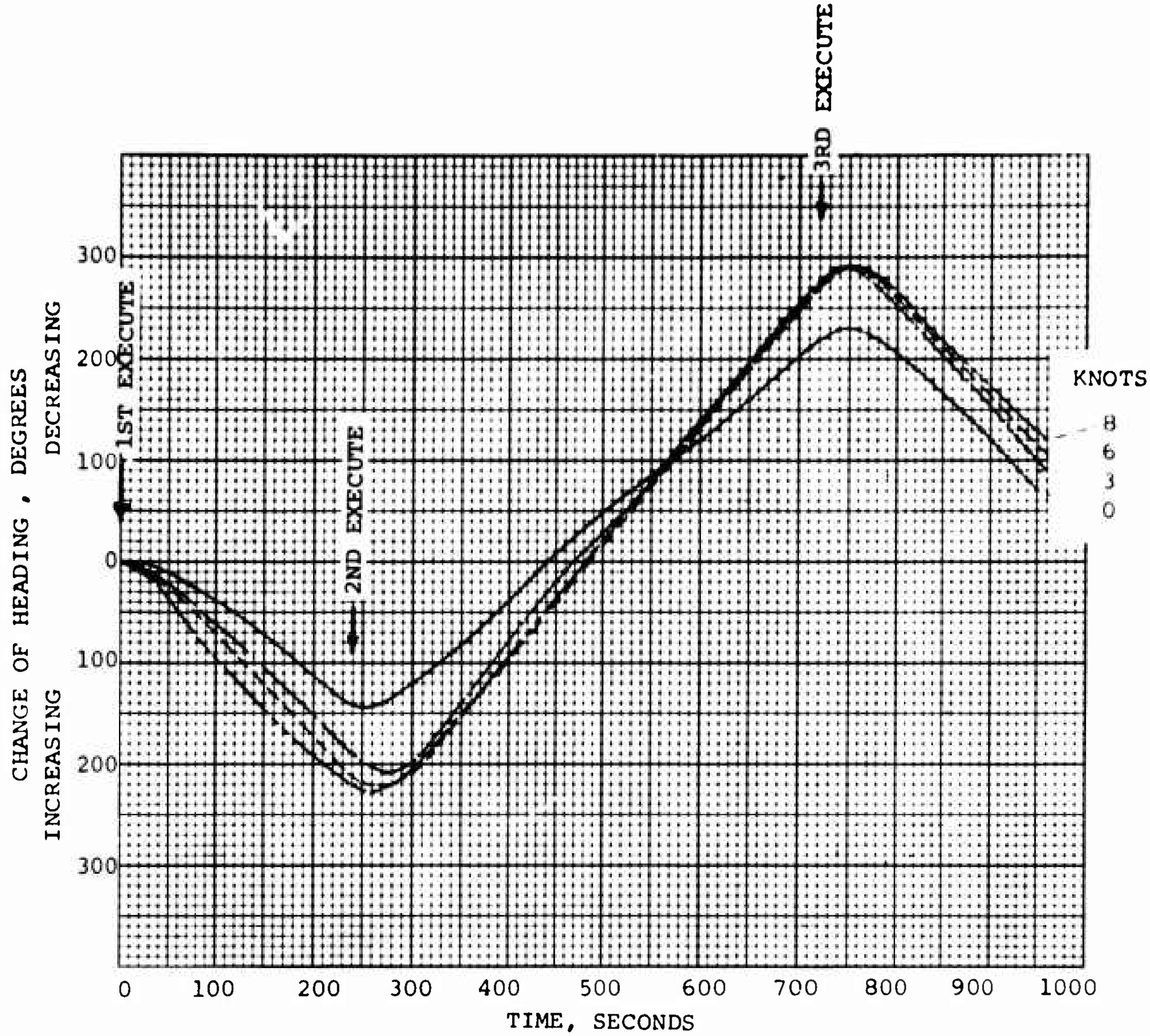



Figure 18 - Change of Heading versus Time Recorded During Swinging Maneuvers Using Main Engines Only at Various Initial Ship Speeds

(720-960 seconds) a slightly higher turning rate was measured when using the thruster. During the maneuvers at approach speeds of 3, 6 and 8 knots, the main engines produced faster turning rates than the thruster.

The results of swinging tests using both the bow thruster and the main engines are shown in Figure 19. These tests were conducted with the ship dead in the water and operating at 3 knots. The data obtained for the combined mode of operation indicate that this is the most effective of the methods tested for creating a swinging moment, particularly when the ship is dead in the water. With the ship operating at 3 knots the use of the bow thruster with the main engines produces slightly higher turning rates than those recorded when only the main engines were used.

## ASTERN CONTROLLABILITY TESTS

Astern controllability tests were conducted at the same displacement, trim, water depth, and sea and weather conditions as the swinging tests. One maneuver was conducted by alternately applying full power to the bow thruster to provide a turning moment while the ship was moving astern at 5 knots. The rudder was held at zero degrees during this maneuver. Thruster power was applied until the ship heading changed 20 degrees off the base course. The thruster was then reversed and held until the heading changed 20 degrees on the opposite side of the base course. Thruster operation was continued in this manner until three course reversals were completed. The results of this maneuver are presented in Figure 20 which shows ship heading plotted against time. This figure shows that the bow thruster is capable of producing course changes when operating at 5 knots astern. It is interesting to note that the amount of overshoot when operating astern is much greater then when operating ahead at speeds up to 6 knots.

Another astern maneuver was attempted at the same speed using 35 degrees rudder in lieu of the bow thruster to control the ship. The ship did not respond to 35 degrees rudder, so a 45-degree rudder maneuver was attempted. The ship appeared to respond to rudder movement at the beginning of the maneuver, but the run had to be terminated due to insufficient maneuvering area.

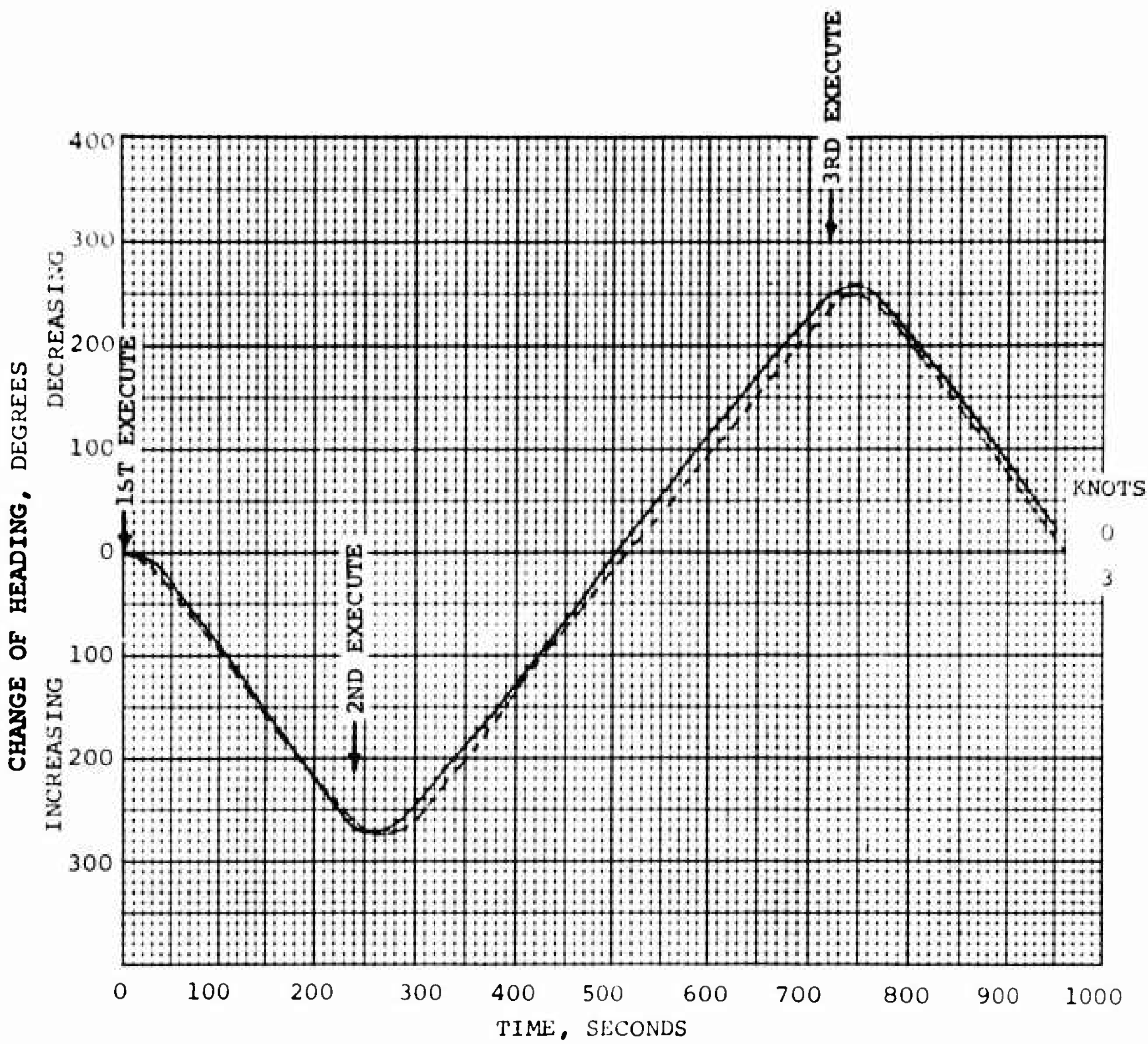



Figure 19 - Change of Heading versus Time Recorded During Swinging Maneuvers Using Bow Thruster and Main Engines at Initial Ship Speeds of 0 and 3 Knots

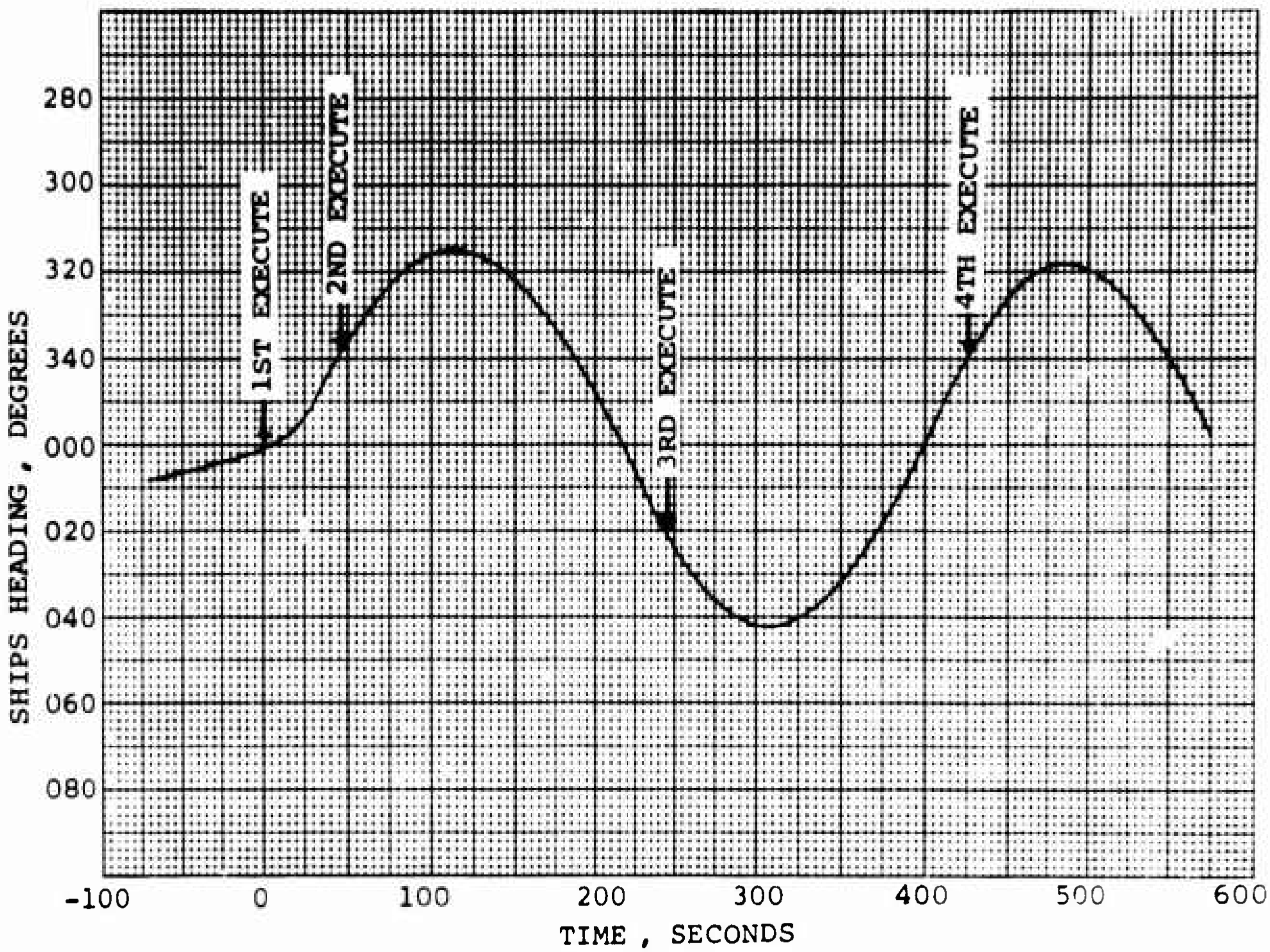



Figure 20 - Ships Heading versus Time Recorded During Astern Controllability Maneuver, Using Bow Thruster at a Ship Speed of 5 Knots Astern

## COMPARISON

The Center has tested no other ships of a similar design that can be compared with USS EDENTON (ATS-1). Such design differences as hull form, rudder area, propeller characteristics, displacement, and propulsion plant distinguish EDENTON from previous designs of the same utility.

## CONCLUSIONS

The results of these trials indicate normal response patterns, and the data reported herein are considered to be valid and representative of the ATS-1 Class. On the basis of these trials, the following conclusions may be drawn concerning the turning and maneuvering characteristics of EDENTON.

1. The results of the turning circles for EDENTON indicate normal turning characteristics in that advance, transfer and tactical diameters increase with increasing speed and decrease with increasing rudder angle. The data are considered valid, and the left turning circles which are not reported herein, were consistent with the right turning circles conducted at the same speeds and rudder angles.

2. EDENTON accelerated from dead in the water to 16 knots in 160 seconds over a distance of 960 yards.

3. The astern stopping pattern is consistent with what would be expected in that the stopping distance is shorter when ordering full power astern than when half power astern was ordered.

4. EDENTON is found to be directionally stable at 11 knots.

5. The bow thruster is capable of generating course changes when operating at speeds up to 6 knots ahead; its effectiveness at 8 knots is reduced considerably. The ship can be controlled with the bow thruster when operating at 5 knots astern. In general, the main engines were more effective in swinging the ship than the bow thruster except when the ship is dead in the water. At zero speed the bow thruster is about as effective as the main engines in creating turning moments. As would be expected, the highest turning rates were recorded when both the main engines and the bow thruster were used to generate the turning moments.

6. EDENTON did not respond to the 5-knot backing controllability test after applying 35° rudder. When backing at 5 knots and applying 45° rudder EDENTON appeared to respond, however the maneuver was not completed because of limited operating area.

# APPENDIX A

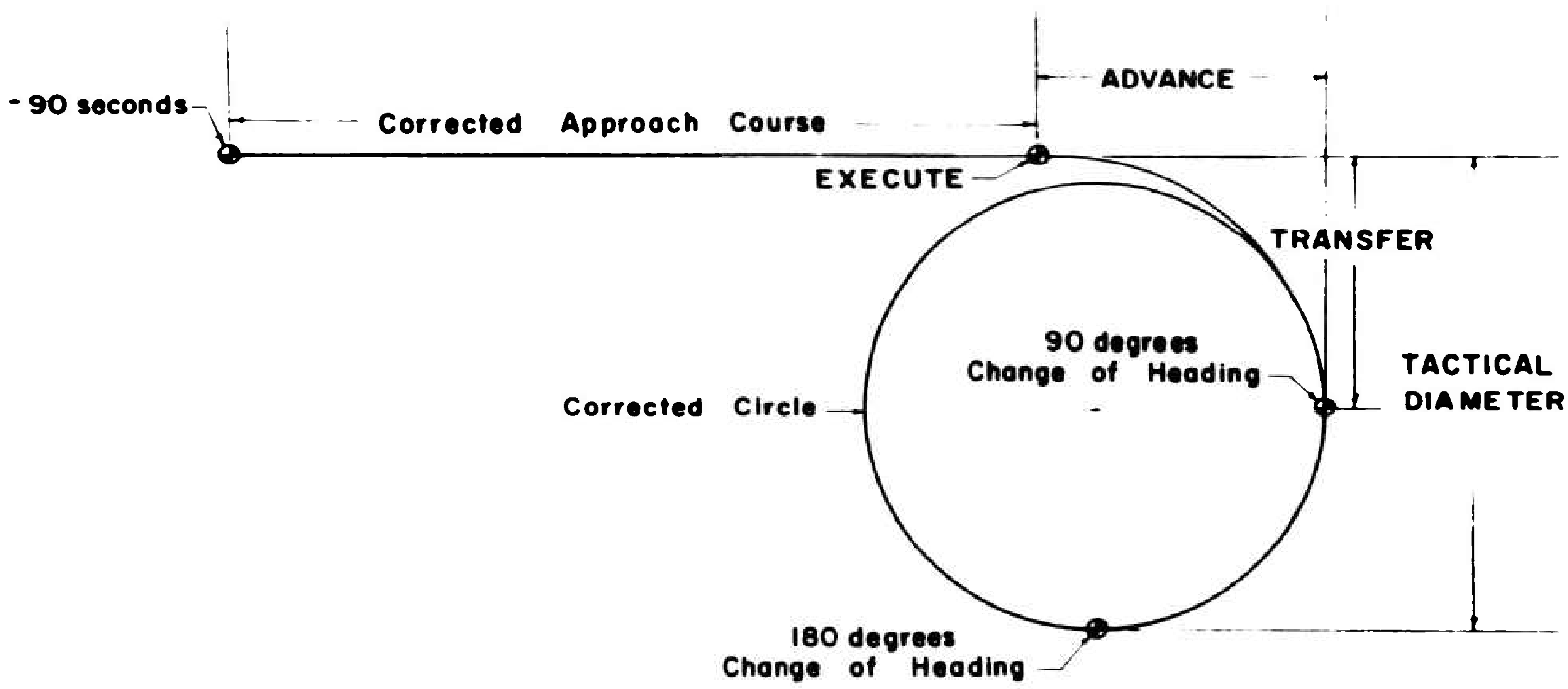



Diagram Showing Measurements Used to Describe a Turning Circle Maneuver

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13. ABSTRACT

This report contains the results of tactical trials conducted on USS EDENTON (ATS-1). The trials consisted of turning circles, acceleration, deceleration, spiral, swinging tests and astern controllability tests conducted at a displacement of 3,200 tons and 0 degrees trim angle. Measurements were made to determine tactical diameters, stopping distances, directional stability, controllability, and maneuvering characteristics. The results show EDENTON has normal turning characteristics, and the ship is directionally stable when operating at 11 knots. The bow thruster is effective in maneuvering the ship when operating at speeds from dead in the water to 6 knots.

| KEY WORDS | LINK A | | LINK B | | LINK C | |
|---|---|---|---|---|---|---|
| | ROLE | WT | ROLE | WT | ROLE | WT |
| USS EDENTON (ATS-1)<br>Tactical and Maneuvering Trials<br>Tactical Diameters<br>Reach<br>Advance<br>Transfer | | | | | | |