NAVY DEPARTMENT

THE DAVID W. TAYLOR MODEL BASIN

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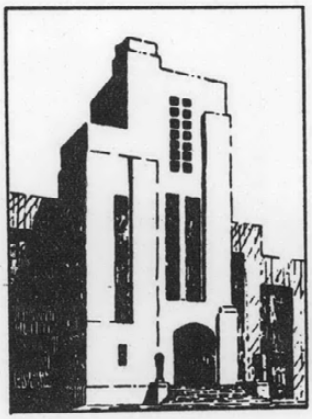
STEERING GEAR PERFORMANCE, BACKING AND TRANSIENT TORQUE TRIALS OF USS RIGEL (AF58)

by

Quentin R. Robinson



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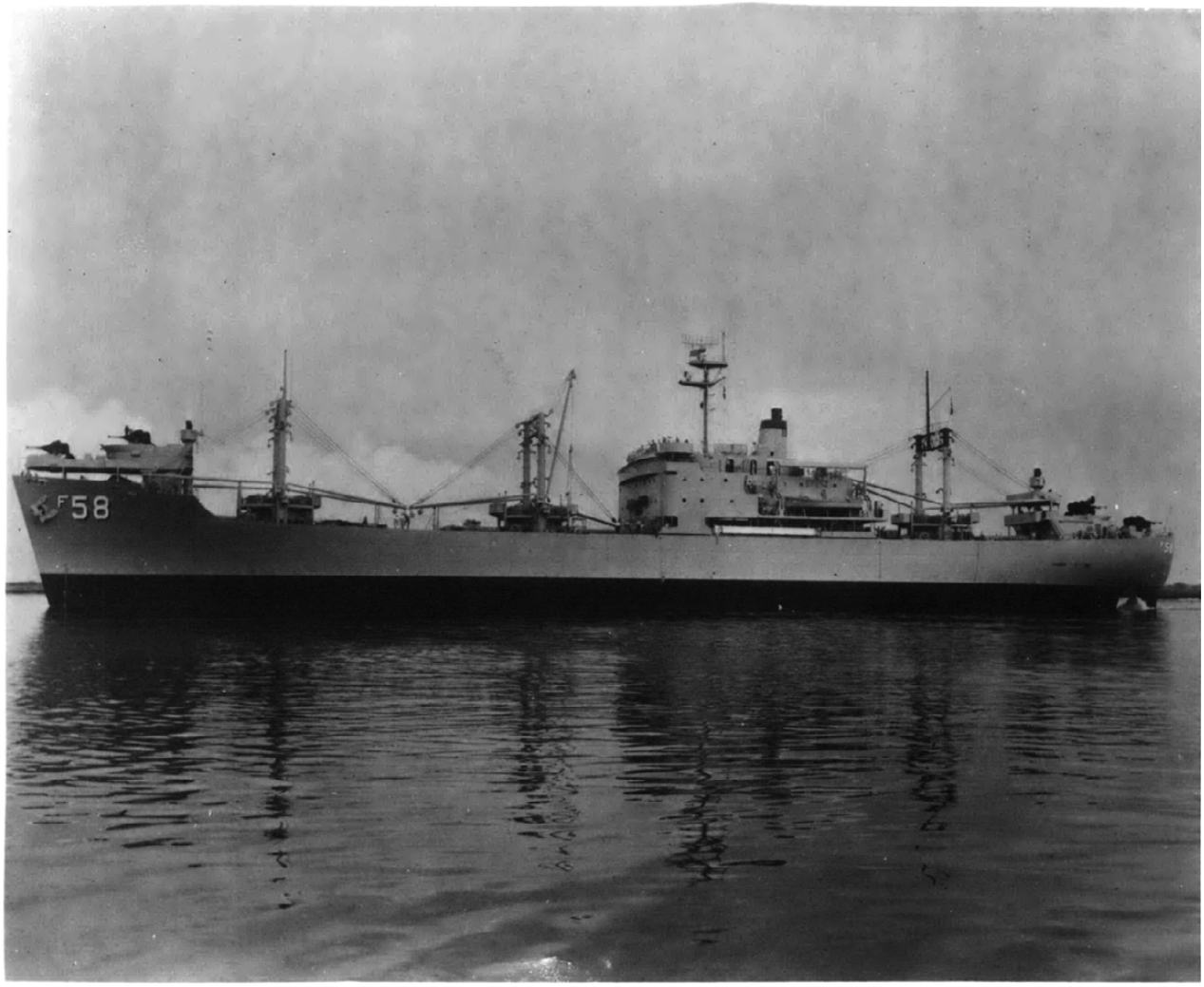

USS RIGEL (AF58)

ABSTRACT

As part of the Special Performance Trials of the USS RIGEL (AF58), tests were conducted to collect data on the performance of the ship's steering gear and on the response of the vessel during various types of turning maneuvers. In addition, torque in the main propulsion shafting was measured during acceleration and deceleration runs, high speed turns, and during steady steaming in the ahead and astern directions. The trials were conducted under favorable operating conditions, and the data are considered to be reliable.

INTRODUCTION

The Special Performance Trials of the USS RIGEL (AF58) as authorized by the Bureau of Ships (1)* were conducted off Guantanamo Bay, Cuba on 29 February and 1 March 1956. The scope of these trials included the collection of data on steering gear performance and turning characteristics of the vessel, on the performance characteristics of the astern turbine, and on the magnitude of transient torque under various operating conditions. The trials were conducted and the results were analyzed by personnel of the David Taylor Model Basin. This report contains the test results and a description of the instrumentation and procedures used in conducting the trials.

INSTRUMENTATION

A block diagram of the shipboard instrumentation is shown in Figure 1. The data measured in the study of the steering gear were the rudder ram pressure, rudder angle, and ship's heading. Shaft torque and speed, boiler water level, ship's speed, and distance were measured during the astern turbine tests.

The rudder ram pressures were measured with TMB Hydrotelegages. This transducer is a diaphragm type which utilizes a TMB Magnigage as a sensing element. The gages were installed in the hydraulic lines of the rudder rams and were electrically connected to Sanborn Strain Gage Amplifiers. The pressures were recorded on a Sanborn Direct-Writing Recorder.

The TMB Rudder Angle Indicator was used for measuring rudder angles. This device consists of a potentiometer mounted on the shaft of a synchro receiver which was electrically connected to the ship's rudder angle repeater. The amplified signal from the potentiometer was recorded on the Sanborn Recorder.

* References are listed on page 7.

Ship's heading was obtained from a Heading Recorder which is a Navy type 2-Speed Gyro Repeater with a camera attachment. A stop watch was placed adjacent to the repeater dial so that both heading and time were recorded photographically.

Torque in the propulsion shafting was measured by means of a TMB Magnetic Micrometer, MK II (2) and a McNab clamp-on torsionmeter husk. The output of the torsionmeter was fed through a Sanborn DC Amplifier to a Sanborn Recorder to obtain instantaneous values during maneuvering. Torque was obtained from manual readings of the Magnetic Micrometer during the steady steaming runs.

A tachometer generator driven by the propeller shaft provided the means of obtaining instantaneous values of shaft speed. The amplified output of the generator was recorded on the Sanborn Recorder during the maneuvering runs. An electric revolution counter and clocks in the standardization panel were used to determine shaft speed during steady steaming.

The ship's force obtained readings of boiler water level from shipboard equipment. Ship speed and distance were calculated from bearings taken by two shore stations.

TYPES OF TESTS AND TEST CONDITIONS

The data contained in this report are divided into the following groups according to the type of run: normal turns, shifting rudder, astern zig-zag, acceleration and deceleration, transient torque, and steady astern. The individual runs conducted during the trials are listed in Table 1. The dimensions of the ship and the conditions that prevailed during the tests, except the transient torque tests, are listed in Table 2. The transient torque tests were conducted on 8 February 1956 enroute from Norfolk, Virginia to Guantanamo Bay, Cuba at a displacement of 12,300 tons. A brief description of the procedure for conducting each type of test is contained under the heading of the respective test.

NORMAL TURNS

These tests were conducted to determine the turning characteristics of the vessel and to obtain experimental data on the steering gear. In addition to obtaining the elements of the ship's turning path (3) the following items were measured during the normal turning circles: rudder ram pressure, rudder angle, ship's heading, and time.

The vessel is equipped with a single rudder actuated by four hydraulic rams. The pressures of only two rams (port side) were measured since the diagonally opposite rams are hydraulically connected.

The trials project manager acted as the official timer for the runs. Bell signals were sounded every ten seconds, and heading photographs were taken on every bell signal. Continuous records of rudder ram pressure and rudder angle were obtained using the Sanborn Recorder.

The procedure followed in conducting the run was to record the data during a 1-minute approach at which time the ship was to be on steady speed and course. At the end of the approach the "Execute" signal was given for the helmsman to lay the rudder to the designated angle. The rudder was then held in position until the ship completed a 540-degree circle. The engine throttle was not changed during the run.

Normal turns were made at approach speeds ranging from 12 knots to full power at rudder angles of 10, 15, 25 and 35 degrees. The results of the data collected on the steering gear performance are shown in Figures 2 through 22.

Recorded values of ram pressure and rudder angle are plotted on the curves, but the heading data has been converted to indicate the change of heading. The 1-minute approach of each run is not plotted since steady conditions existed; therefore, zero time on each figure represents the time of "Execute". The data are plotted for only a 360-degree change of heading although 540-degree circles were run in order to obtain tactical data.

SHIFTING THE RUDDER

Steering gear data and ship's heading were recorded during these runs utilizing the same instrumentation used for the normal turns. The procedure followed on these runs was to operate the ship at a steady speed with zero rudder angle. On command the rudder was moved as rapidly as possible to a predetermined angle. The run was terminated when the rudder reached the desired angle.

Runs were made at approach speeds of 15 knots, 20 knots, and full power with rudder angles of 25, 30 and 35 degrees right rudder. The results of these tests are shown in Figures 23 through 31. The actual ship's heading, rather than the change of heading, is plotted for these runs to illustrate the direction of swing of the ship.

ASTERN ZIG-ZAG

Steering gear data were also recorded during astern zig-zag maneuvers with the ship operating 1/3, 2/3, and full power astern. At each ship speed the rudder was moved from amidships to 15 degrees right, to 15 degrees left and back to amidships. After the rudder was returned to amidships, similar maneuvers were performed with rudder angles of 25 degrees and 35 degrees. The data obtained during these maneuvers are shown in Figures 32, 33, and 34. The 15-degree portion of the run shown on Figure 33 was missed because of an instrumentation failure. Zero time shown on this figure indicates the "Execute" time for the 25-degree rudder maneuvers.

ACCELERATION AND DECELERATION

The data obtained during the acceleration and deceleration runs were: torque, shaft speed, boiler water level, ship speed, and distance. Each run was preceded by a 1-minute steady-condition approach. At the end of the approach the "Execute" signal was given for the start of the run. Torque and shaft speed data were recorded continuously, and the boiler water level readings and shore station data were taken every ten seconds. Signal bells aboard ship and radio communication with the shore stations provided a means of correlating the data takers.

Two runs were made with the ship accelerating to full power -- one from dead in the water, the other from an approach speed of 12 knots. Deceleration runs were made from approach speeds of full power, 17 knots, and 12 knots.

A deceleration run was made at each approach speed with the engine ordered "Stop" when the "Execute" signal was sounded. A similar run was made at each approach speed with the engine ordered "Back Full."

Figures 35 through 42 show the various data plotted against time. Although data were taken during the approach of each run to insure that steady conditions existed, zero time indicated on the curve represents the time the "Execute" signal was sounded. Torque and shaft speeds are plotted as percentages of design full power values. These values are:

Torque 8.158×10^5 pound feet

Shaft Speed 103 RPM

Boiler water level is plotted in inches above or below the normal boiler water level. Ship speed and distance are plotted in actual values.

TRANSIENT TORQUE

The transient torque tests were conducted to obtain data on torque transients at steady shaft speeds and on torque variations and shaft speed changes during high speed turns. During the steady speed runs the mean torque was obtained from manual readings of the torsionmeter indicator, and the transients were recorded on the Sanborn Recorder. Shaft speeds were obtained by means of an electric revolution counter. The transient data were taken with the rudder amidships. Measurements were made at 5-RPM increments ranging from 25 RPM to 99 RPM.

Figure 43 shows the results of the steady speed tests. The mean torque is plotted as a percentage of design full power torque, and the transient torque is plotted as a percentage of the mean torque measured at each particular shaft speed. Double amplitudes of transient torque were used in the calculation of percentages. The transients are predominately fourth order or blade frequency (four times shaft RPM). It will be noted in the figure that a torsional resonance of the shafting occurs at about 34.5 RPM (138 CPM). Actual measurements were made at shaft speeds of 30.0, 34.5, and 39.4 RPM, and no attempt was made to define the resonance point more definitely.

Continuous recordings of torque and shaft speed were made with the Sanborn Recorder during right and left turns at full power. Heading data were taken every ten seconds during these turns. Figures 44 and 45 show the results of these tests. Both the mean torque and shaft speed are plotted as percentages of design values. The base course is subtracted from each heading reading, and this difference is plotted as change of heading.

STEADY ASTERN

Torque and shaft speed data were taken with the ship running astern at steady speeds with zero rudder angle. The ship operated at each speed for about three minutes during which time ten torsionmeter readings were taken. The average of these readings was used in calculating the torque.

Shaft speed was determined by electric revolution counters. Data were taken at nominal shaft speeds of 20, 40, 50, and 63 RPM.

The results of the steady astern runs are shown in Figure 46 which shows torque, plotted as a percentage of design full power ahead, versus shaft speed.

SUMMARY

The steering gear tests indicate that the ram pressures required to position the rudder are slightly lower for the left rudder maneuvers than for the right rudder maneuvers. For a given ship speed, an increase in the angle to which the rudder is laid requires an increase in the ram pressure to position the rudder as might be expected. Similarly, an increase in ship speed requires an increase in ram pressure to position the rudder to any given angle. The maximum pressures observed ranged from 250 psi for a 12-knot circle at 10 degrees rudder angle to 1550 psi for a full power circle at 35 degrees. In general, the maximum pressure in the working ram occurred about 3 to 5 seconds before the rudder reached the ordered angle.

Except for the high speed turns the rate of change of heading, after the rate became constant, was slightly higher for left turns as compared to the right turns. During the full power turns at 25 and 35 degrees rudder angle, the rate of change of heading was the same for both right and left turns. The constant change of heading rates ranged from 0.5 degree/second for the 12-knot circle at 10 degrees rudder to 1.3 degrees/second for the full power circle at 35 degrees rudder angle.

The vessel responded to rudder movements while operating in the ahead direction, and a change of heading occurred shortly after the rudder reached the ordered angle. During the astern runs the ship did not respond to rudder movements, and there appeared to be no relation between the position of the rudder and the movement of the ship.

The transient torque measurements indicate that a torsional resonance occurs in the shafting at about 34.5 RPM (138 CPM). The double amplitude of the transient torque measured at this speed was approximately 99,000 pound feet. The torque measurements made during the high speed turns at full power revealed that during the right turn the mean torque

increased to 131 percent of rated design while the shaft speed decreased to 85 percent of rated RPM. The data recorded during the left turn indicate a lower mean torque and a higher shaft speed than were recorded during the right turn.

During astern steaming the propulsion machinery developed about 56 percent of rated design ahead torque and about 61 percent of the design ahead shaft speed. The torque developed during the steady astern operations ranged from 15 to 20 percent higher than that developed during ahead operation at the same shaft speed.

The tests were conducted under favorable conditions, and the data contained in this report are considered reliable. The data obtained aboard ship were recorded by means of calibrated instrumentation with the exception of the boiler water level readings. The water level readings were taken from shipboard equipment and no information is available as to the accuracy or reliability of these data.

REFERENCES

(1) Bureau of Ships letter AF58/(436) Ser 436-334 of 6 December 1955.

(2) Pimlott, J. Rex, "The TMB Magnetic Micrometer MK II," David Taylor Model Basin Report 847 (May 1953).

(3) Heffner, James A., "Tactical Trials of USS RIGEL (AF58)," David Taylor Model Basin Report C-810 (January 1957). CONFIDENTIAL.

TABLE 1

USS RIGEL (AF58)

List of Runs Conducted During Special Performance Trials

Run No.	Figure No.	Description
101	2	Normal Turn, 12 Knots, 10° Right Rudder
2	3	Normal Turn, 12 Knots, 15° Right Rudder
3	4	Normal Turn, 12 Knots, 25° Right Rudder
4	5	Normal Turn, 12 Knots, 35° Right Rudder
105	6	Normal Turn, 12 Knots, 10° Left Rudder
7	7	Normal Turn, 12 Knots, 25° Left Rudder
108	8	Normal Turn, 12 Knots, 35° Left Rudder
9	9	Normal Turn, 17 Knots, 10° Right Rudder
110	10	Normal Turn, 17 Knots, 15° Right Rudder
11	11	Normal Turn, 17 Knots, 25° Right Rudder
12	12	Normal Turn, 17 Knots, 35° Right Rudder
13	13	Normal Turn, 17 Knots, 10° Left Rudder
15	14	Normal Turn, 17 Knots, 25° Left Rudder
16	15	Normal Turn, 17 Knots, 35° Left Rudder
21	16	Normal Turn, Full Power, 10° Right Rudder
22	17	Normal Turn, Full Power, 15° Right Rudder
23	18	Normal Turn, Full Power, 25° Right Rudder
24	19	Normal Turn, Full Power, 35° Right Rudder
25	20	Normal Turn, Full Power, 10° Left Rudder

TABLE 1 (Continued)

Run No.	Figure No.	Description
27	21	Normal Turn, Full Power, 25° Left Rudder
28	22	Normal Turn, Full Power, 35° Left Rudder
29	35	Acceleration, 0 Knot to Full Power
30	36	Acceleration, 12 Knots to Full Power
31	37	Deceleration, Full Power to 0 Knot (Engine Back Full)
32	38	Deceleration, Full Power to 0 Knot (Engine Stop)
33	39	Deceleration, 17 Knots to 0 Knot (Engine Back Full)
34	40	Deceleration, 17 Knots to 0 Knot (Engine Stop)
35	41	Deceleration, 12 Knots to 0 Knot (Engine Back Full)
36	42	Deceleration, 12 Knots to 0 Knot (Engine Stop)
37	32	Astern Zig-Zag, at 1/3 Speed
38	33	Astern Zig-Zag, at 2/3 Speed
39	34	Astern Zig-Zag, at Full Power Astern
40	23	Shifting Rudder, 15 Knots, 0 to 25° Right
41	24	Shifting Rudder, 15 Knots, 0 to 30° Right
42	25	Shifting Rudder, 15 Knots, 0 to 35° Right
43	26	Shifting Rudder, 20 Knots, 0 to 25° Right
44	27	Shifting Rudder, 20 Knots, 0 to 30° Right
45	28	Shifting Rudder, 20 Knots, 0 to 35° Right

TABLE 1 (Concluded)

Run No.	Figure No.	Description
46	29	Shifting Rudder, Full Power, 0 to 25° Right
47	30	Shifting Rudder, Full Power, 0 to 30° Right
48	31	Shifting Rudder, Full Power, 0 to 35° Right
--	43	Transient Torque Measurements During Steady Speed Runs
--	44	Torque Measurements During Full Power Turn at 35° Right Rudder
--	45	Torque Measurements During Full Power Turn at 35° Left Rudder
--	46	Torque Measurements During Steady Speed Runs Astern

TABLE 2

USS RIGEL (AF58)

Dimensions and Trial Conditions

Ship Dimensions	
Length overall (LOA), feet	502.0
Length between perpendiculars (LBP), feet	475.0
Breadth, molded, feet	72.0
Rudder Area, square feet	216.0
Propeller Characteristics	
Type	Solid
Number of Propellers	1
Number of Blades	4
Diameter, feet	22.00
Pitch, feet	21.69
MWR	0.250
BTF	0.050
Projected Area + Disc Area	0.509
Direction of Rotation	RH
Material	Manganese Bronze
Trial Conditions	
Displacement, tons	10,230
Trim by the Stern, feet	6.1
Draft (mean), feet	18.6
Sea State	1 - 2
Wind Velocity, knots	4 - 23

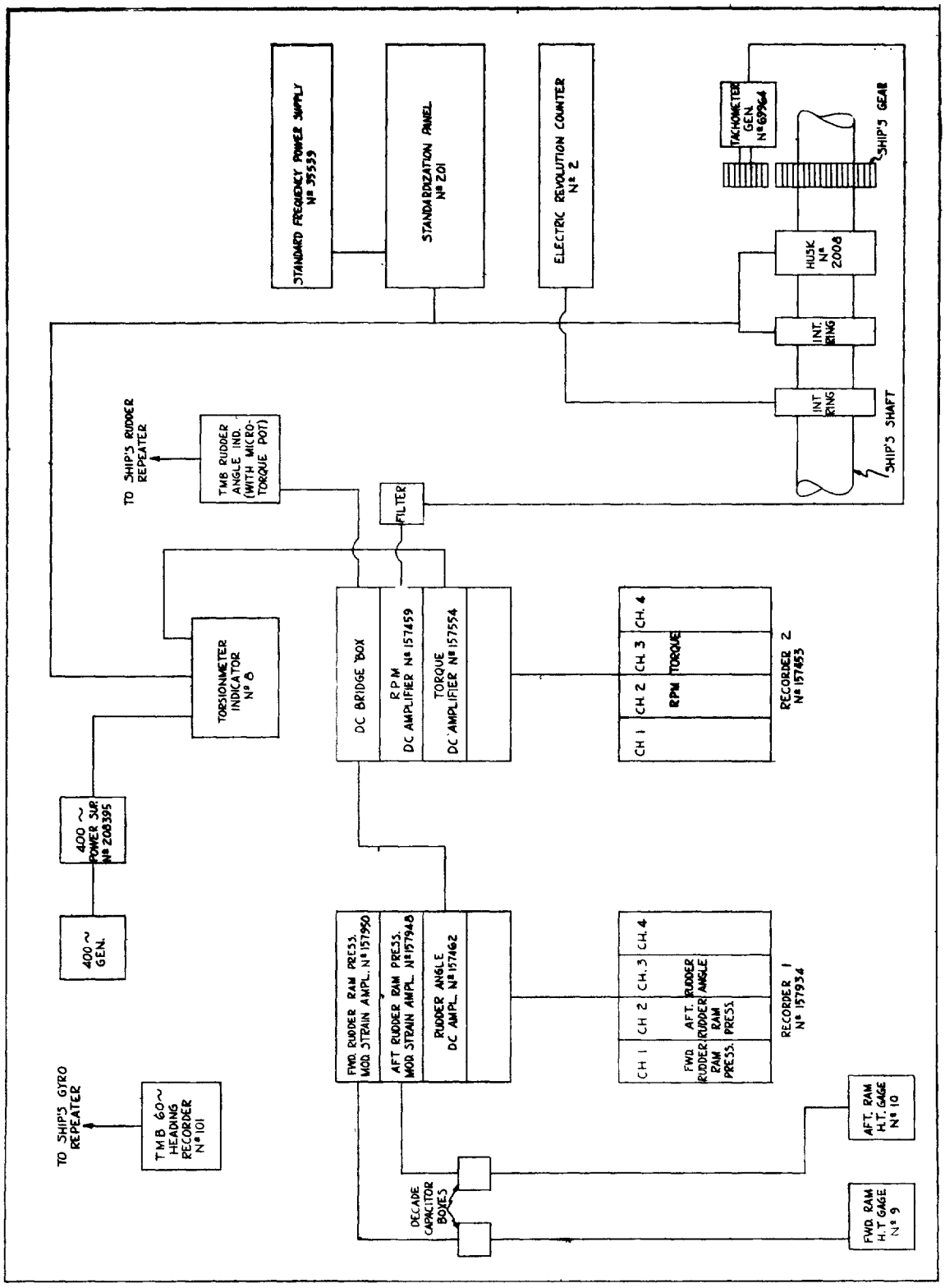

Figure 1 - USS RIGEL (AF58)-Block Diagram of Trial Equipment.

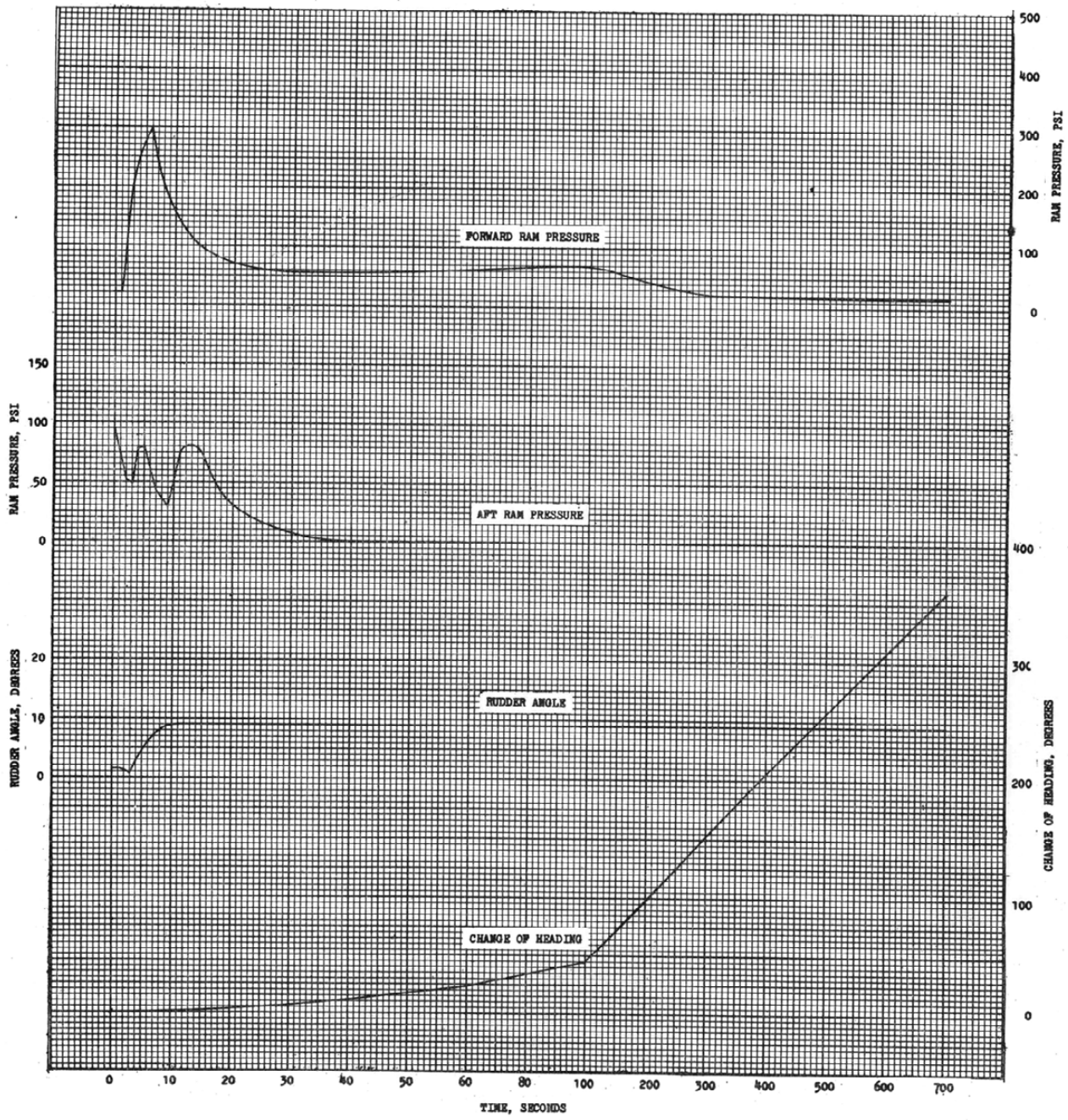

Figure 2 - USS RIGEL (AF58)-Normal Turn at 12 Knots With 10 Degrees Right Rudder.

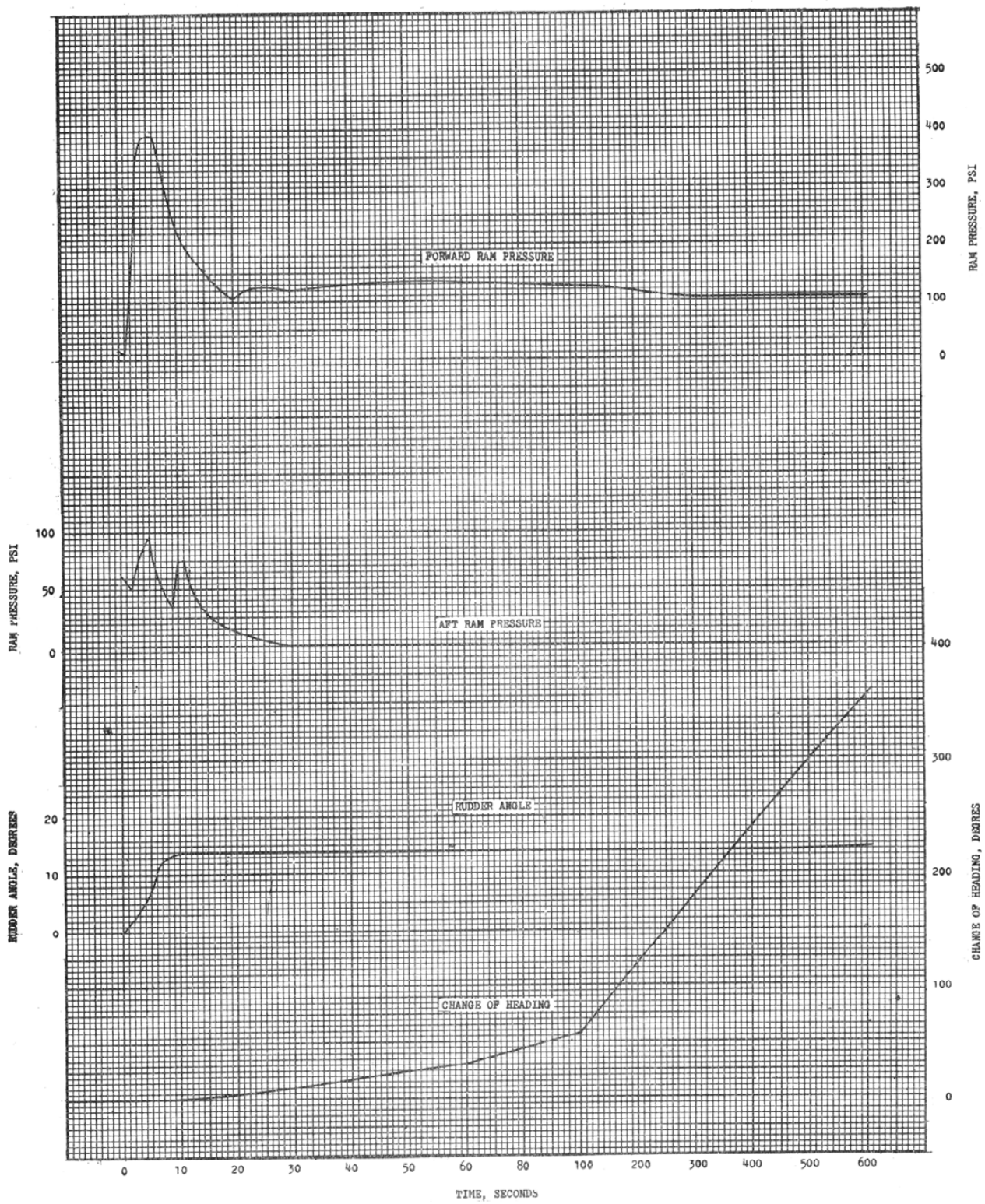

Figure 3 - USS RIGEL (AF58)-Normal Turn at 12 Knots With 15 Degrees Right Rudder.

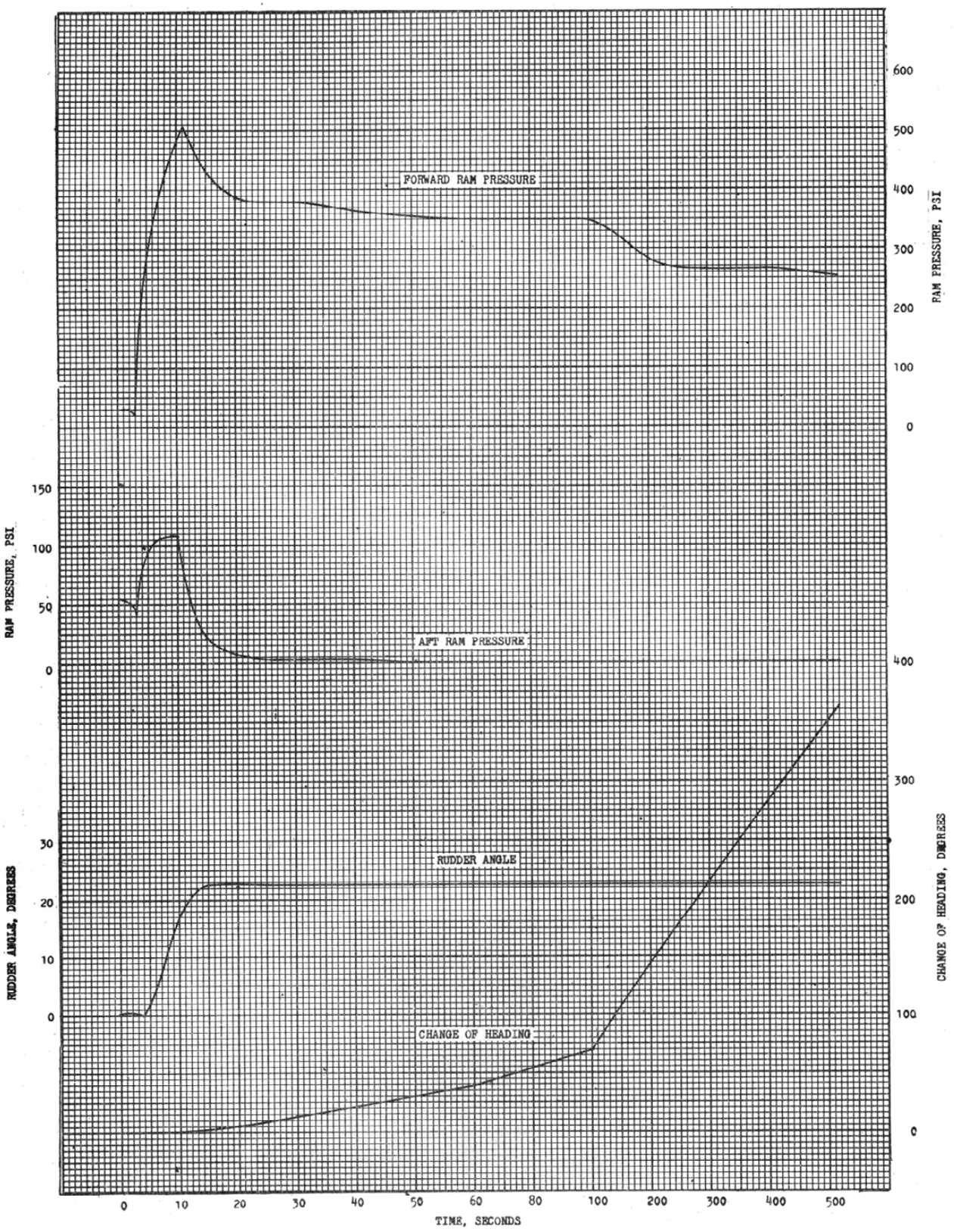

Figure 4 - USS RIGEL (AF58)-Normal Turn at 12 Knots With 25 Degrees Right Rudder.

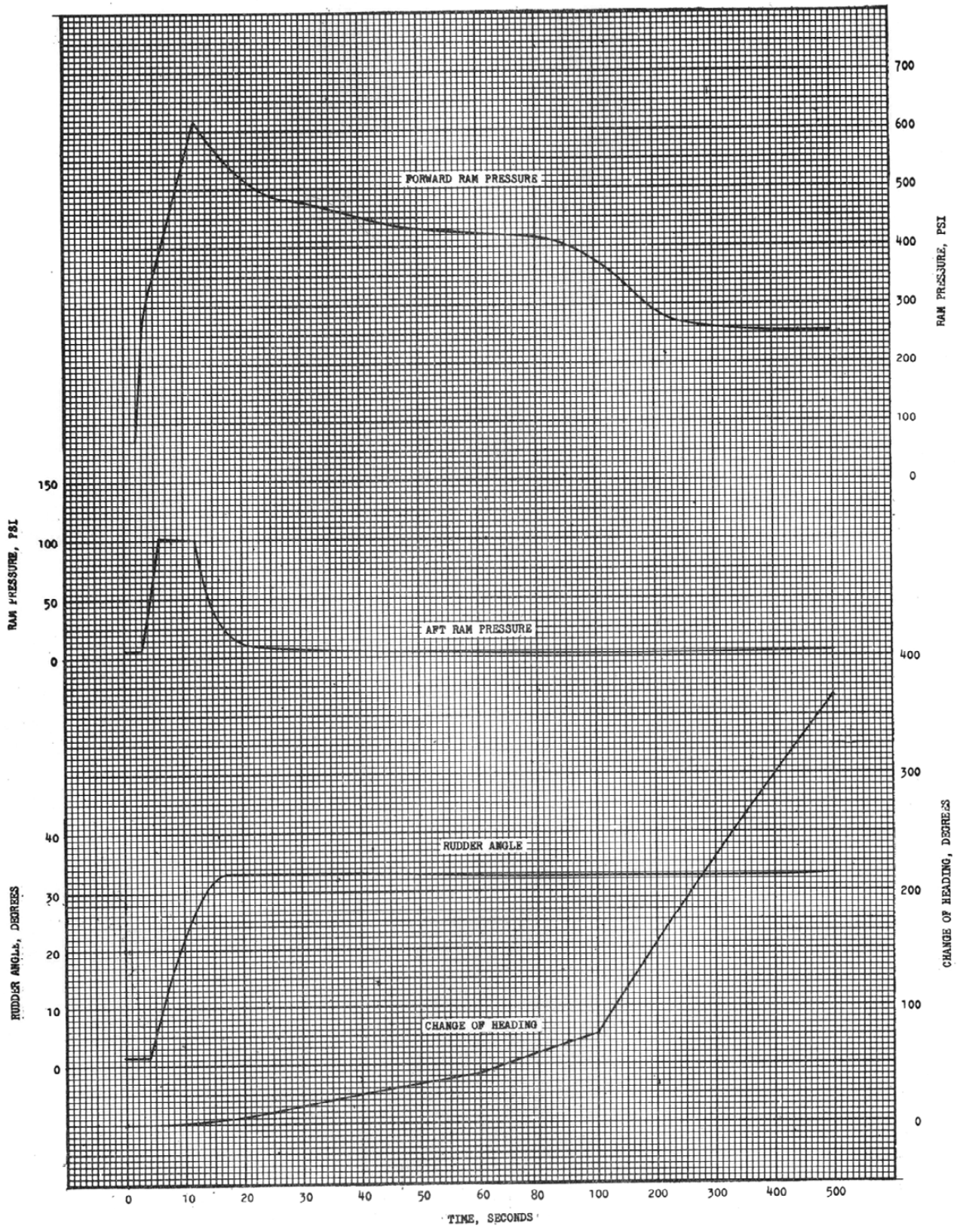

Figure 5 - USS RIGEL (AF58)-Normal Turn at 12 Knots With 35 Degrees Right Rudder.

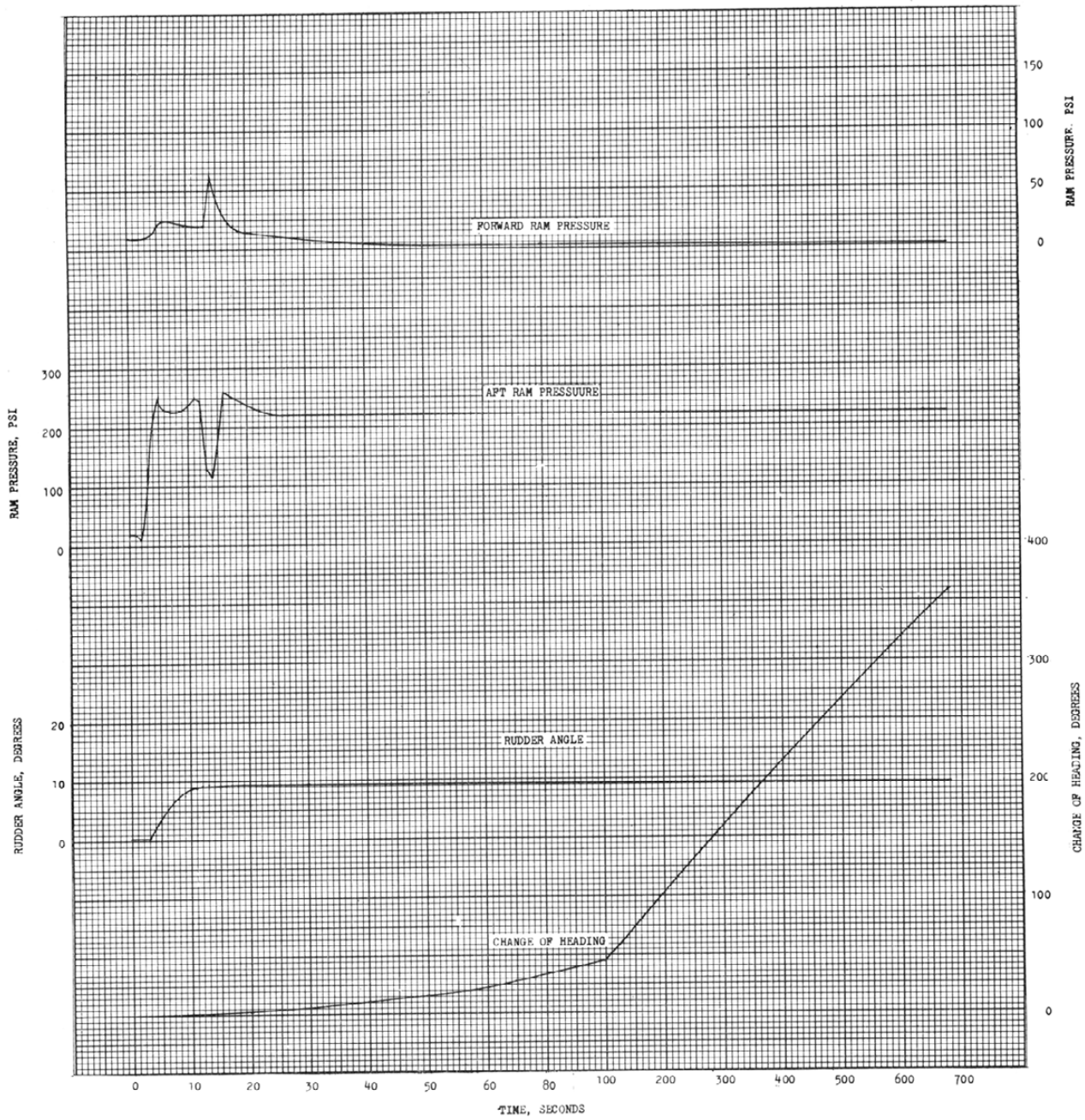

Figure 6 - USS RIGEL (AF58)-Normal Turn at 12 Knots With 10 Degrees Left Rudder.

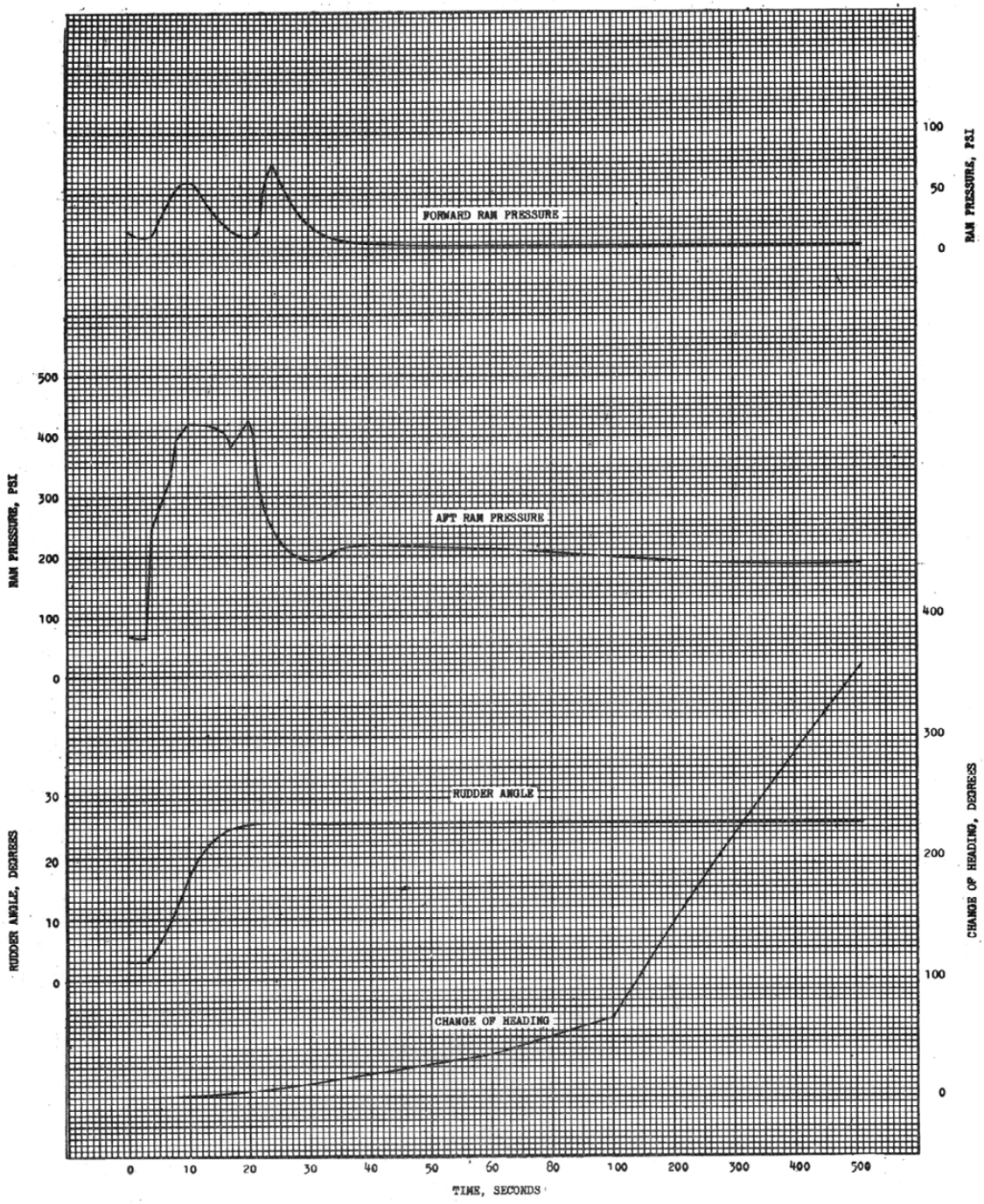

Figure 7 - USS RIGEL (AF58)-Normal Turn at 12 Knots With 25 Degrees Left Rudder.

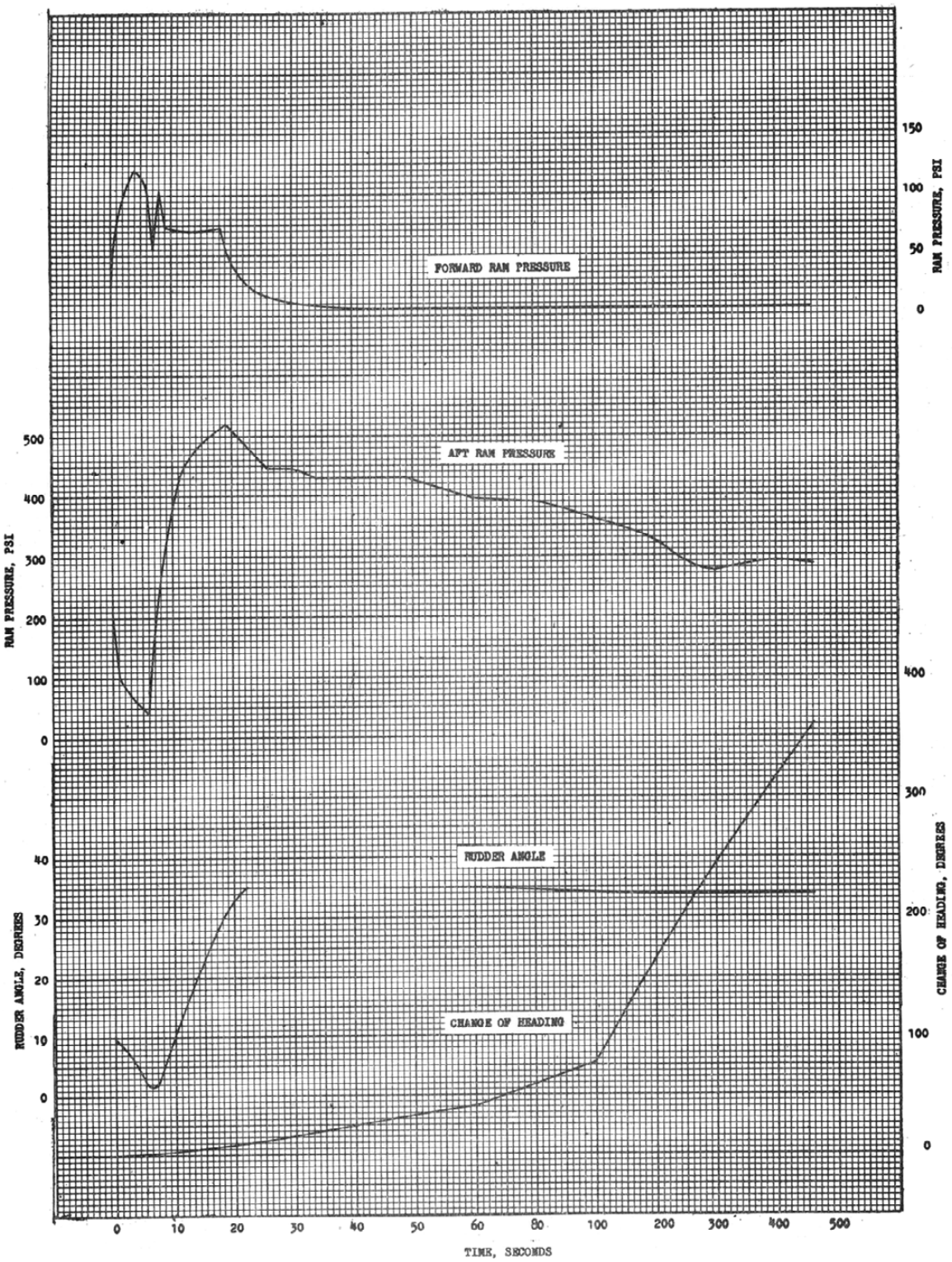

Figure 8 - USS RIGEL (AF58)-Normal Turn at 12 Knots With 35 Degrees Left Rudder.

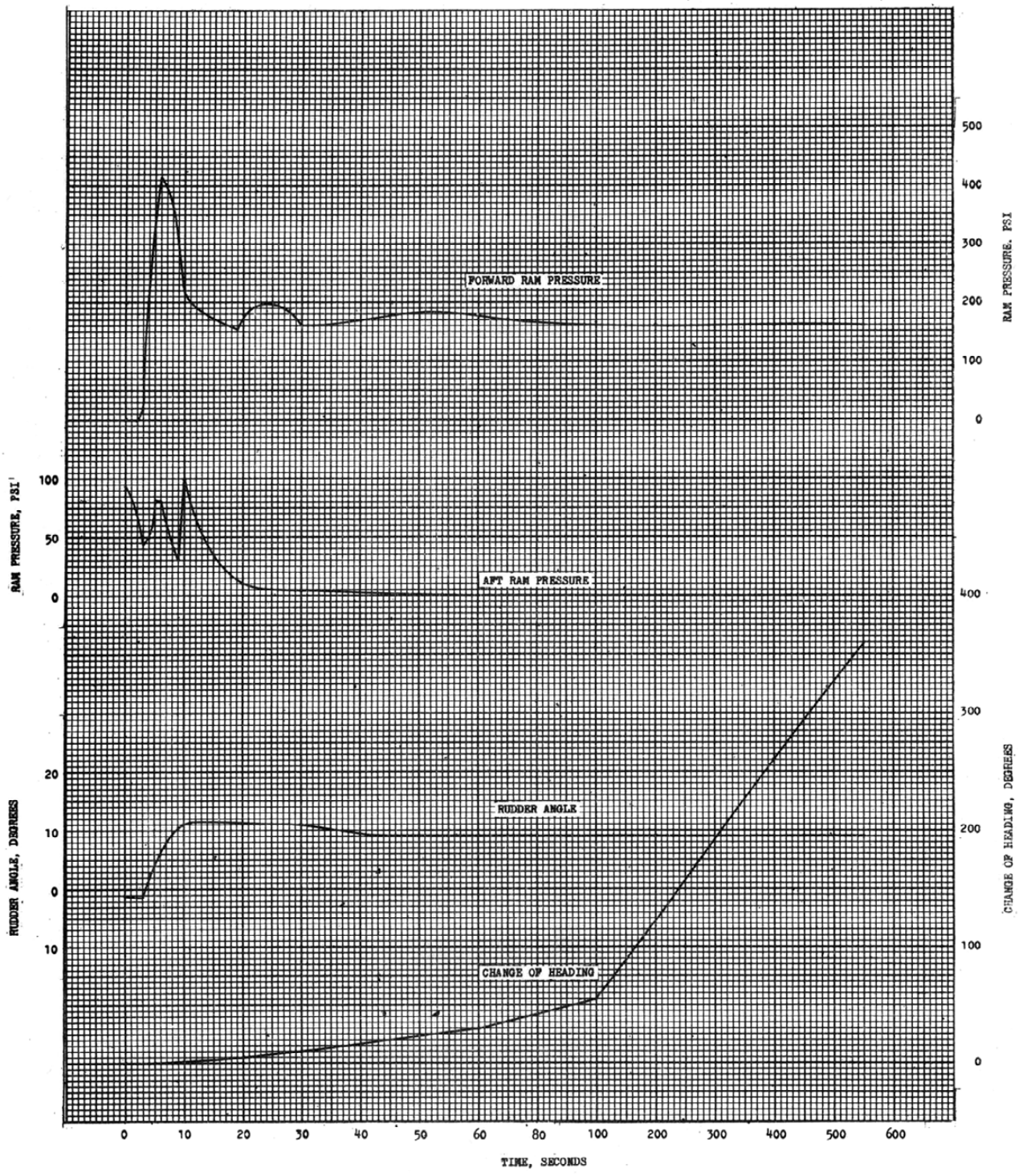

Figure 9 - USS RIGEL (AF58)-Normal Turn at 17 Knots With 10 Degrees Right Rudder.

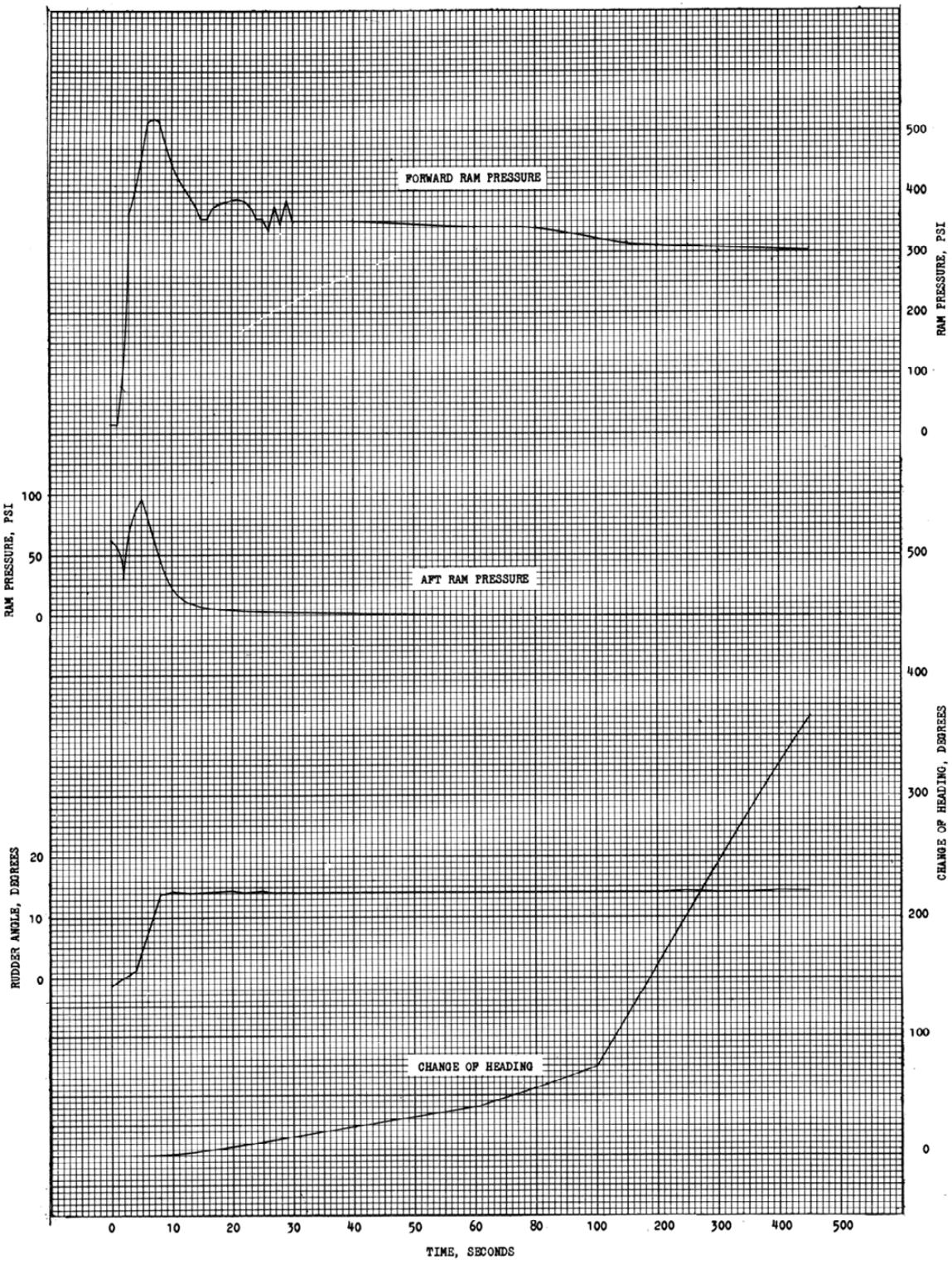

Figure 10 - USS RIGEL (AF58)-Normal Turn at 17 Knots With 15 Degrees Right Rudder.

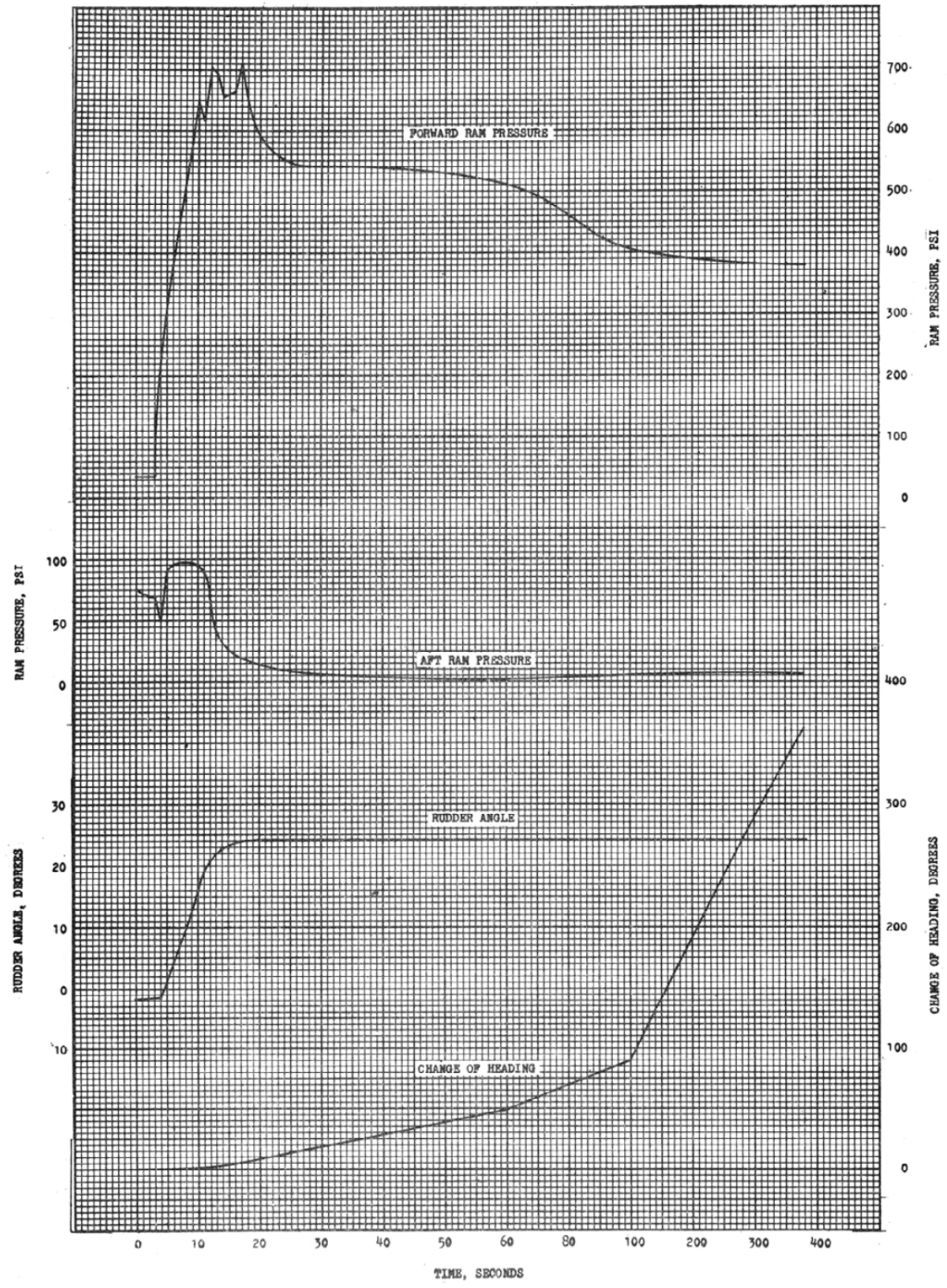

Figure 11 - USS RIGEL (AF58)-Normal Turn at 17 Knots With 25 Degrees Right Rudder.

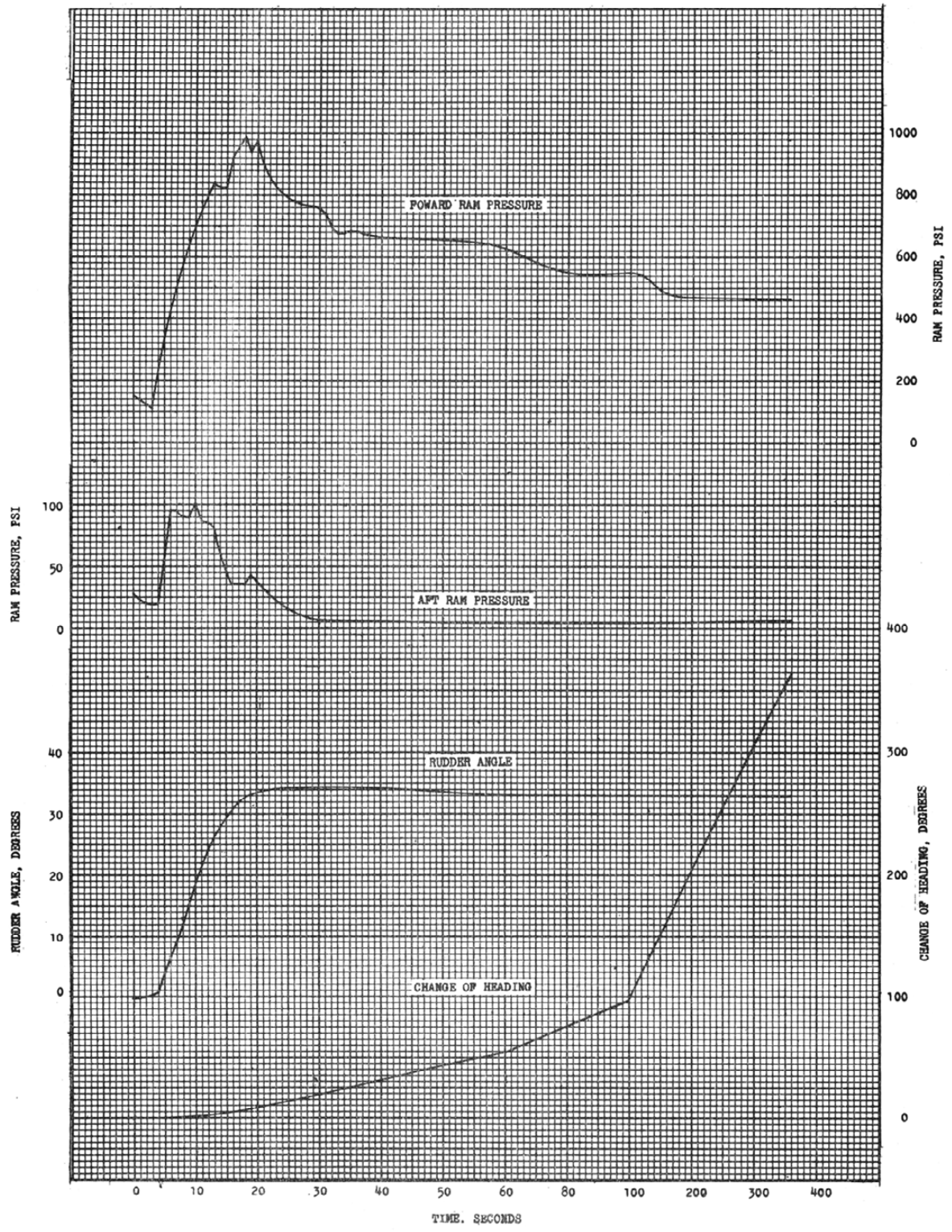

Figure 12 - USS RIGEL (AF58)-Normal Turn at 17 Knots With 35 Degrees Right Rudder.

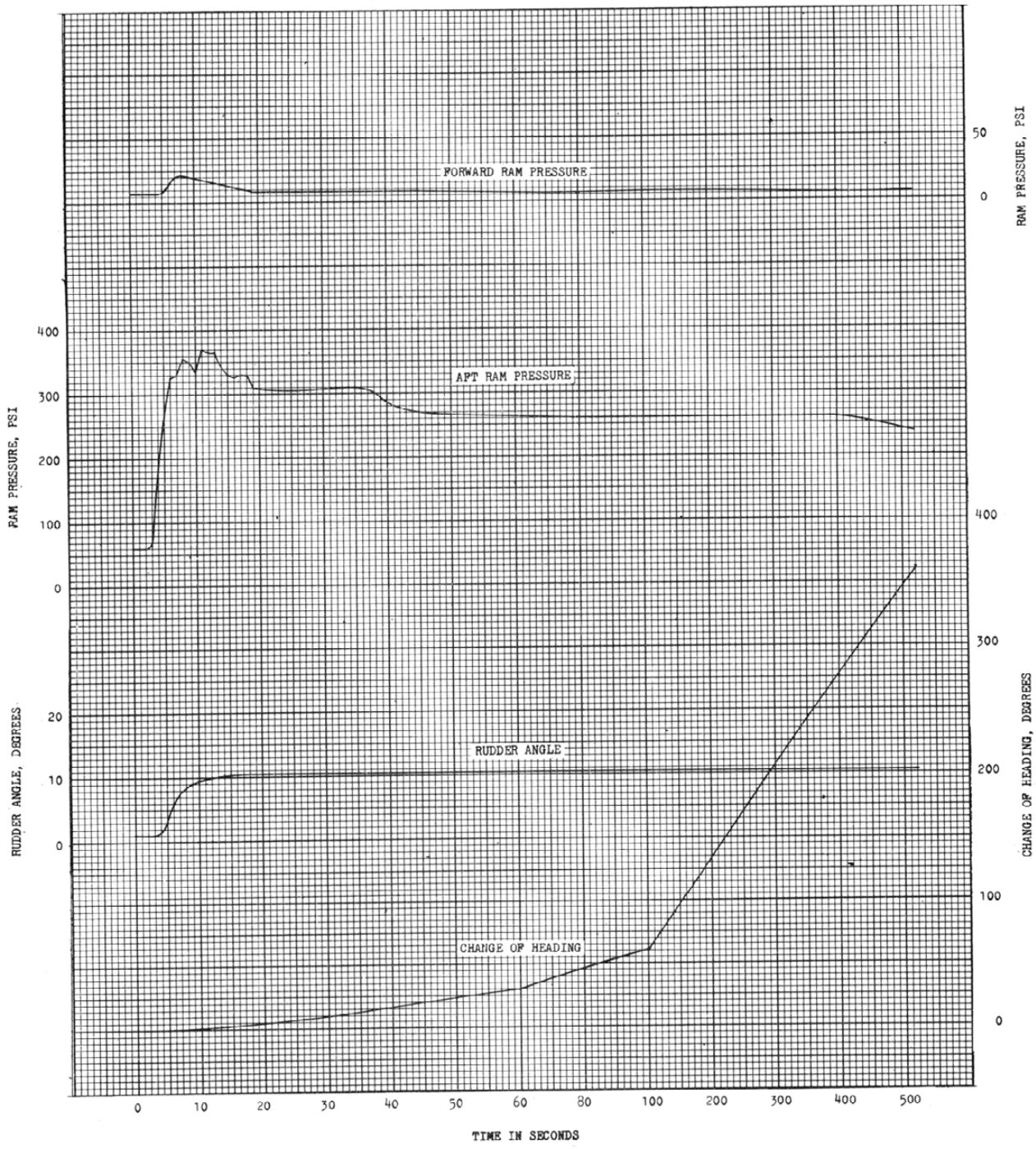

Figure 13 - USS RIGEL (AF58)-Normal Turn at 17 Knots With 10 Degrees Left Rudder.

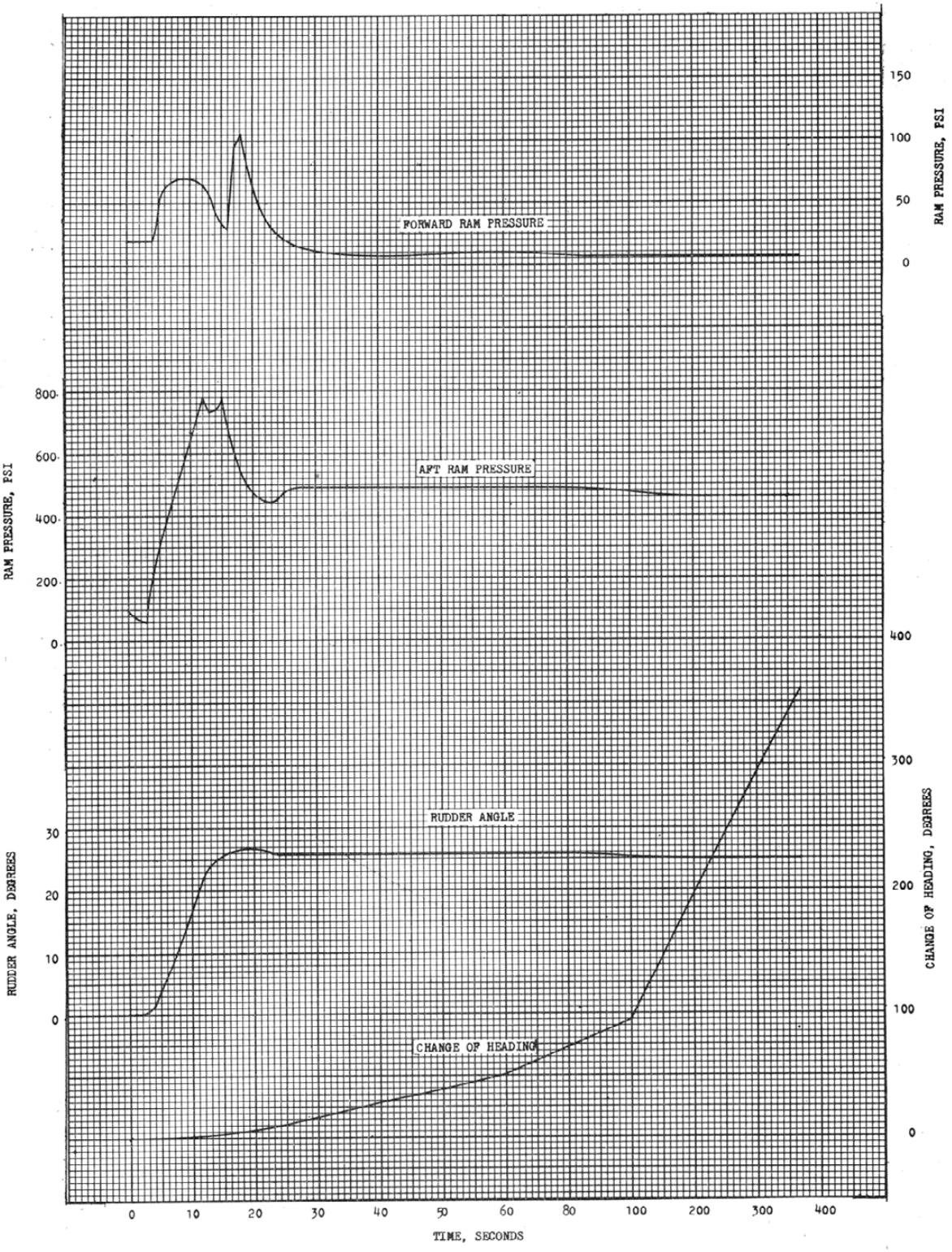

Figure 14 - USS RIGEL (AF58)-Normal Turn at 17 Knots With 25 Degrees Left Rudder.

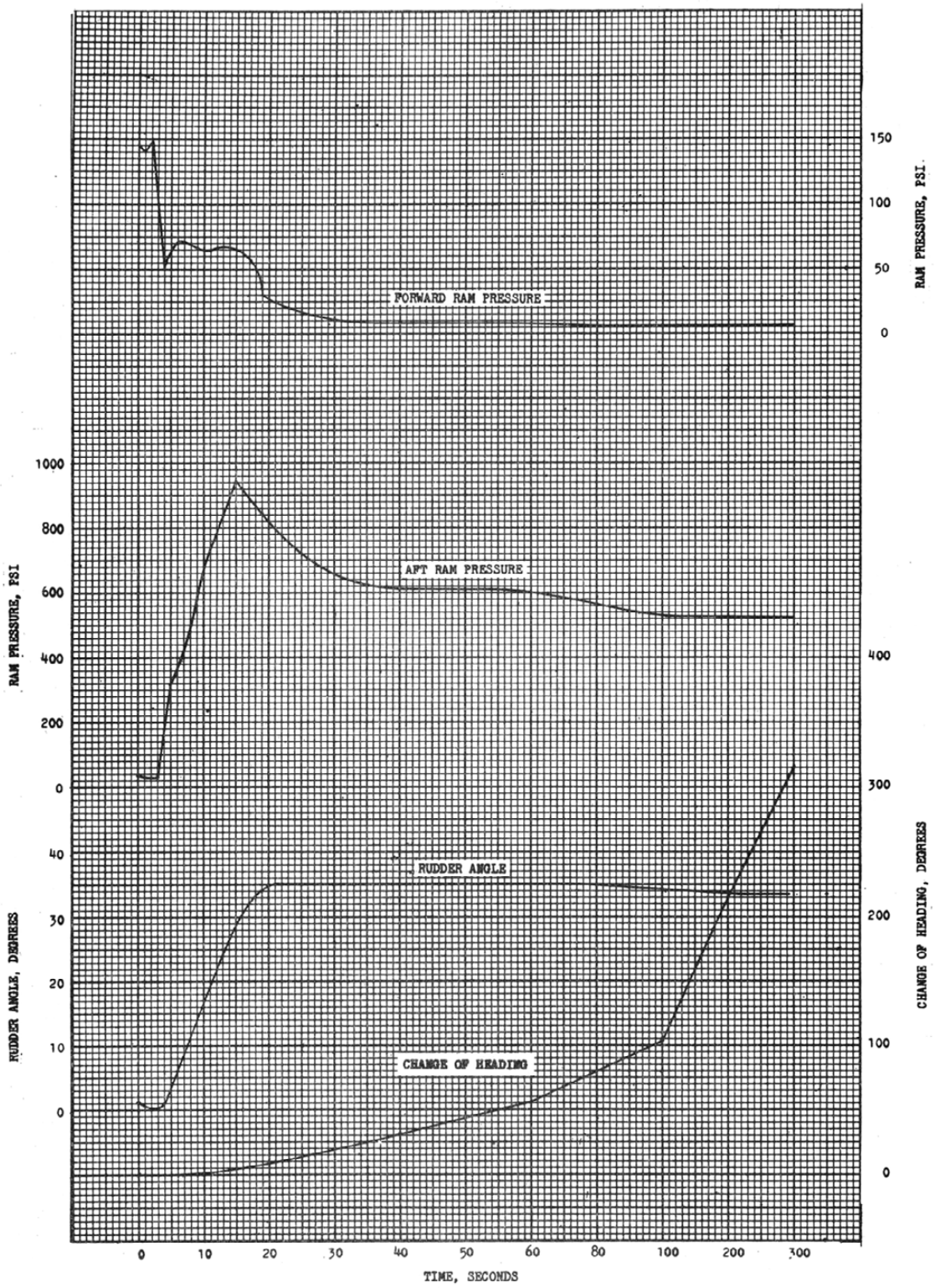

Figure 15 - USS RIGEL (AF58)-Normal Turn at 17 Knots With 35 Degrees Left Rudder.

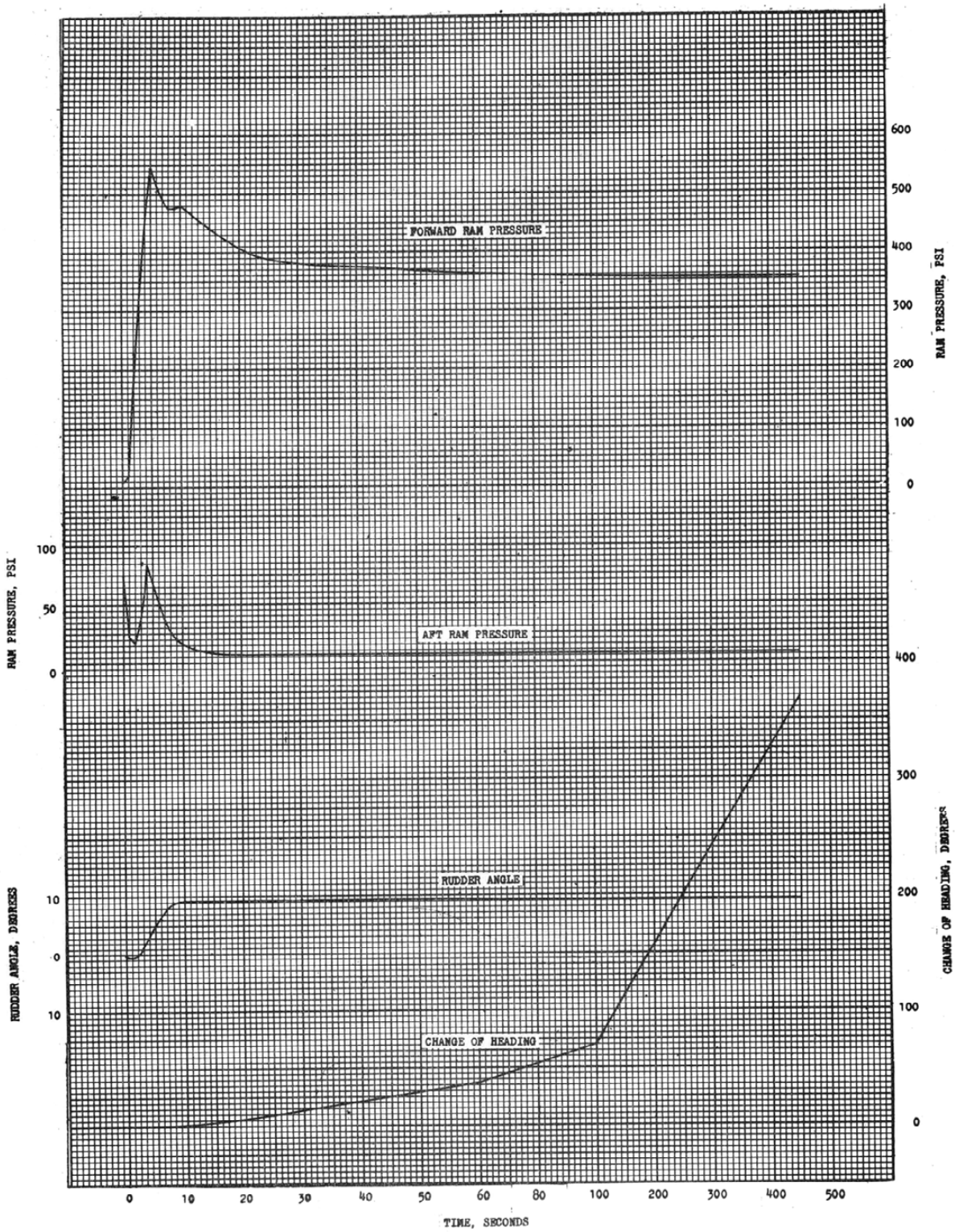

Figure 16 - USS RIGEL (AF58)-Normal Turn at Full Power With 10 Degrees Right Rudder.

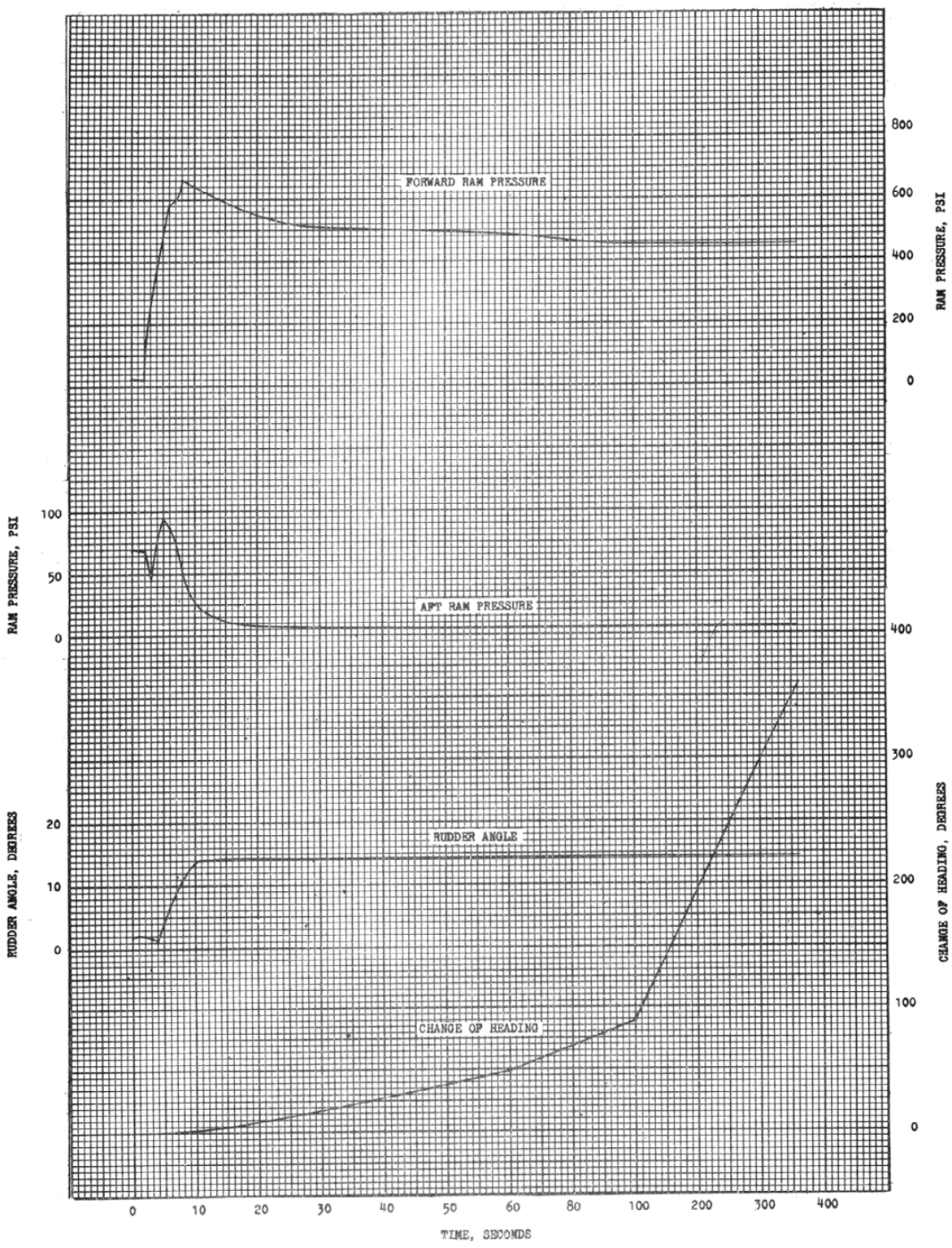

Figure 17 - USS RIGEL (AF58)-Normal Turn at Full Power With 15 Degrees Right Rudder.

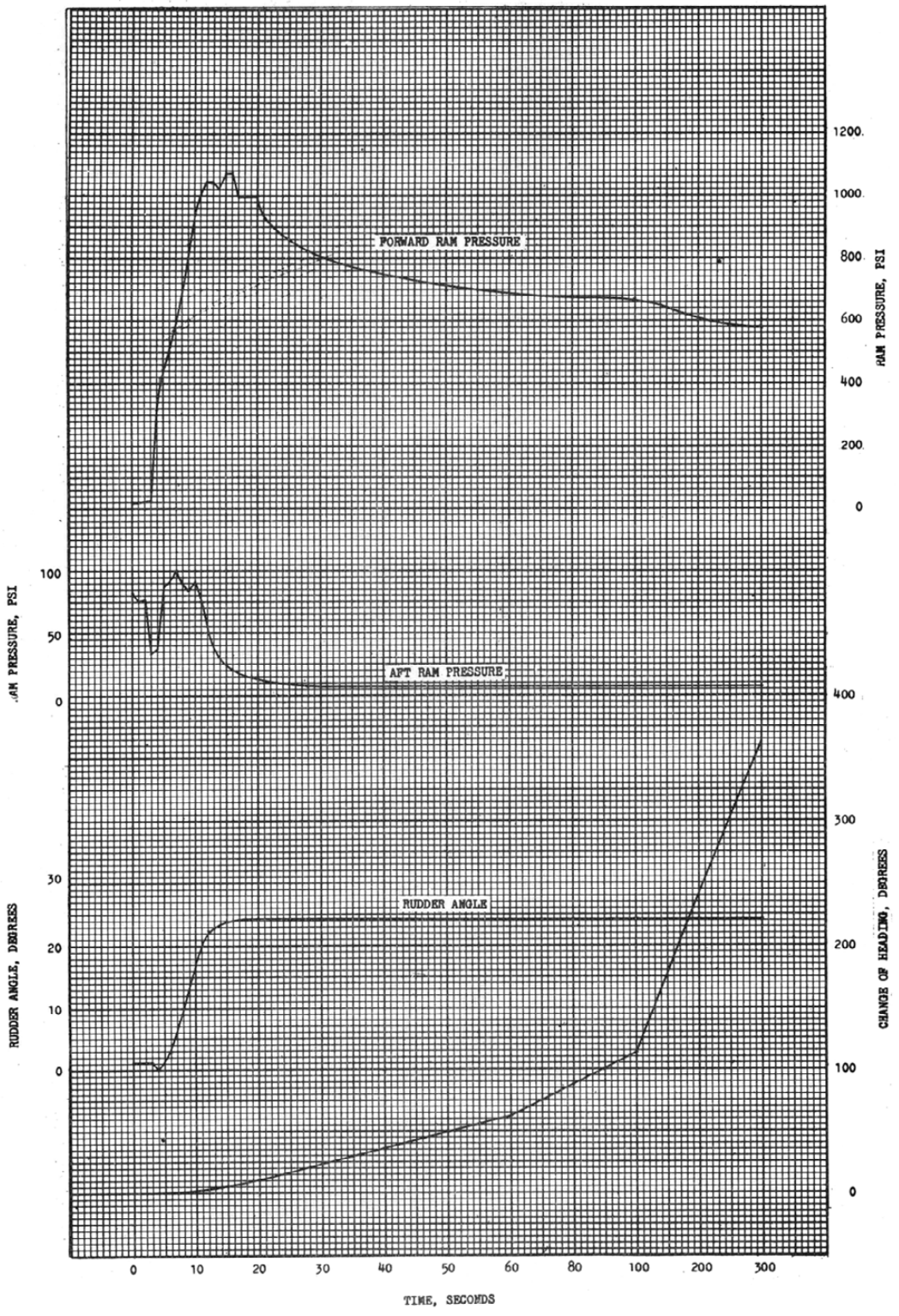

Figure 18 - USS RIGEL (AF58)-Normal Turn at Full Power With 25 Degrees Right Rudder.

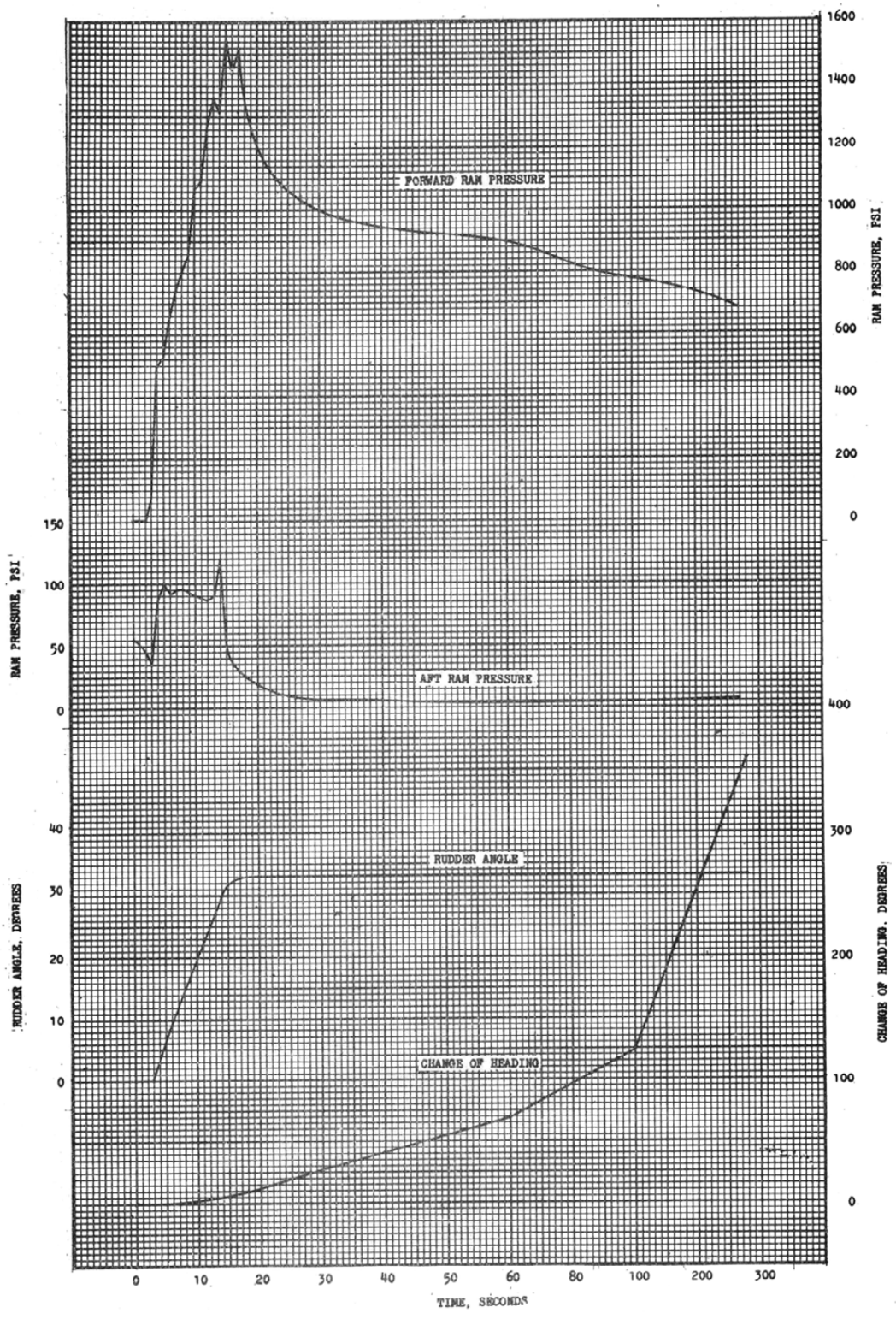

Figure 19 - USS RIGEL (AF58)-Normal Turn at Full Power With 35 Degrees Right Rudder.

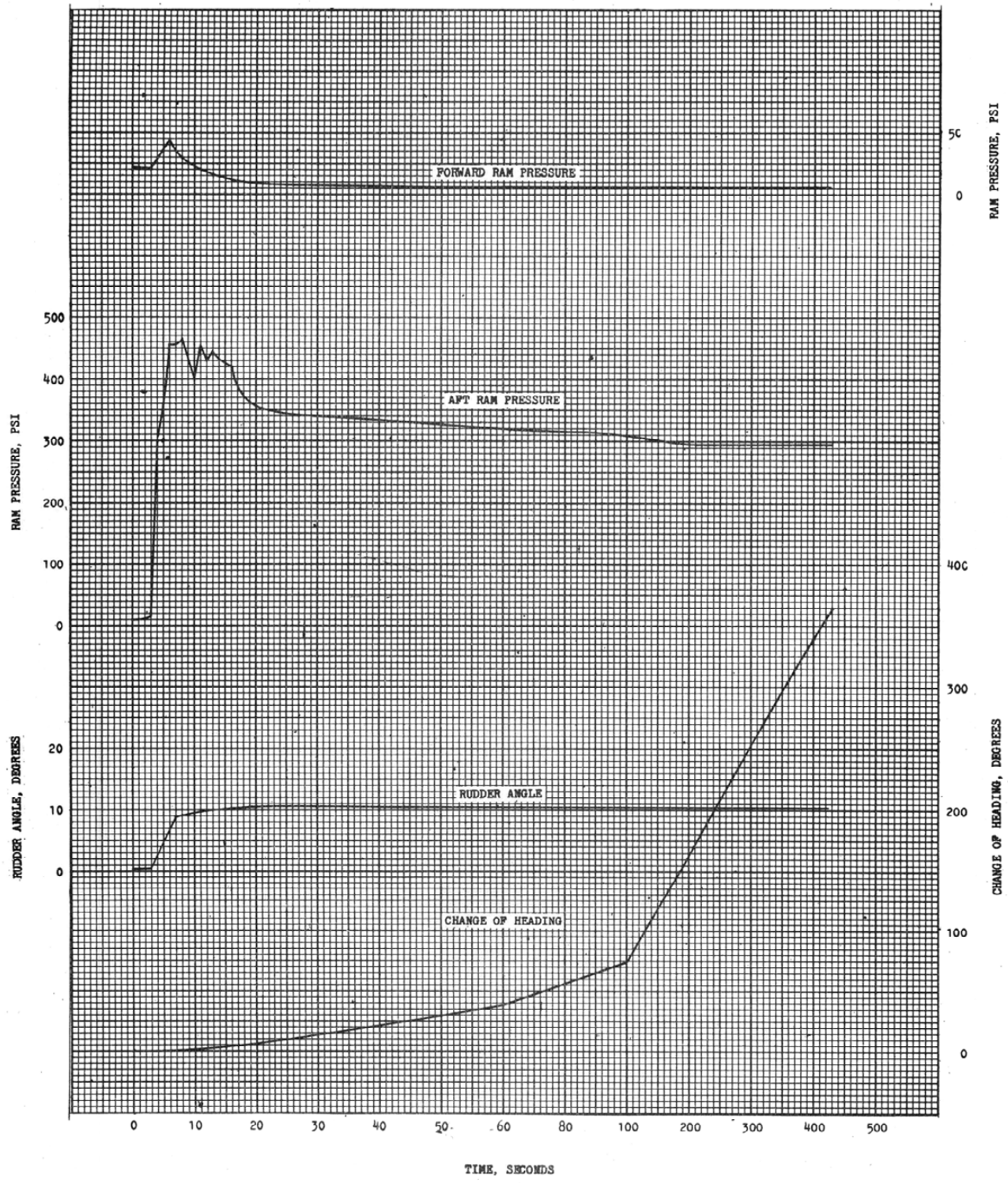

Figure 20 - USS RIGEL (AF58)-Normal Turn at Full Power With 10 Degrees Left Rudder.

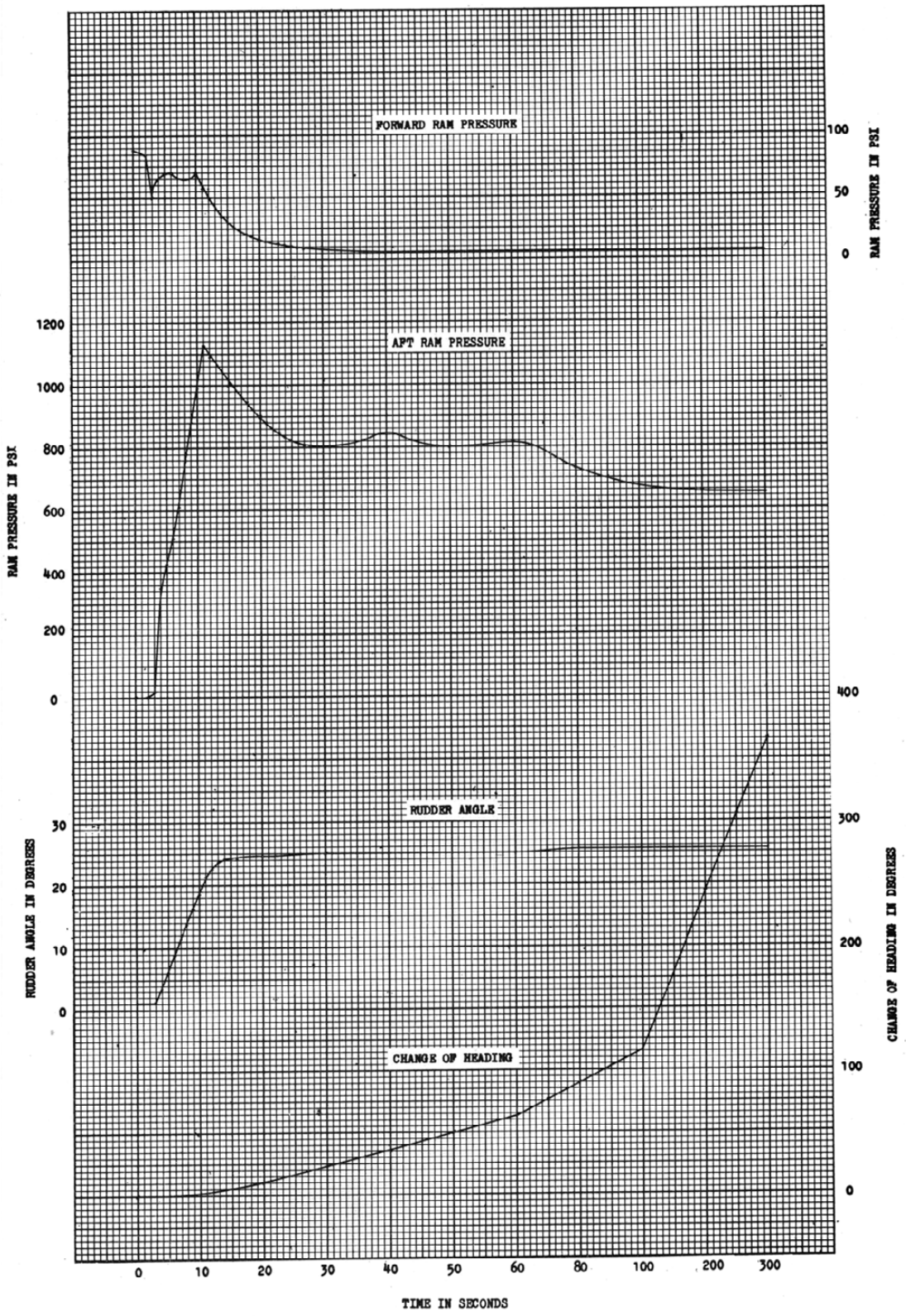

Figure 21 - USS RIGEL (AF58)-Normal Turn at Full Power With 25 Degrees Left Rudder.

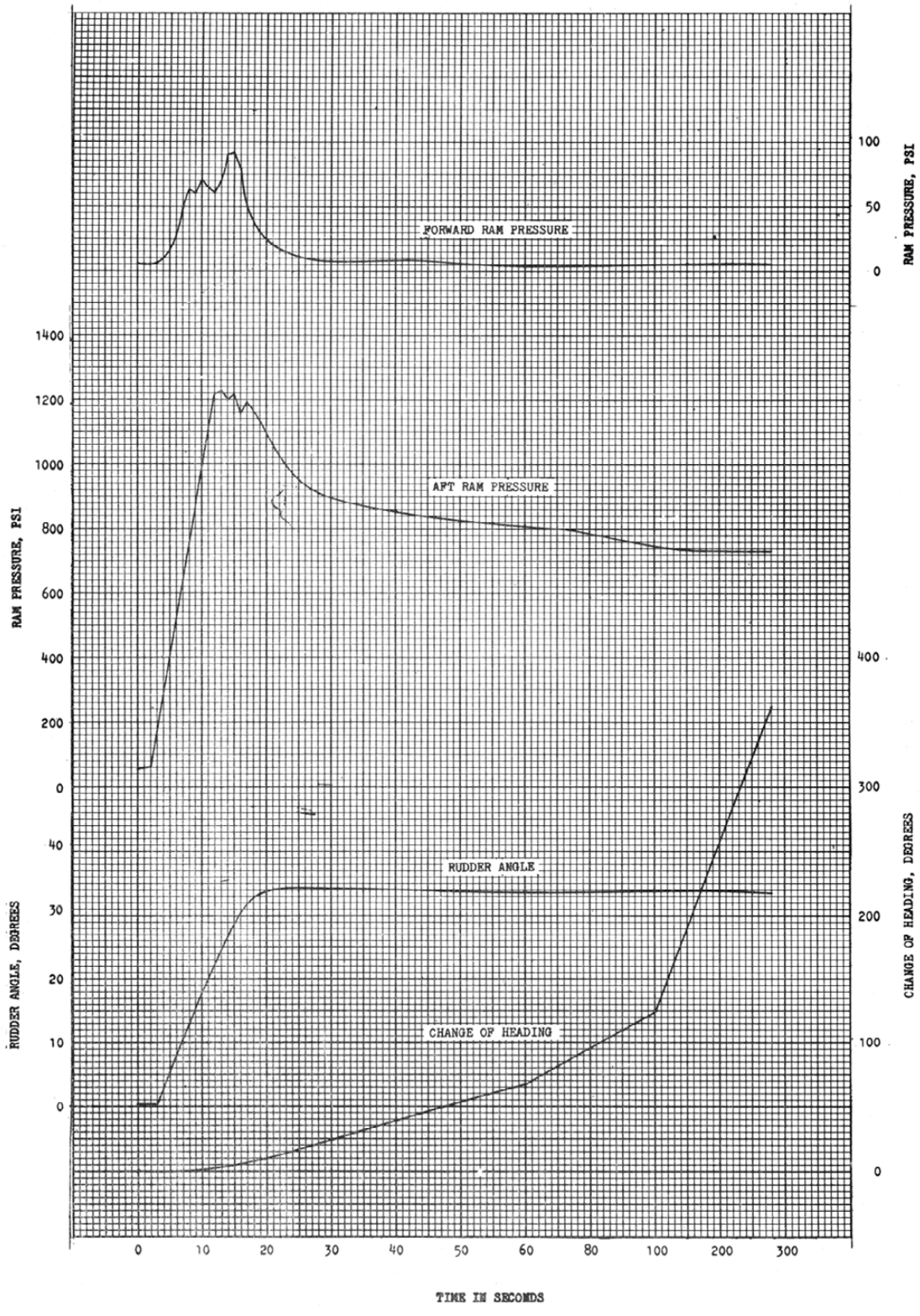

Figure 22 - USS RIGEL (AF58)-Normal Turn at Full Power With 35 Degrees Left Rudder.

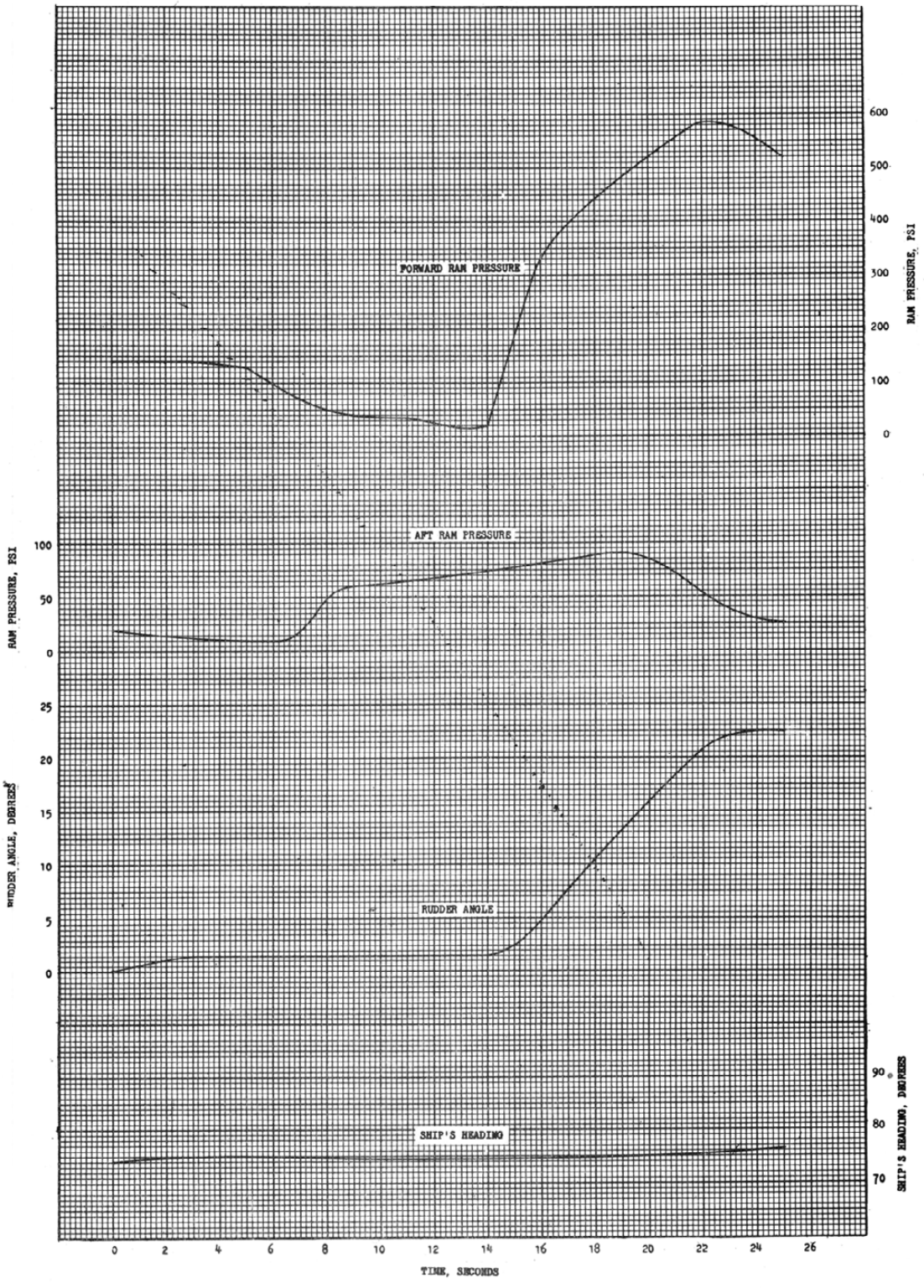

Figure 23 - USS RIGEL (AF58)-Shifting Rudder From Amidships to 25 Degrees Right, 15-Knot Approach.

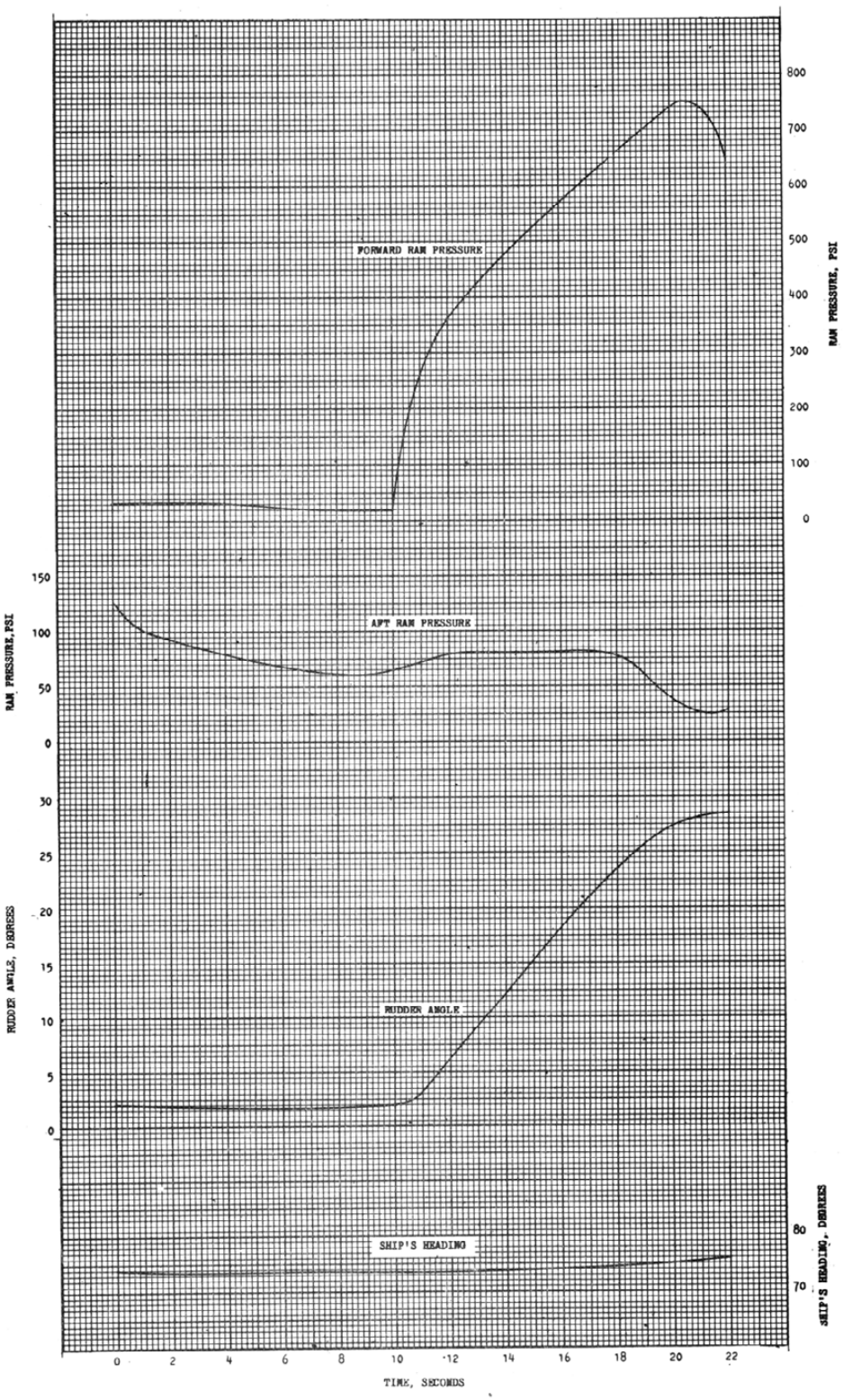

Figure 24 - USS RIGEL (AF58)-Shifting Rudder From Amidships to 30 Degrees Right, 15-Knot Approach.

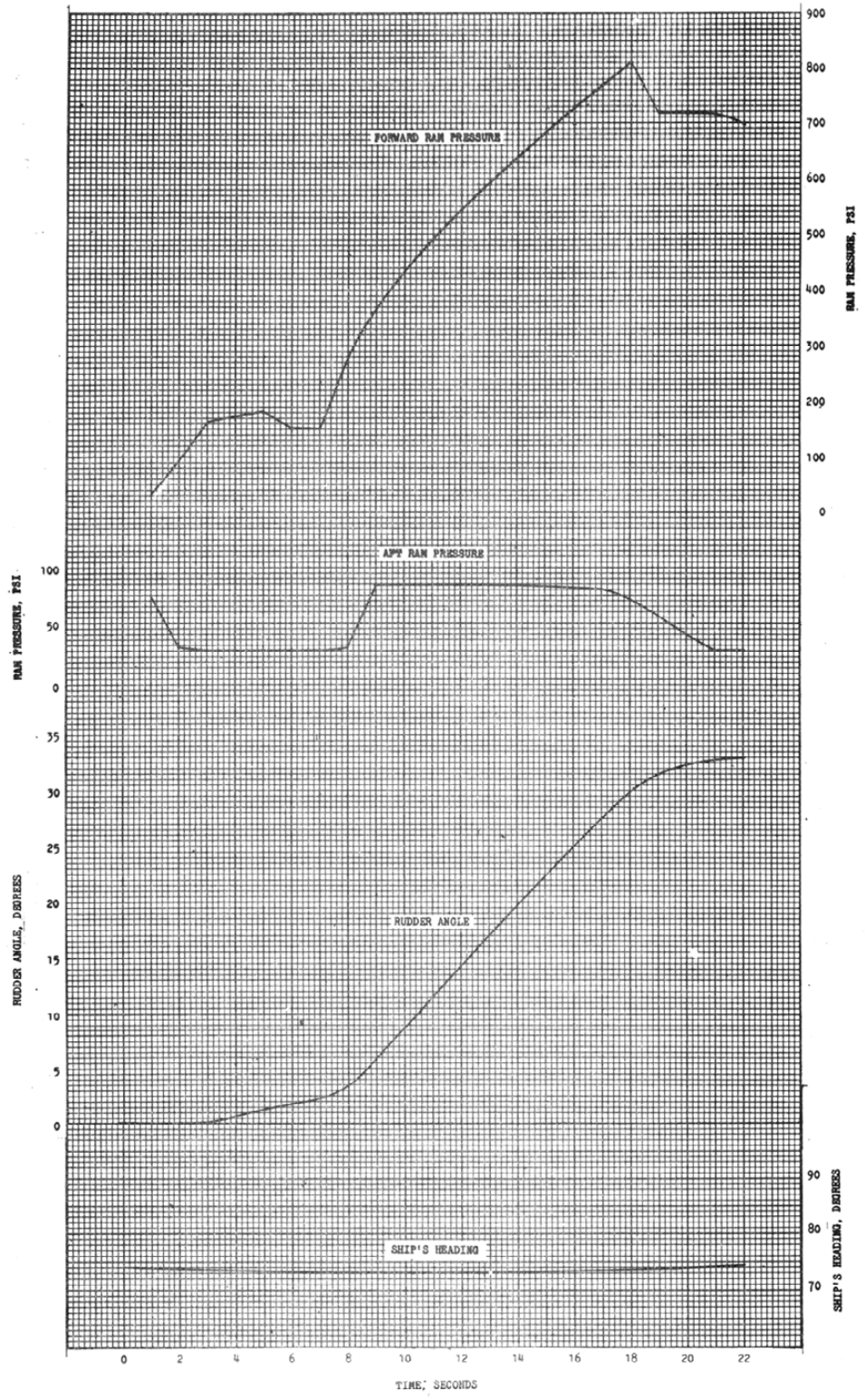

Figure 25 - USS RIGEL (AF58)-Shifting Rudder From Amidships to 35 Degrees Right, 15-Knot Approach.

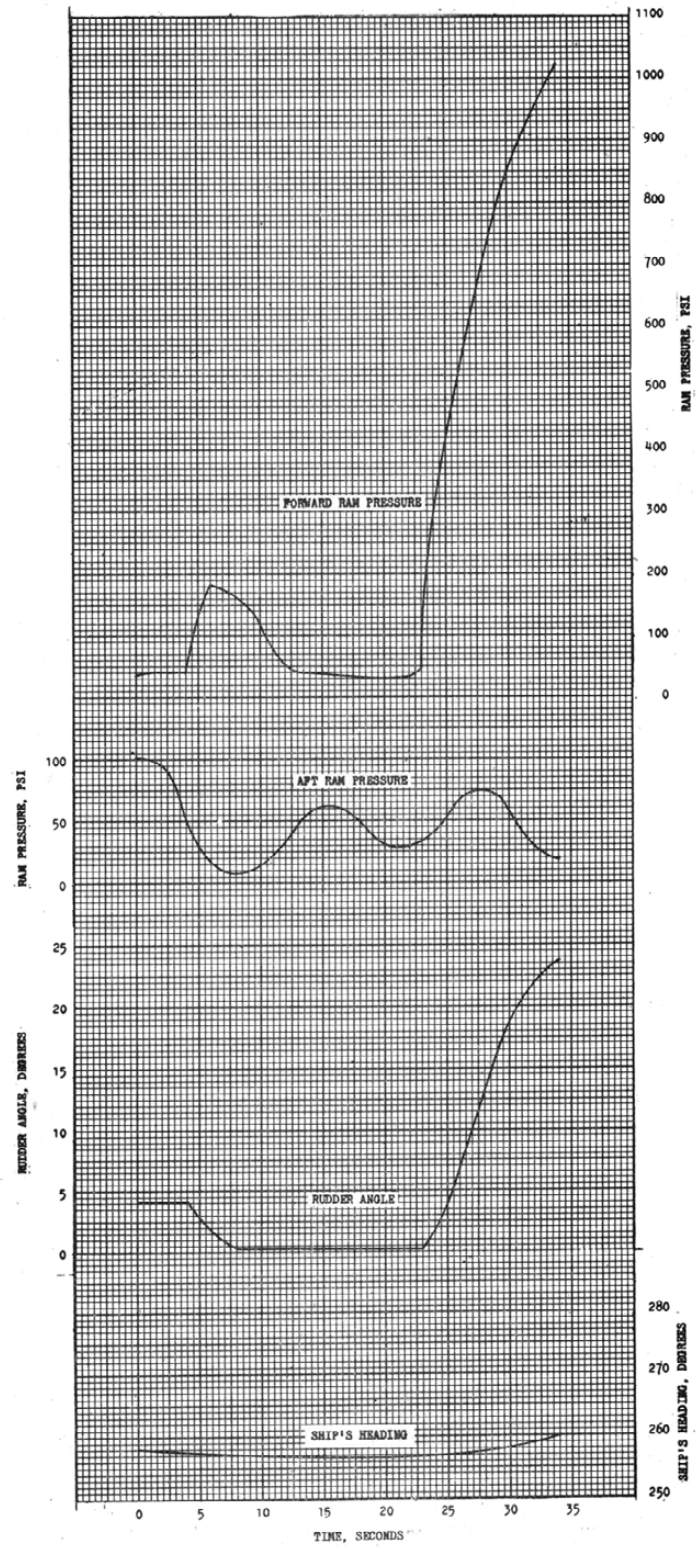

Figure 26 - USS RIGEL (AF58)-Shifting Rudder From Amidships to 25 Degrees Right, 20-Knot Approach.

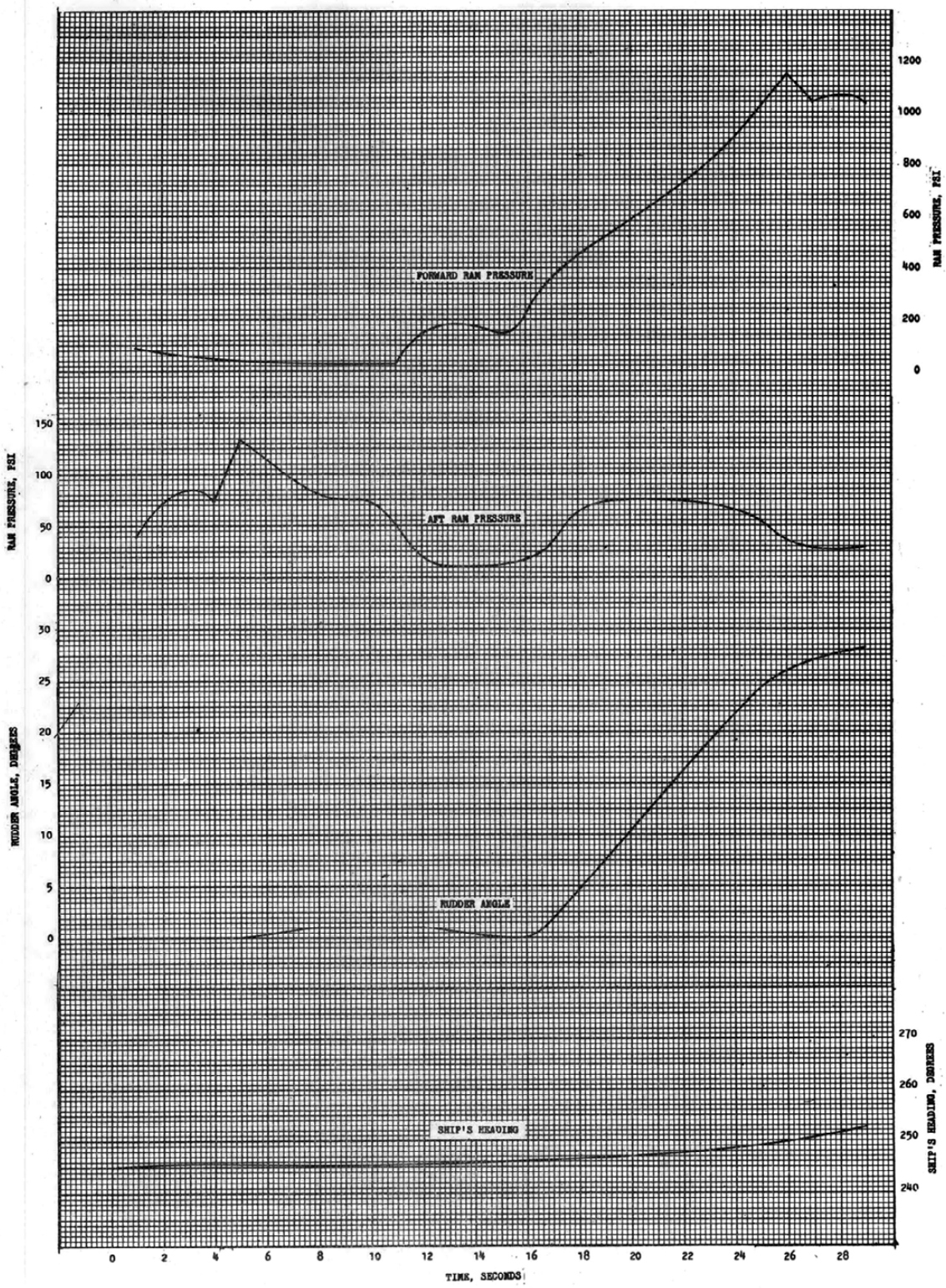

Figure 27 - USS RIGEL (AF58)-Shifting Rudder From Amidships to 30 Degrees Right, 20-Knot Approach.

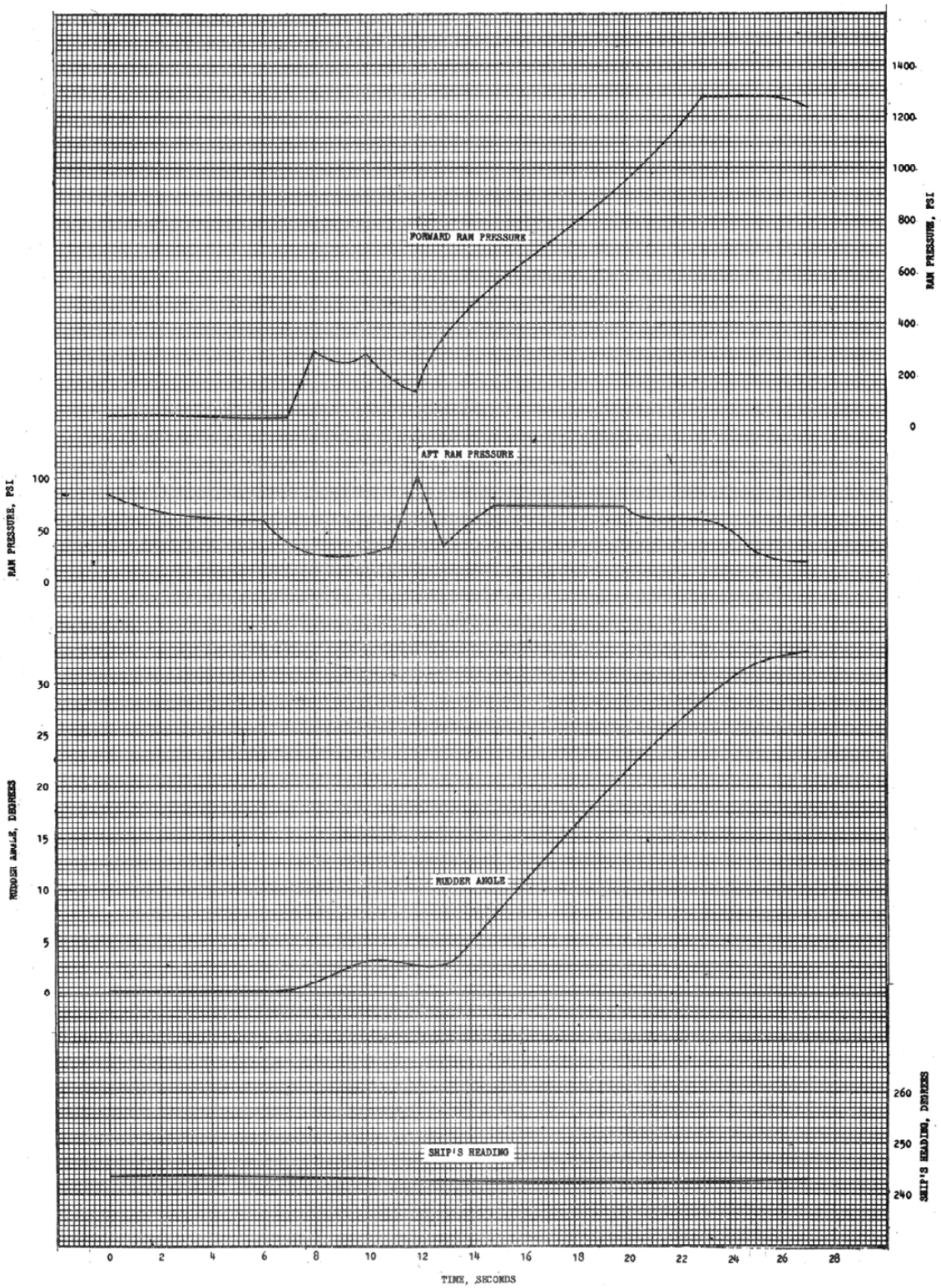

Figure 28 - USS RIGEL (AF58)-Shifting Rudder From Amidships to 35 Degrees Right, 20-Knot Approach.

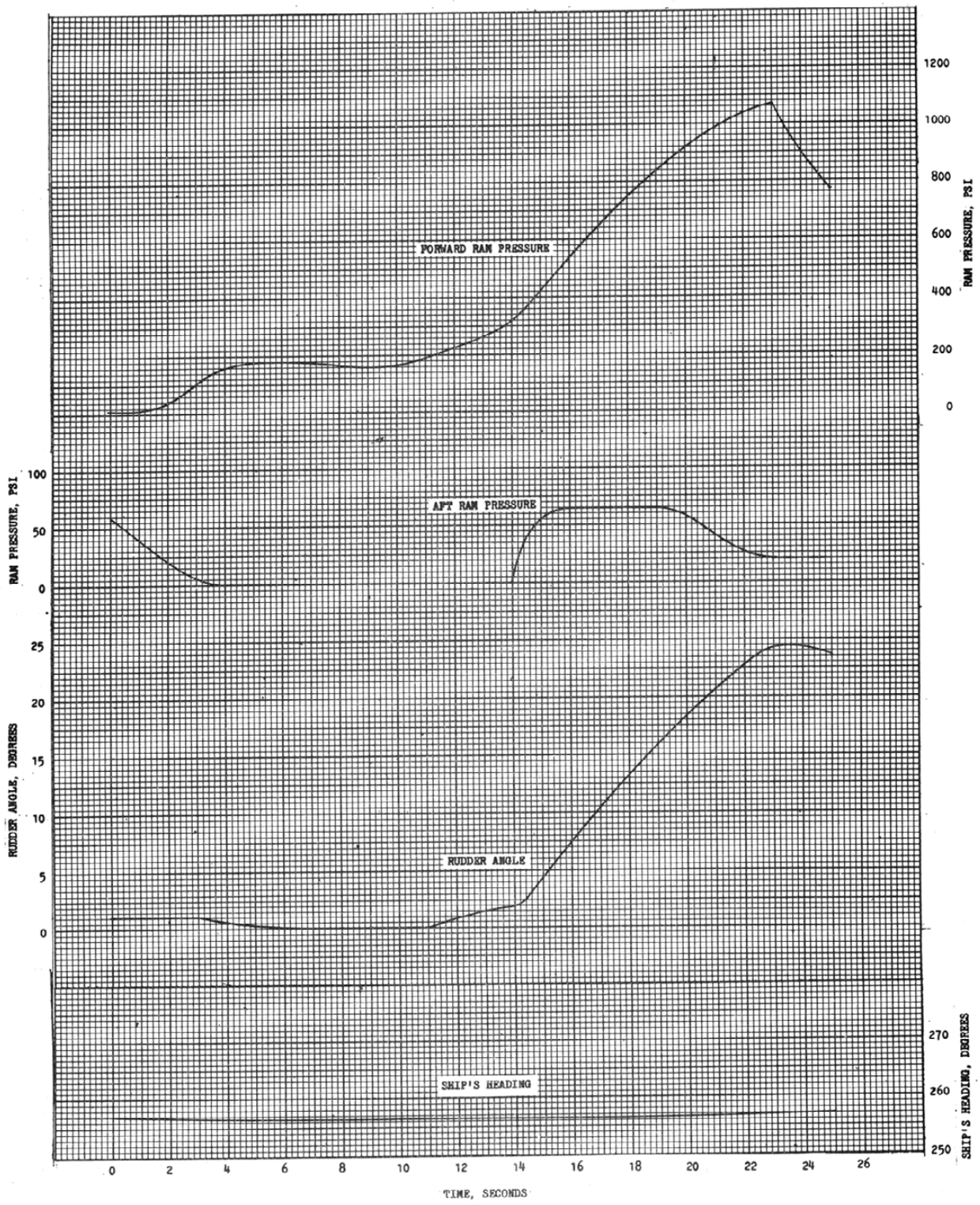

Figure 29 - USS RIGEL (AF58)-Shifting Rudder From Amidships to 25 Degrees Right, Full Power Approach.

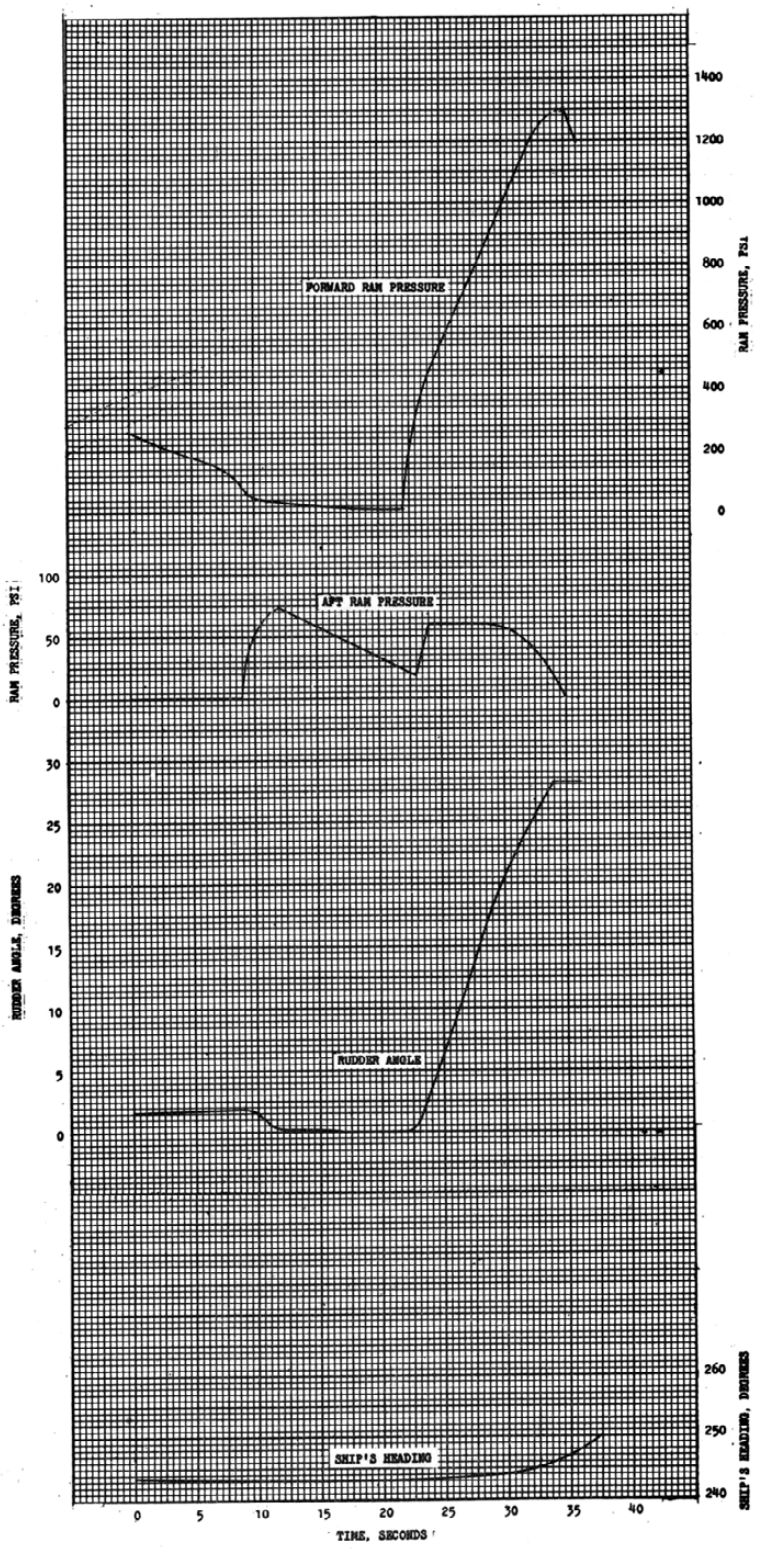

Figure 30 - USS RIGEL (AF58)-Shifting Rudder From Amidships to 30 Degrees Right, Full Power Approach.

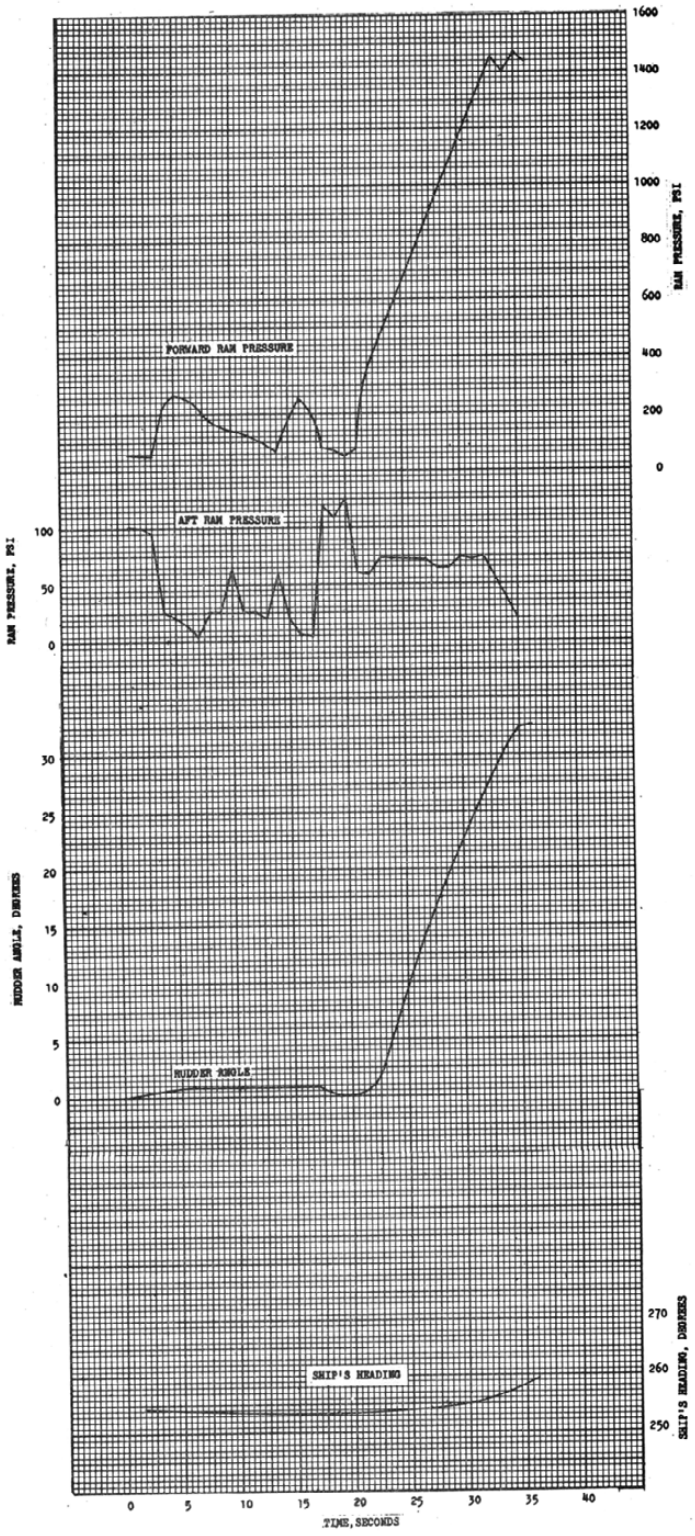

Figure 31 - USS RIGEL (AF58)-Shifting Rudder From Amidships to 35 Degrees Right, Full Power Approach.

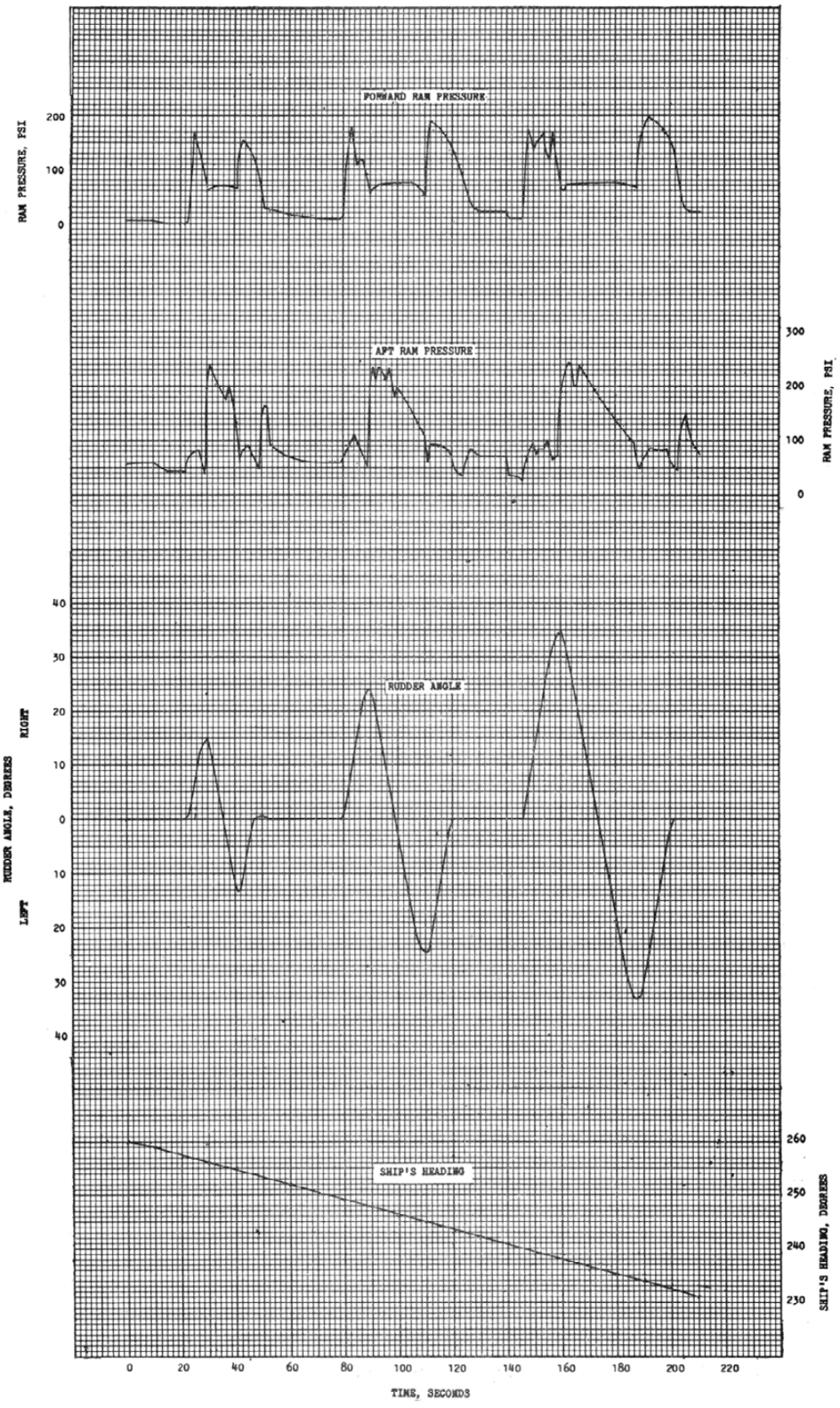

Figure 32 - USS RIGEL (AF58)-Zig-Zag Maneuvers at 1/3 Astern Speed.

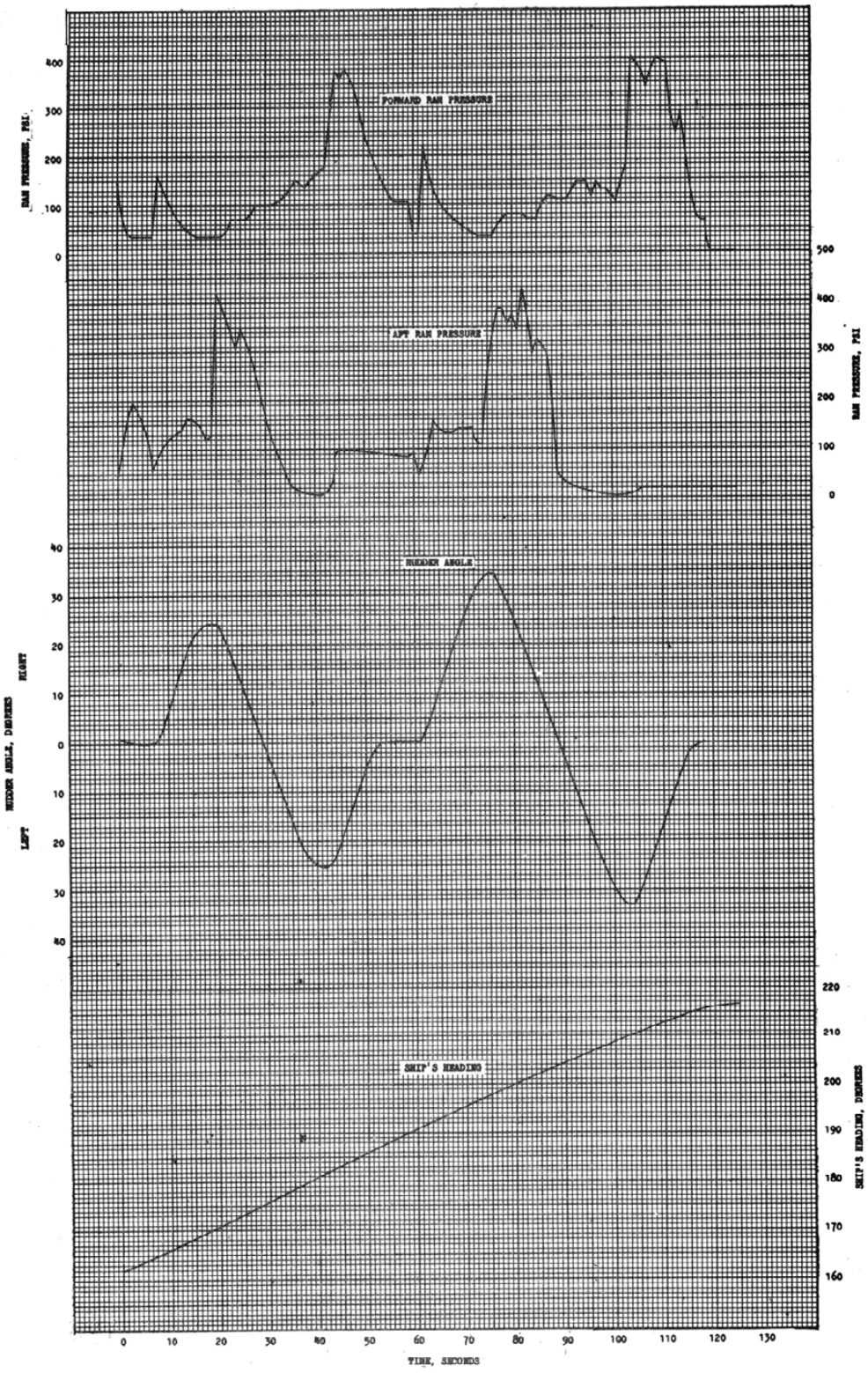

Figure 33 - USS RIGEL (AF58)-Zig-Zag Maneuvers at 2/3 Astern Speed.

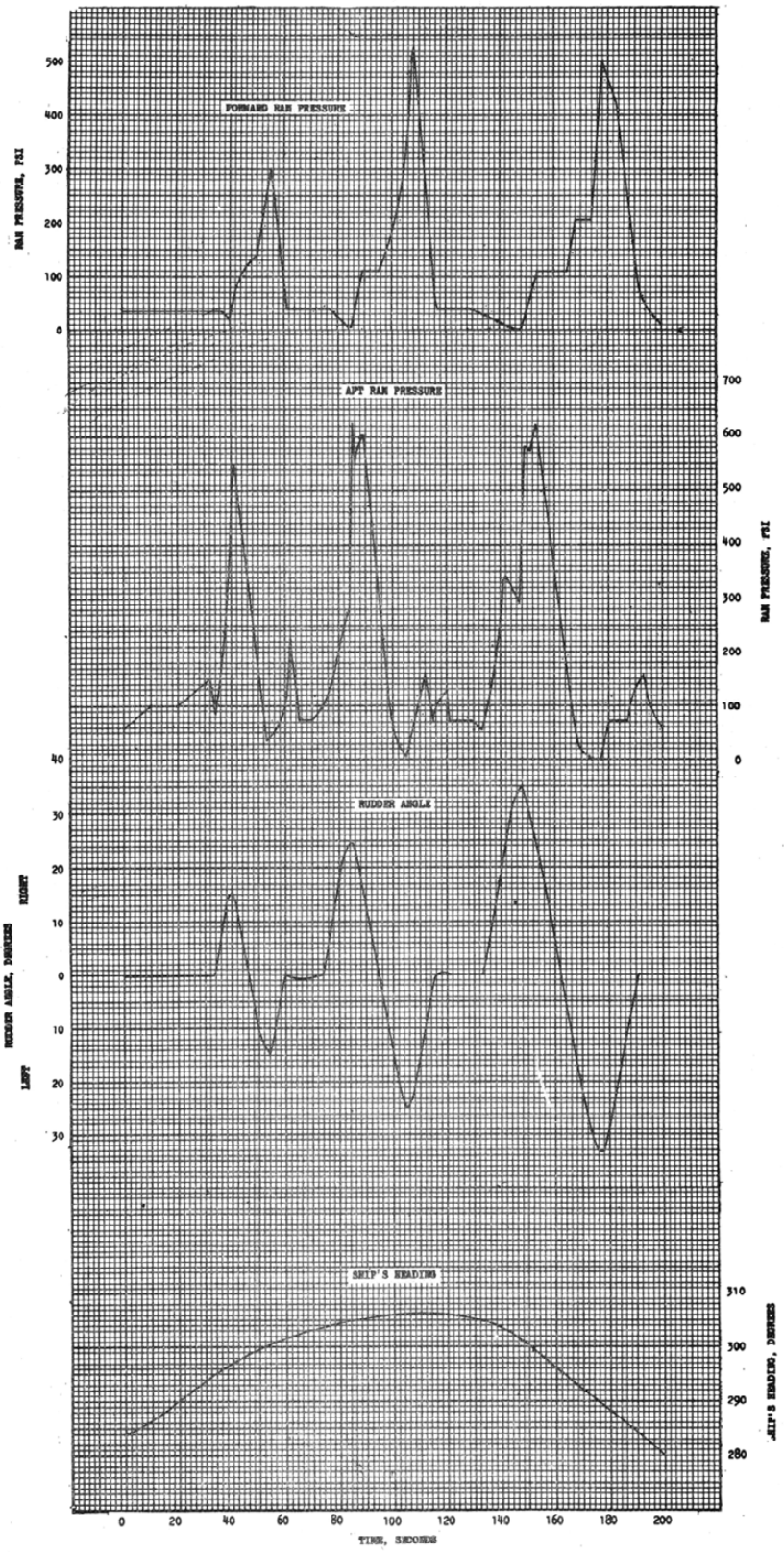

Figure 34 - USS RIGEL (AF58)-Zig-Zag Maneuvers at Full Power Astern.

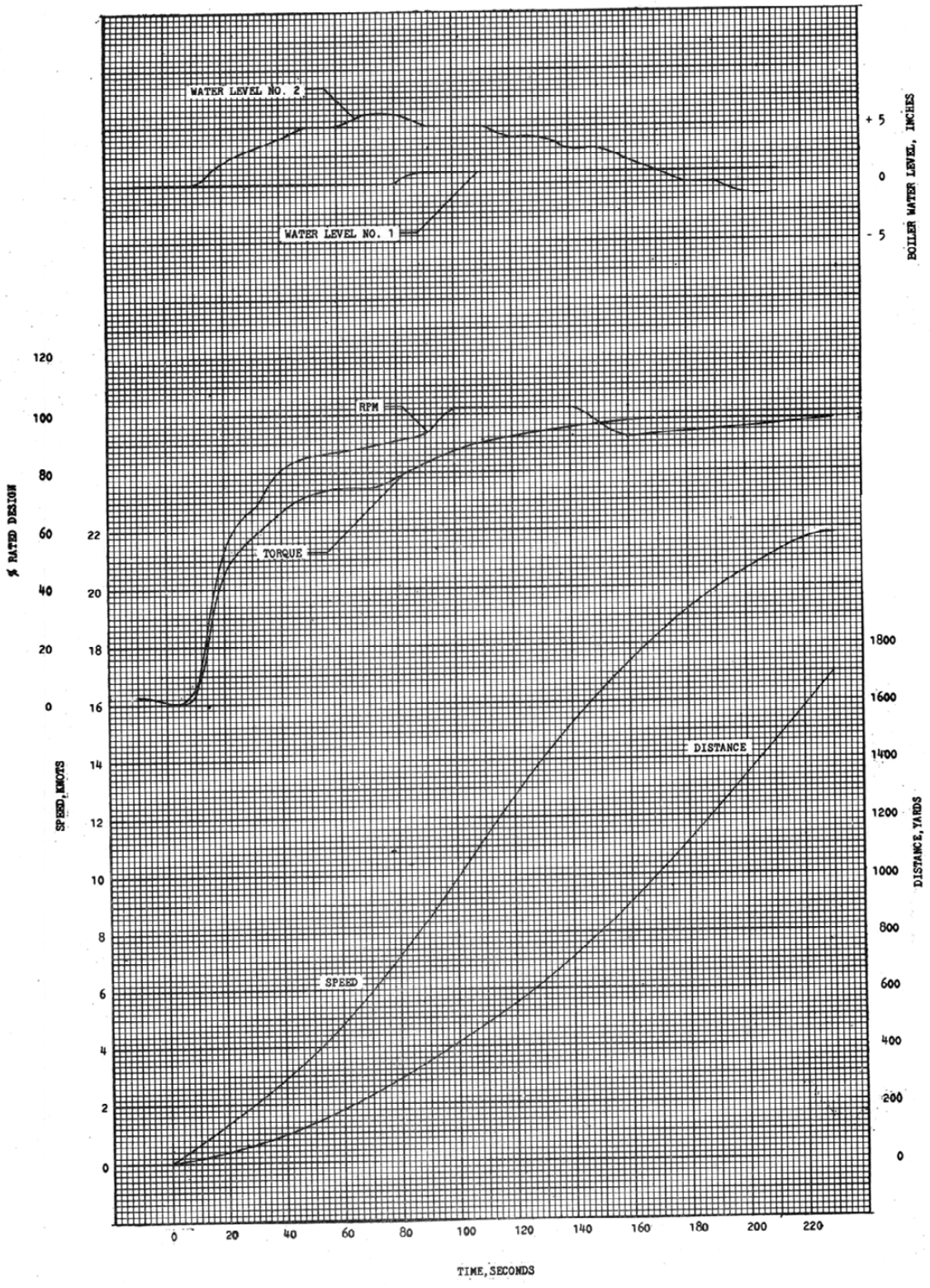

Figure 35 - USS RIGEL (AF58)-Acceleration Run From Dead in the Water to Full Power

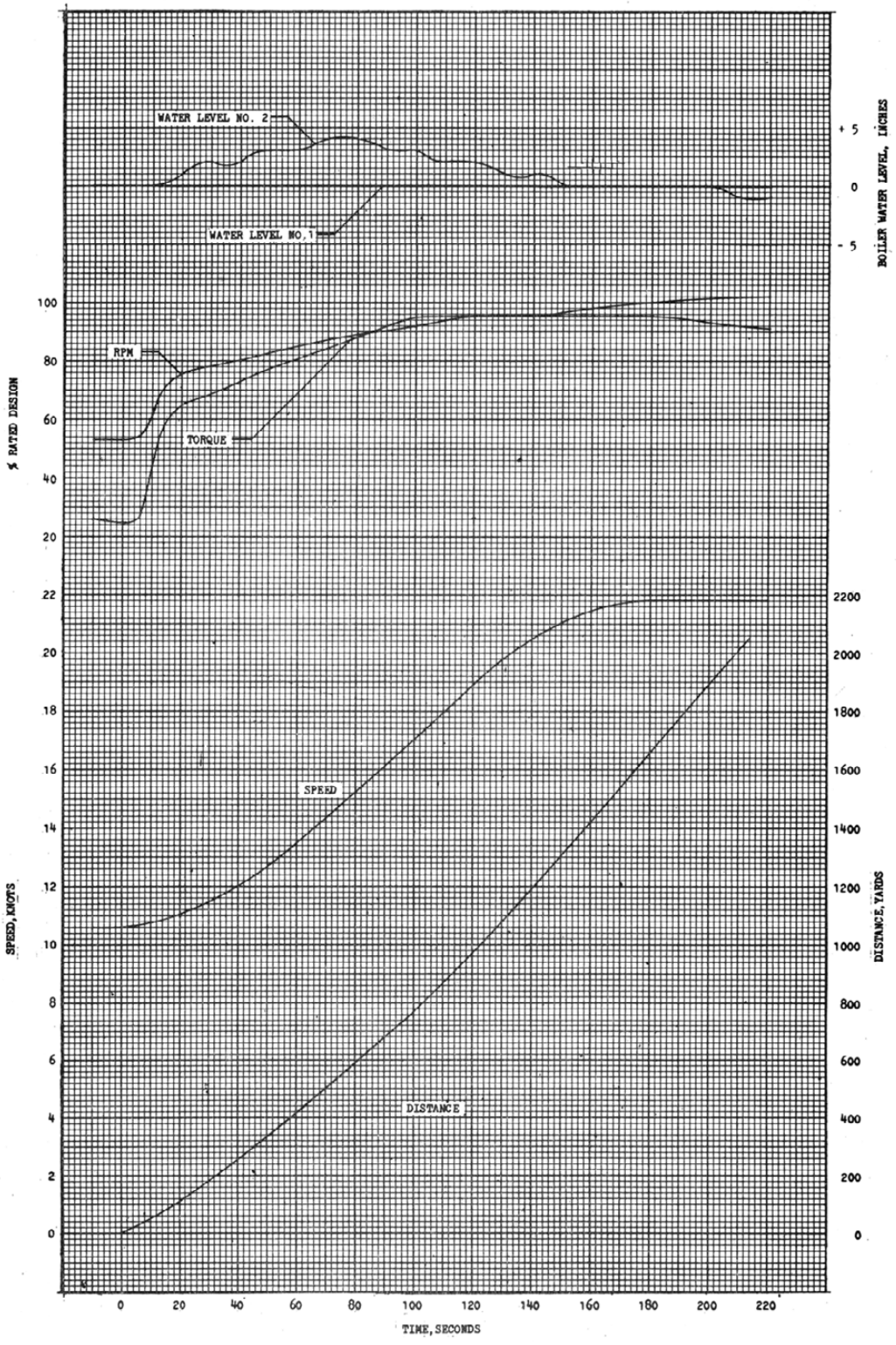

Figure 36 - USS RIGEL (AF58)-Acceleration Run From 12 Knots to Full Power.

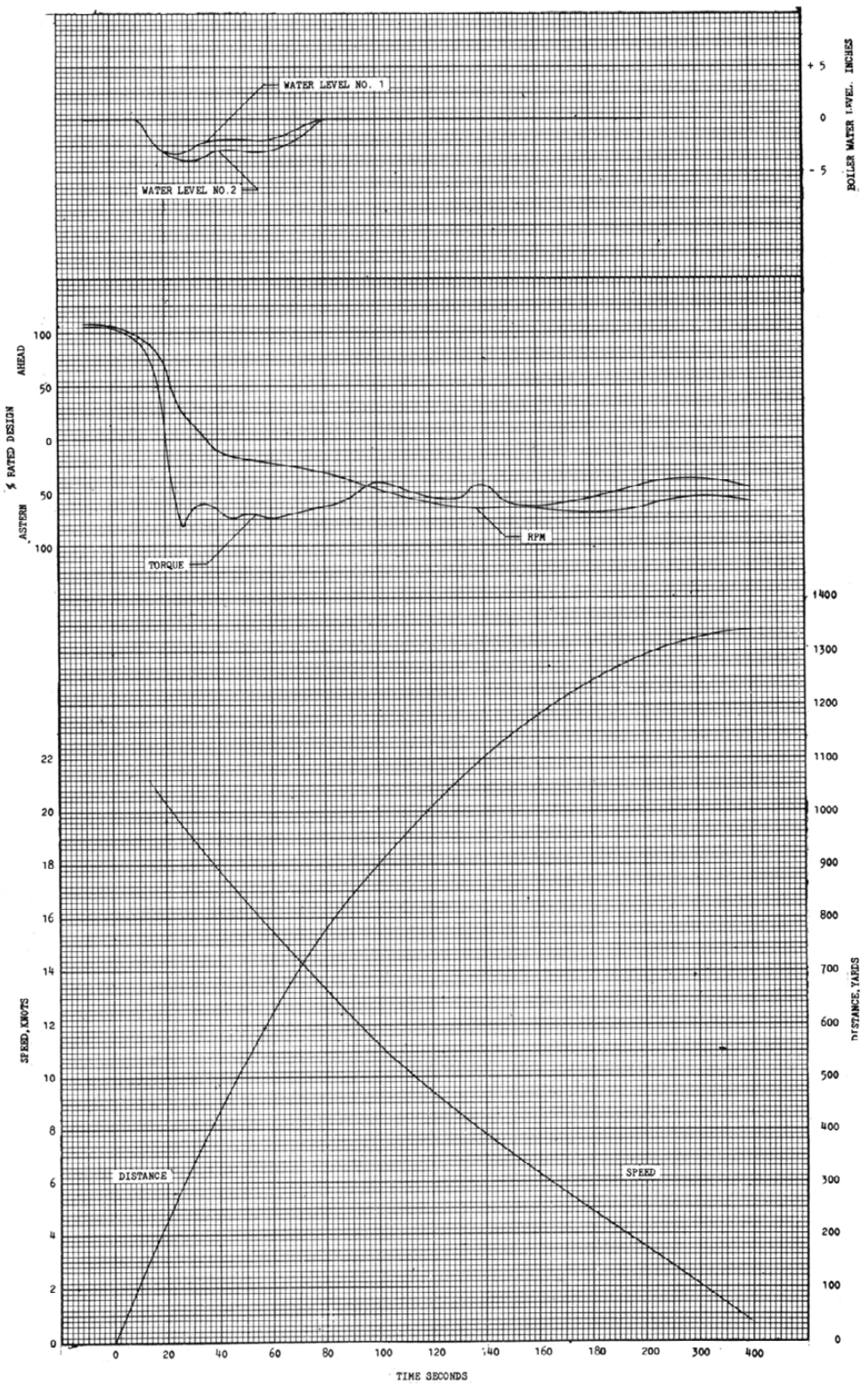

Figure 37 - USS RIGEL (AF58)-Deceleration Run From Full Power With Engine Ordered "Back Full."

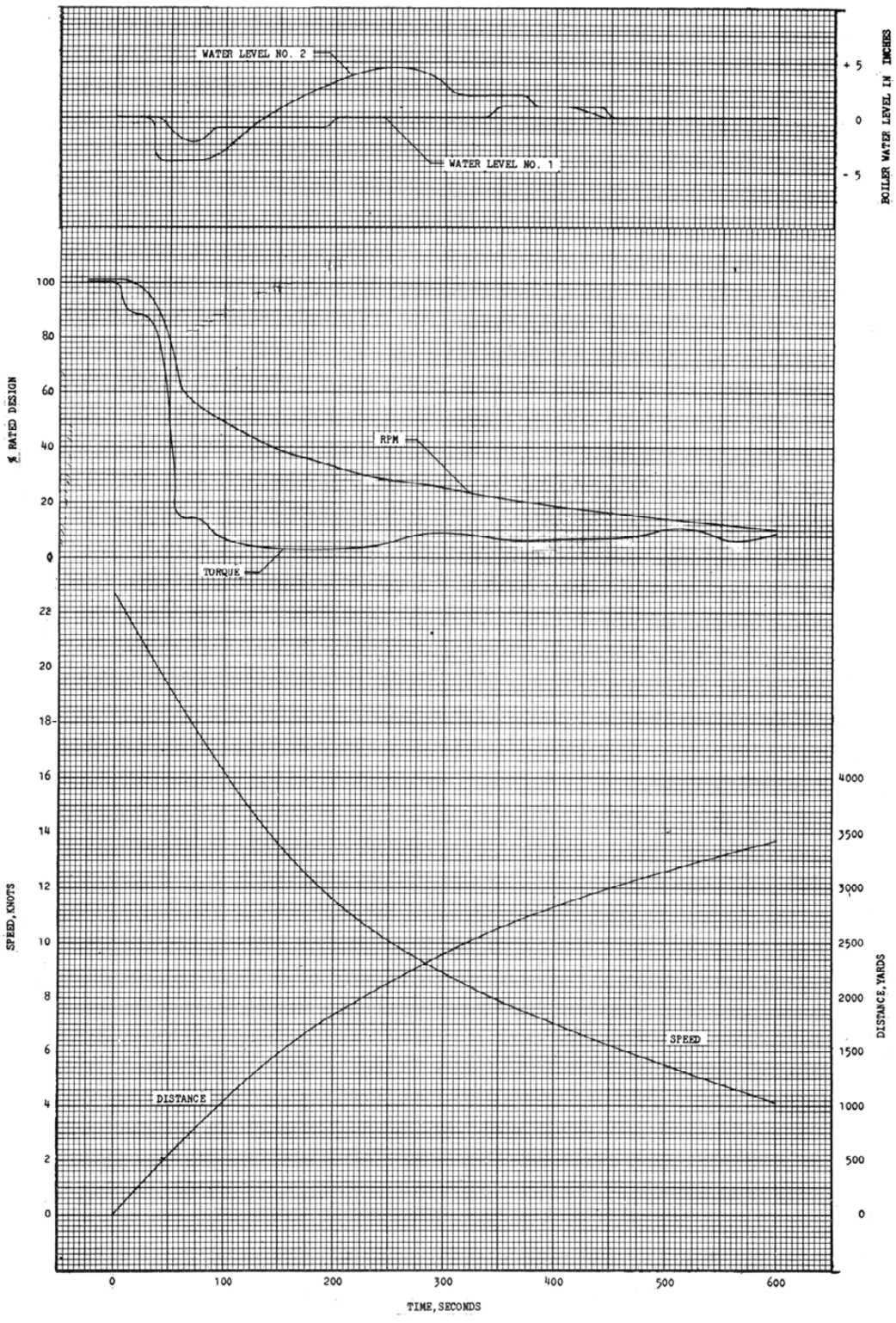

Figure 38 - USS RIGEL (AF58)-Deceleration Run From Full Power With Engine Ordered "Stop."

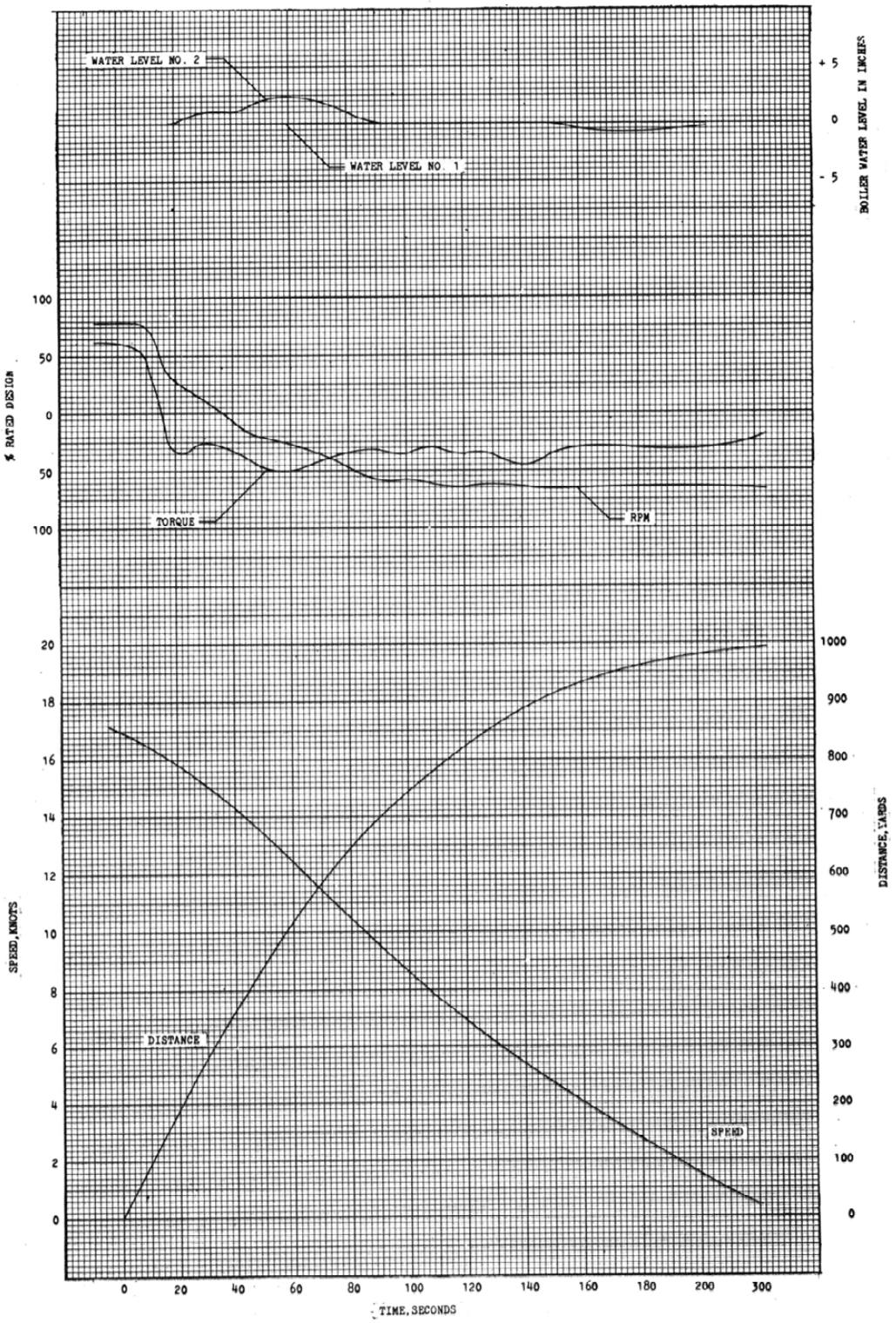

Figure 39 - USS RIGEL (AF58)-Deceleration Run From 17 Knots With Engine Ordered "Back Full."

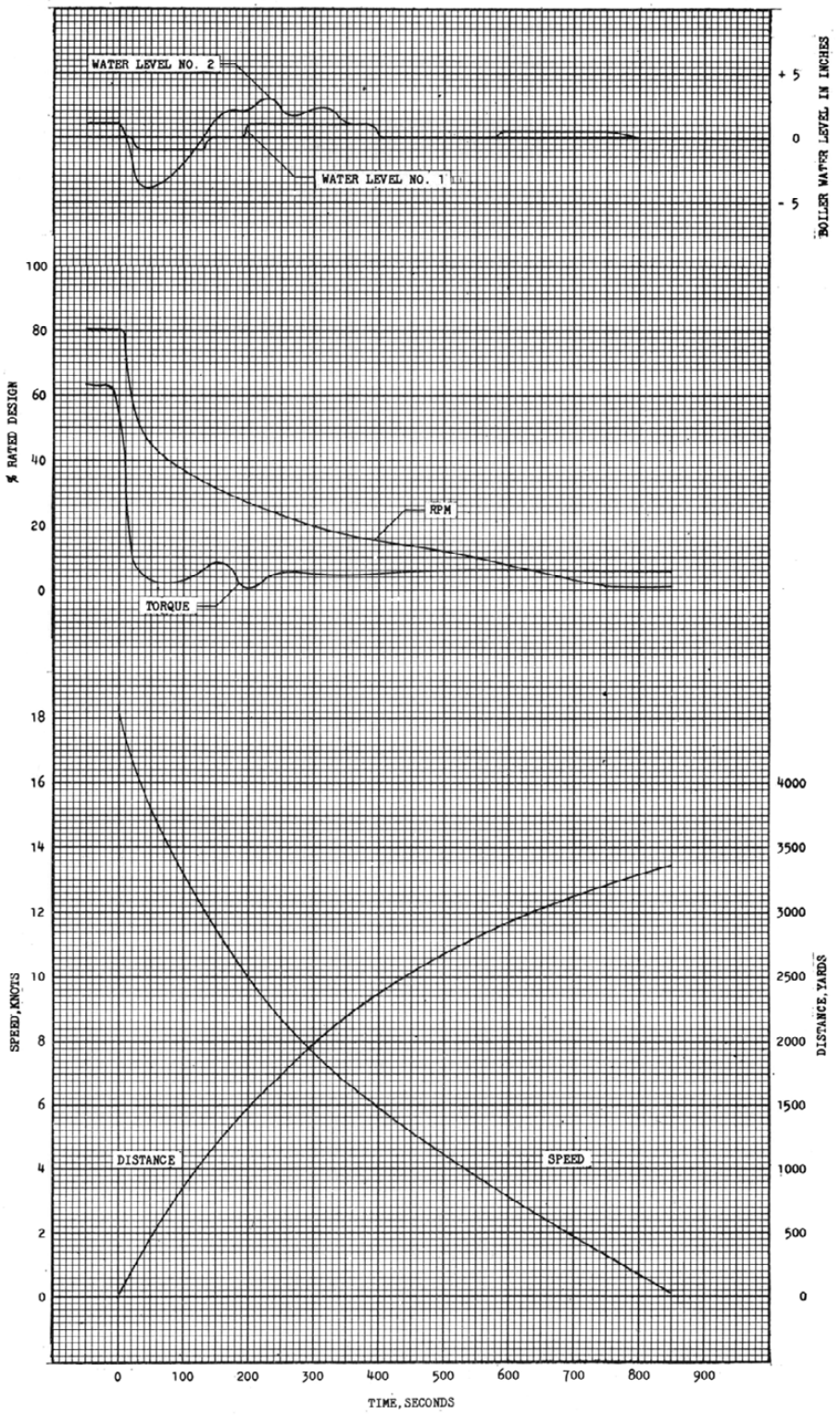

Figure 40 - USS RIGEL (AF58)-Deceleration Run From 17 Knots With Engine Ordered "Stop."

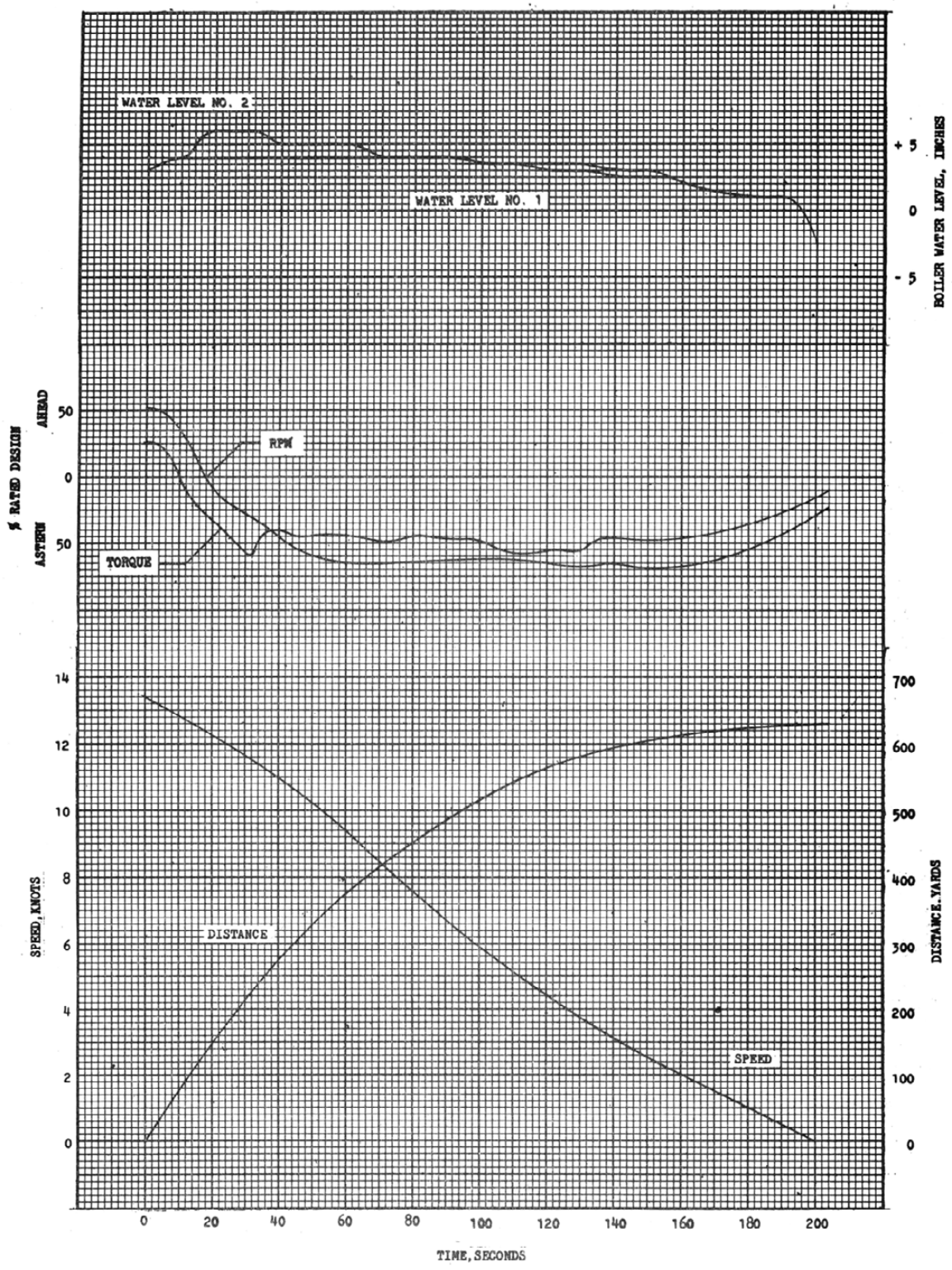

Figure 41 - USS RIGEL (AF58)-Deceleration Run From 12 Knots With Engine Ordered "Back Full."

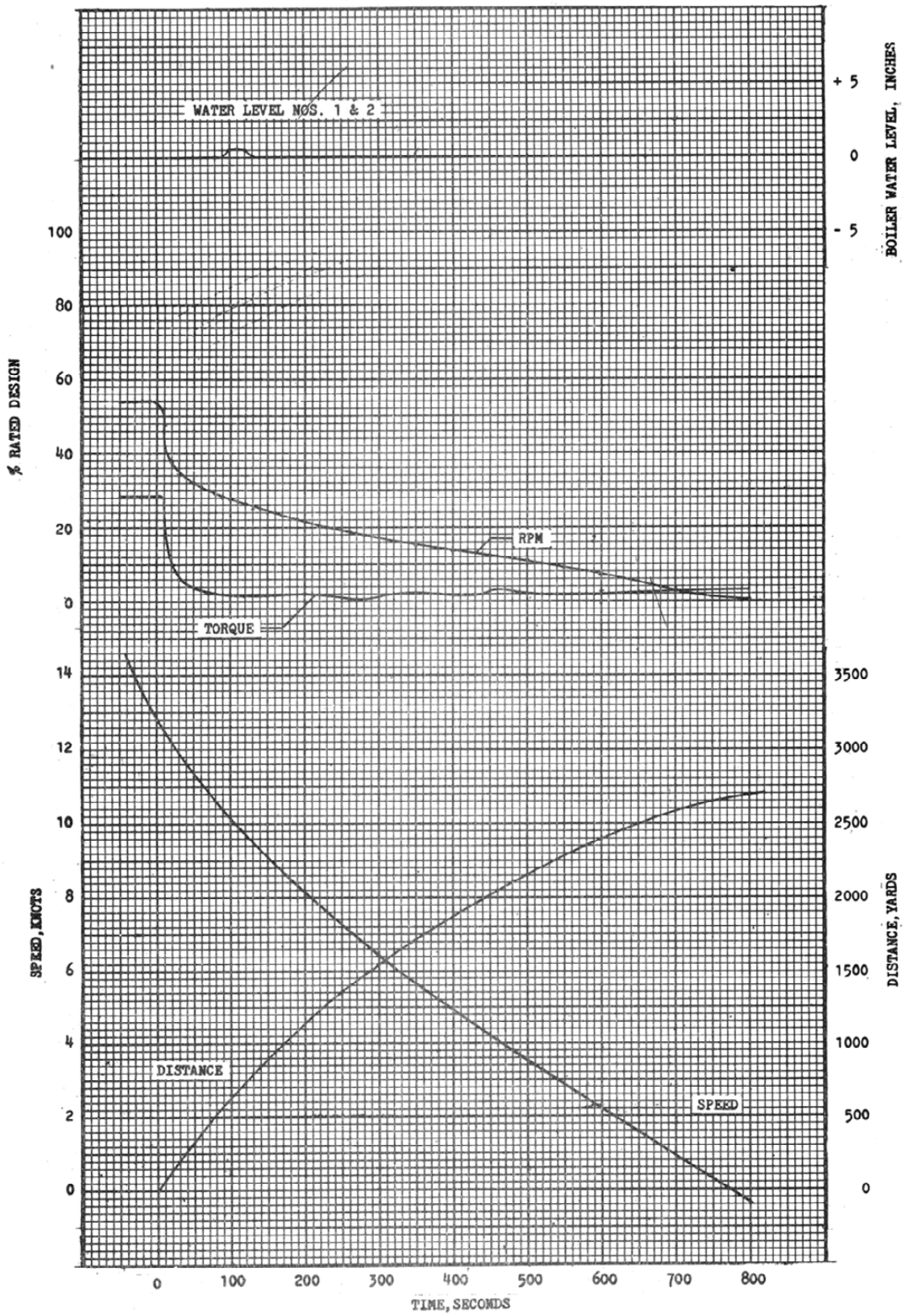

Figure 42 - USS RIGEL (AF58)-Deceleration Run From 12 Knots With Engine Ordered "Stop."

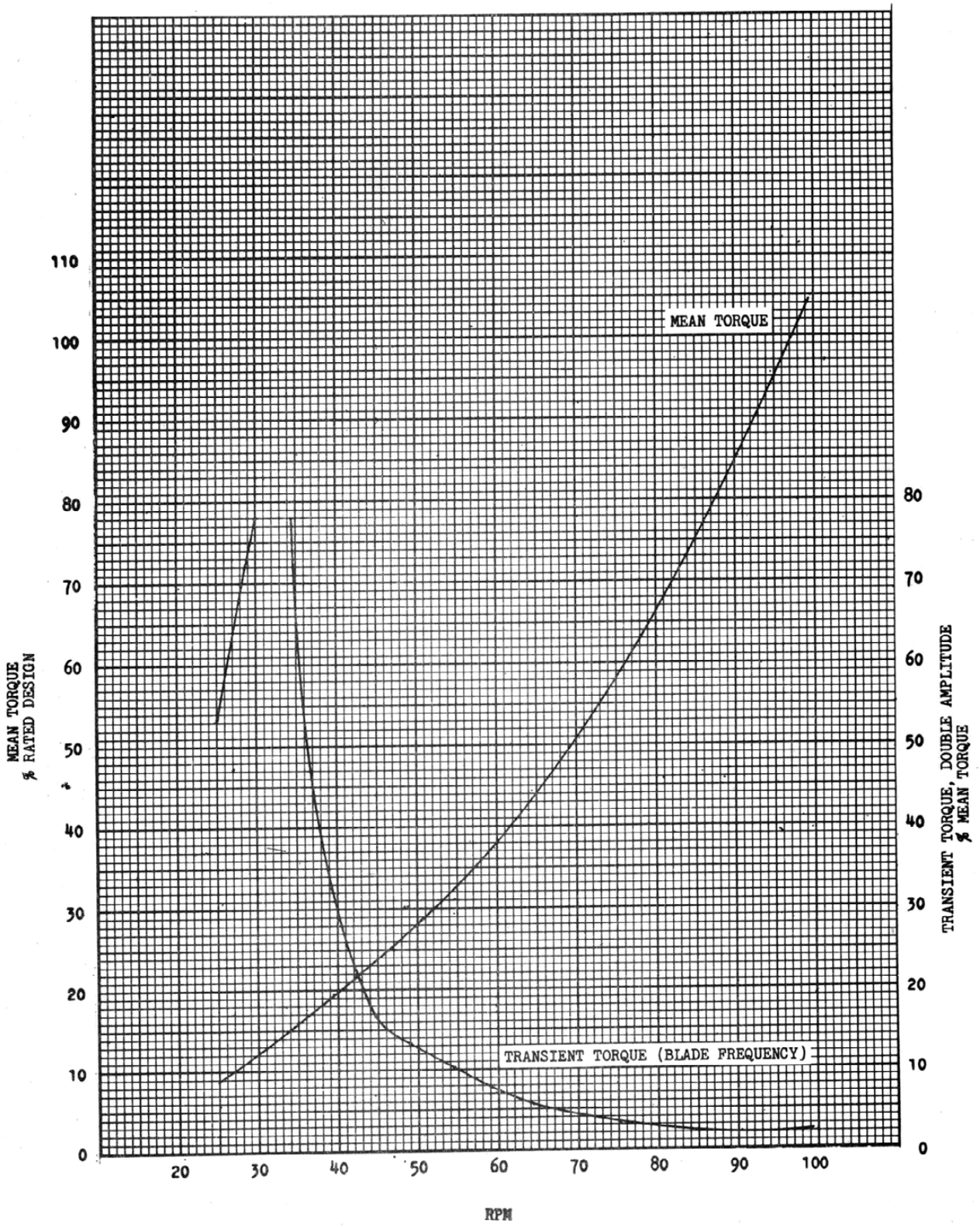

Figure 43 - USS RIGEL (AF58)-Transient Torque Measurements During Steady Speed Runs.

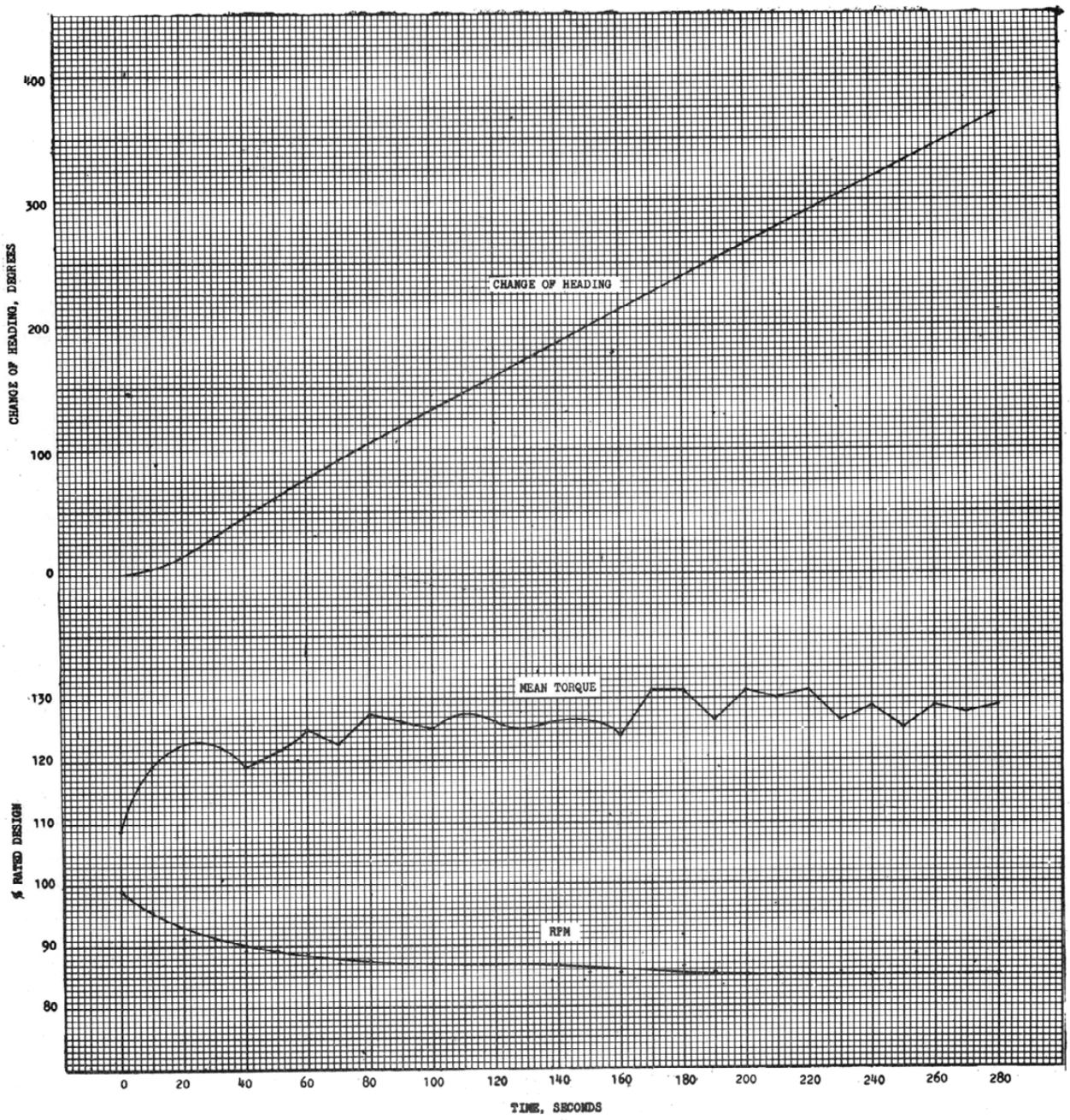

Figure 44 - USS RIGEL (AF58)-Torque and RPM Measurements During a Full Power Turn With 35 Degrees Right Rudder.

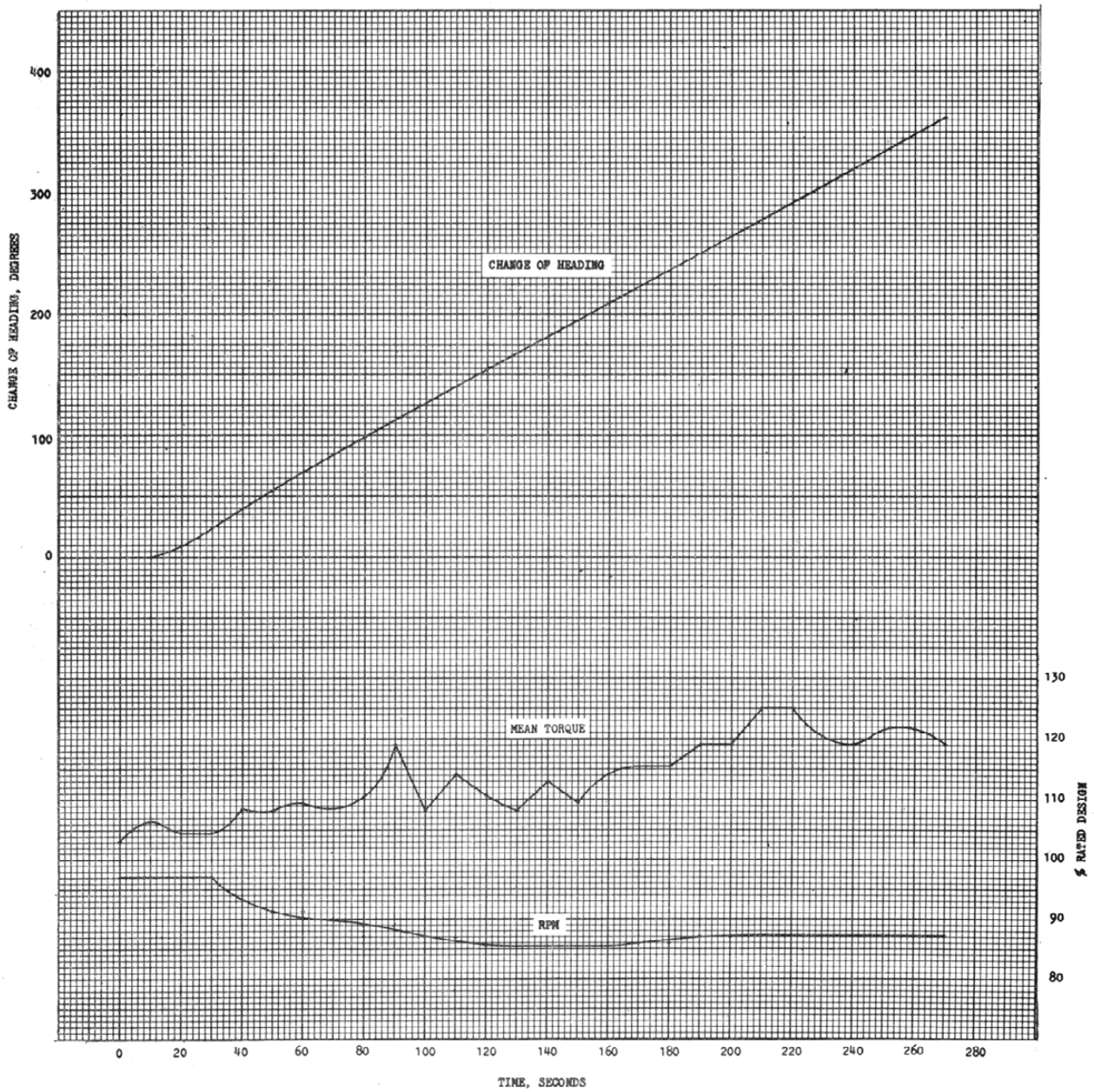

Figure 45 - USS RIGEL (AF58)-Torque and RPM Measurements During a Full Power Turn With 35 Degrees Left Rudder.

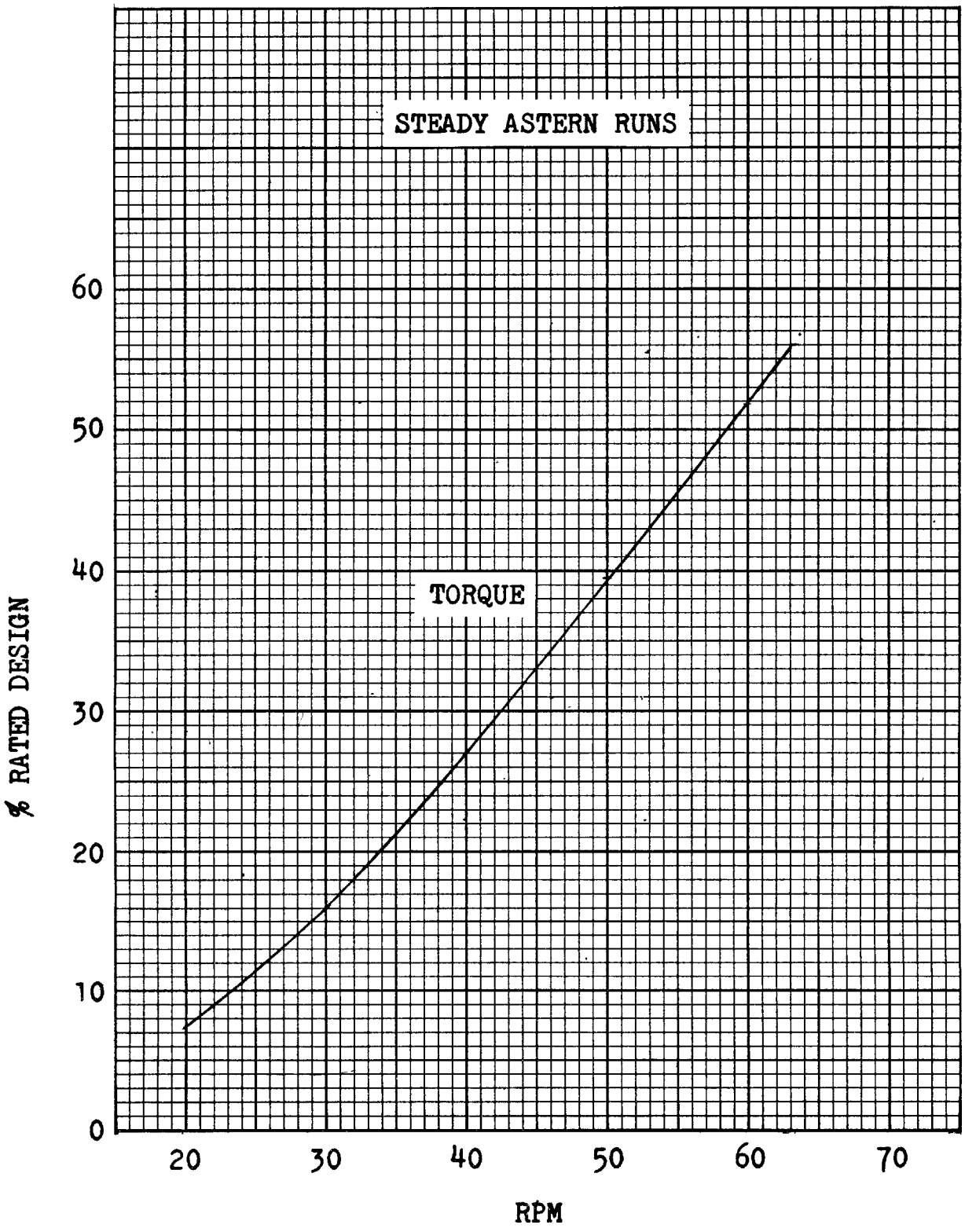

Figure 46 - USS RIGEL (AF58)-Torque Measurements During Astern Steady Speed Runs.

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