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This report contains the results of tactical and maneuvering trials and speed versus shaft rpm trials conducted on United States Coast Guard Cutter KATMAI BAY (WTGB-101). KATMAI BAY is the lead ship of a new class of ice-breaking tugboats. The trials were conducted in Whitefish Bay, Lake Superior, Michigan. Tactical data determined that the ship has a tactical diameter of approximately three ship lengths when using 30 degrees rudder.

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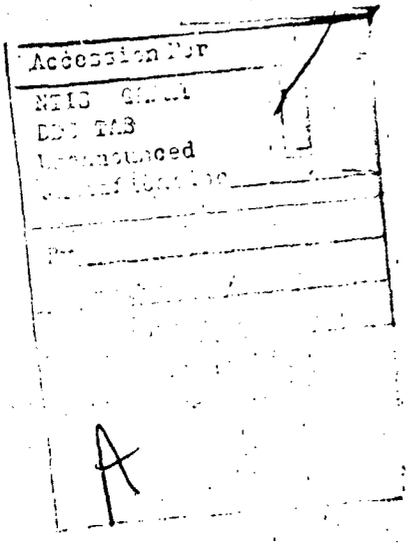
Maneuvering data indicated that the ship could stop in 40 seconds with a reach of four ship lengths from an approach speed of 12.8 knots when ordering full astern power. Ship's speed versus propeller shaft rpm trials indicate that the ship can obtain a speed of 14.7 knots at an average rpm of 303.7.



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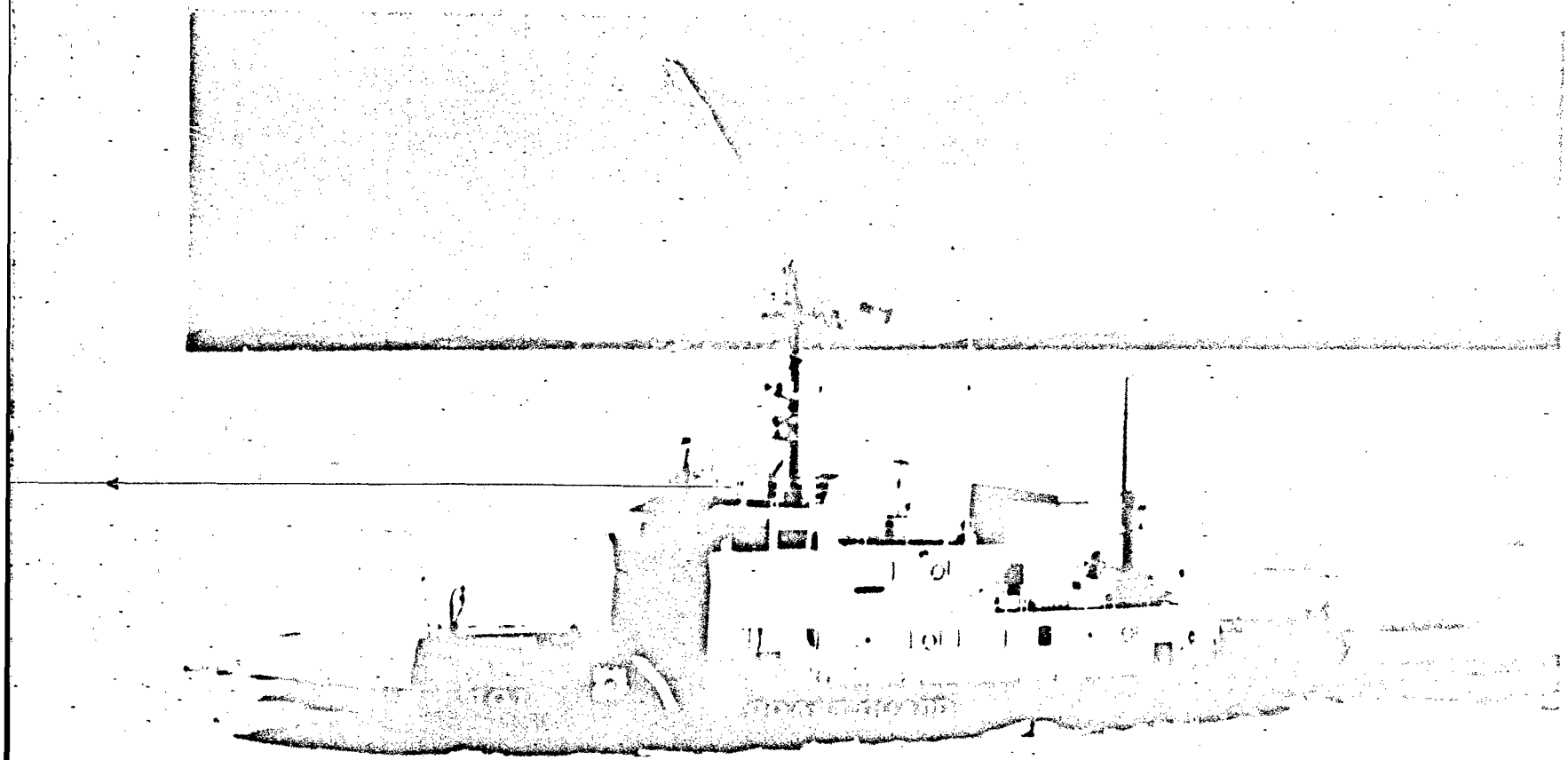


ABSTRACT

This report contains the results of tactical and maneuvering trials and speed versus shaft rpm trials conducted on United States Coast Guard Cutter KATMAI BAY (WTGB-101). KATMAI BAY is the lead ship of a new class of ice-breaking tugboats. The trials were conducted in Whitefish Bay, Lake Superior, Michigan. Tactical data determined that the ship has a tactical diameter of approximately three ship lengths when using 30 degrees rudder. Maneuvering data indicated that the ship could stop in 40 seconds with a reach of four ship lengths from an approach speed of 12.8 knots when ordering full astern power. Ship's speed versus propeller shaft rpm trials indicate that the ship can obtain a speed of 14.7 knots at an average rpm of 303.7.

ADMINISTRATIVE INFORMATION

The tactical, maneuvering, and speed versus shaft rpm trials on KATMAI BAY were authorized by the Commandant, United States Coast Guard, letter 9080, Serial 333 of 13 June 1978. The work was accomplished under David W. Taylor Naval Ship Research and Development Center Work Unit Number 1536-204.

INTRODUCTION

The new U.S. Coast Guard Cutter KATMAI BAY (WTGB-101) was commissioned in Cleveland, Ohio on 8 January 1979. KATMAI BAY is the lead ship of a new class of ice-breaking tugboats designed to have greater multi-mission capabilities than the 110-foot (33.5-meter) WYTM. The most significant differences include: greater horsepower; greater speed; longer range; increased ice-breaking capability; a hull lubrication system; greater degree of automation; and better habitability. During the months of January and February 1979, extensive ice-breaking trials were conducted on KATMAI BAY. Data obtained from these ice-breaking trials are the subject of a separate report. On 9 and 10 July 1979, speed versus rpm and tactical and maneuvering trials were conducted on KATMAI BAY. These trials were conducted on a trial course established in Lake Superior's Whitefish Bay. This report is concerned with the reporting of data obtained during these trials.

The trial program for KATMAI BAY consisted of a series of speed versus rpm runs, right and left tactical circles at three ship speeds, deceleration runs, quick reversals, spiral maneuvers, and an astern run powered only by the forward bubbler system. The results of the spiral maneuvers will be reported by the Coast Guard Research and Development Center. These trials were conducted by the Coast Guard Research and Development Center, Groton, Connecticut, David W. Taylor Naval Ship Research and Development Center, Bethesda, Maryland, and members of the ship's force.

SHIP CHARACTERISTICS AND TRIAL CONDITIONS

KATMAI BAY is equipped with two diesel engines capable of delivering 2500 shaft horsepower (1864 kilowatts). The diesel engines drive two 125 kW generators which supply power for an electric motor that drives the main propulsion shaft. The ship is equipped with a single rudder mounted on the centerline of the ship. Ship and propeller characteristics are presented in Table 1.

TABLE 1 - SHIP AND PROPELLER CHARACTERISTICS

SHIP CHARACTERISTICS		
Length Overall, ft (m)	140.0	(42.7)
Length between Perpendiculars, ft (m)	130.0	(39.6)
Maximum Beam, ft (m)	37.5	(11.4)
Mean Draft (Fresh Water), ft (m)	12.0	(3.7)
Maximum Full Load Displacement, ton (metric ton)	650.0	(739.6)
Freeboard to Main Deck (minimum), ft (m)	6.0	(1.8)
Shaft Horsepower, (kW)	2500	(1864)
Speed (maximum), knot	14.7	
Speed (cruising), knot	12.0	
Endurance, 12 knots per route, mile (km)	4000	(7413)

TABLE 1 (Continued)

PROPELLER CHARACTERISTICS	
Propeller Diameter, ft (m)	8.5 (2.6)
Pitch at 0.7 Radius, ft (m)	6.1 (1.9)
Pitch/Diameter	0.715
Mean Width Ratio	0.356
Projected Area/Developed Area	0.594
Blade Thickness Fraction	0.067
Expanded Area/Developed Area	0.697

KATMAI BAY is equipped with a bubbler system which can emit air from four manifolds near the keel. Air is emitted from the manifolds while the ship is operating in ice and causes an upward flow of air and water which lubricates the ice-hull interface. This flow of air and water causes a reverse thrust to be applied to the ship.

KATMAI BAY operated out of the Coast Guard Station at Saulte Ste. Marie, Michigan. The trials were conducted in Pendills Bay located in the southern end of Lake Superior's Whitefish Bay. Water depth in the area of operation averaged approximately 150 feet (45.7 meters). Wave heights were 0 to 1 foot (0.3 meter) and appeared to average approximately 0.5 foot (0.15 meter). Winds were very light for the day the speed versus rpm runs were conducted, approximately 3 to 5 knots from an easternly direction. On the day the tactical and maneuvering trials were conducted, the winds were from 4 to 6 knots ranging in direction from 170 to 230 degrees. The speed versus rpm trials were conducted by running parallel to a baseline on which tracking equipment was set. Each set rpm condition was run in alternate directions. Only two pass spots were necessary to obtain good trial data because current in the area was negligible and speeds obtained in alternate directions were for the most part identical. KATMAI BAY was at a displacement of 650 tons (739.6 metric tons) with a trim of 0.5 foot (0.15 meter) by the stern.

INSTRUMENTATION

Instrumentation provided for these trials was furnished and installed by the David W. Taylor Naval Ship Research and Development Center (DTNSRDC) with assistance from the Coast Guard Station at Saulte Ste. Marie, Michigan. Ship tracking was accomplished with a Motorola Mini-Ranger, a radar tracking system utilizing a receiver/transmitter unit aboard the ship and two transponders located at either end of a measured baseline. The western transponder was located at the boat ramp, while the eastern transponder was located on the beach adjacent to a state picnic area at a distance of 6694 yards (6123 meters) in a direction of 8 degrees magnetic from the ramp location. A processing unit determined the distance between the ship and the transponders. This information, along with the baseline distance and time, were automatically entered into a Hewlett Packard data processor which displayed X, Y position coordinates and ship speed. Ship's heading, propulsion shaft rpm, and rudder angle were also interfaced with the data processor and recorded. The rudder angle was obtained from the ship's synchro output. Ship's heading was obtained from the ship's gyro stepping motor outputs that drove the ship's gyro repeaters. These pulses were used to drive a stepping motor which in turn drove a synchro. Voltage outputs from the synchro transmitter were coupled with a solid state synchro and voltage outputs from the solid state synchro were calibrated and used for heading. Both ship's heading and change of heading from the approach course were recorded on flexible disks and an on-line printer and displayed on a cathode ray tube for easy monitoring. Propulsion shaft rpm was obtained by mounting sixty metal bars around the propulsion shaft in close proximity to a magnetic pickup. The voltage pulses generated were shaped and then counted. The counter data were also entered into the data processor. All instrumentation functioned well during the trials and data could be easily monitored. The display of X, Y position coordinates proved very useful in keeping the ship in an operating area for optimum range accuracy.

PRESENTATION AND DISCUSSION OF RESULTS

SPEED VERSUS RPM TRIALS

Data obtained during the speed versus rpm trials conducted on 9 July 1979 are presented in Table 2 and are shown graphically in Figure 1. The maximum speed attained was 14.7 knots at an average rpm of 303.7. The slight hump in the rpm curve at approximately 12 knots is due to the increased resistance caused by wavemaking at the speed length ratio of unity. These data are remarkably consistent and accurately characterize the rpm/speed relationship for KATMAI BAY under these trial conditions.

TACTICAL TRIALS

Tactical trials were conducted on 10 July 1979. The procedure for the conduct of a tactical circle was as follows. The ship was maneuvered into the desired area of the tracking range on a heading parallel to the tracking baseline. Seventy to ninety seconds of steady approach data were recorded, after which the execute signal was given and the rudder was moved as rapidly as possible to the desired angle. The rudder was held at this angle until the ship turned 540 degrees from the approach course. The run was ended, and the ship was set up for another circle.

Approach rpm, heading, time, and speed were recorded. Time of execute was indicated and change of heading after execute was recorded. A plot of the ship's path was made while the run was in progress. Thus it was easily decernable if the circle was acceptable. The data are presented in Table 3 and are shown graphically in Figures 2 through 5.

Change of heading curves presented in Figure 2 and the tactical diameter data in Figure 5 indicate that at 5 knots, KATMAI BAY turns slightly better with 10 and 20 degrees left rudder than with 10 and 20 degrees right rudder. With 30 degrees rudder at 5 knots, and at the higher speeds, there is no appreciable difference between left and right turns.

KATMAI BAY was found to have a minimum turning diameter of 162 yards (148 meters) at an approach speed of 14.7 knots when using 30 degrees left rudder. Advance, transfer, and tactical diameter were found to be essentially independent of approach speed, and to decrease with increasing rudder angle as expected.

TABLE 2 - SUMMARY OF RPM AND SPEED DATA
USCG CUTTER KATMAI BAY (WTGB-101)

Run No.	RPM	Ship Speed (knot)	Direction of Run
101	40.5	2.5	West
102	41.3	2.5	East
Average	40.9	2.5	
104	80.7	5.1	West
105	80.0	5.1	East
Average	80.4	5.1	
107	120.4	7.6	West
108	120.4	7.5	East
Average	120.4	7.6	
110	162.5	9.9	West
111	162.9	9.9	East
Average	162.7	9.9	
113	200.7	11.4	West
114	201.3	11.4	East
Average	201.0	11.4	
116	241.1	13.1	West
117	241.5	13.1	East
Average	241.3	13.1	
119	283.4	14.4	West
120	283.6	14.2	East
Average	283.5	13.4	
122	303.9	14.7	West
123	303.4	14.7	East
Average	303.7	14.7	

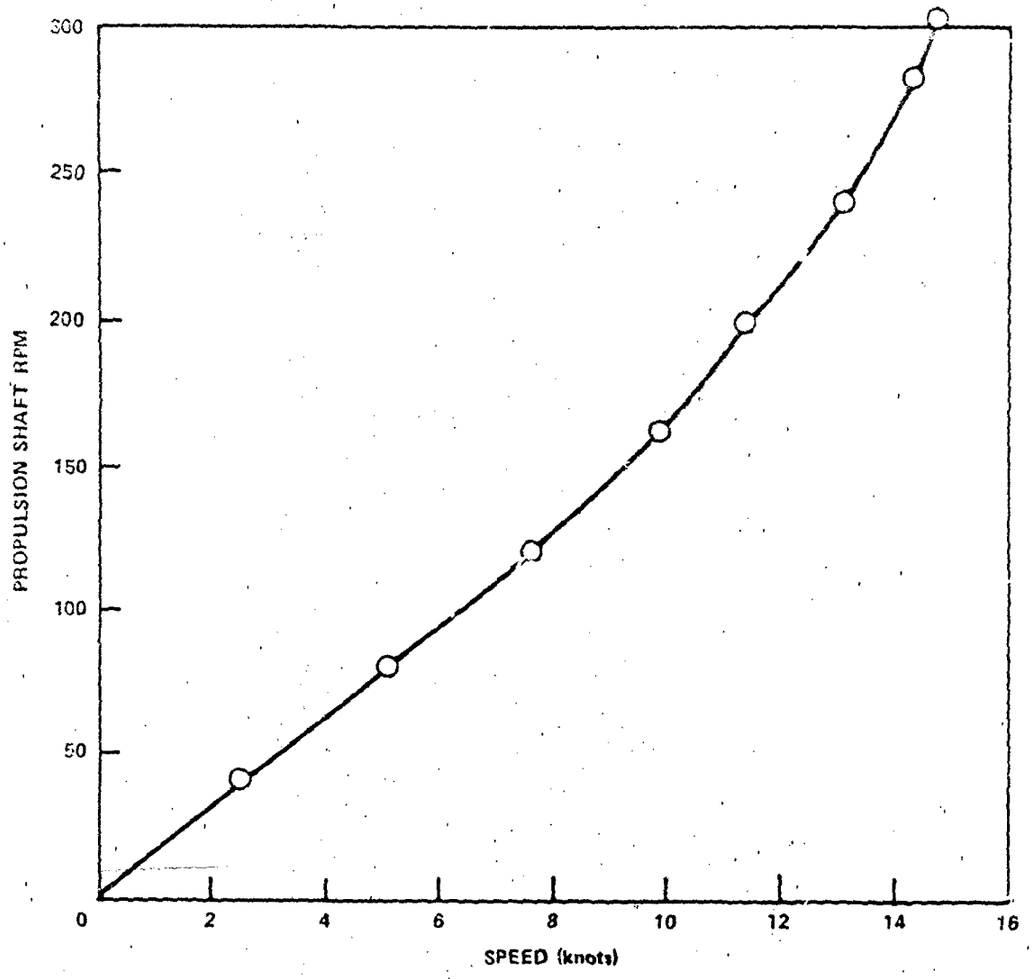


Figure 1 - Speed versus Revolutions per Minute Relationship for CGC KATMAI BAY (WTGB-101)

TABLE 3 - USCG CUTTER KATMAI BAY (WTGB-101), SUMMARY OF TACTICAL DATA

Run No.	Rudder Angle (deg)	Approach Course (deg)	Speed (knot) Approach	Speed (knot) Turn	Approach rpm	Advance (yd)	Advance (m)	Transfer (yd)	Transfer (m)	Tactical Diameter (yd)	Tactical Diameter (m)	Circle Diameter (yd)	Circle Diameter (m)	Time at 360° (s)
201	9.5 R*	264	5.0	4.4	81	294	269	189	173	420	384	405	370	314
202	19.5 R	268	5.5	3.6	79	160	146	125	114	242	221	222	203	340
203	29.5 R	264	5.5	2.9	78	118	108	74	68	172	157	153	140	292
204	10.0 L	262	5.0	4.3	80	241	220	187	171	386	353	365	334	473
205	20.0 L	262	5.0	3.4	80	164	150	94	86	212	194	199	182	326
206	28.5 L	262	5.3	2.9	80	136	124	71	65	166	152	147	134	280
207	10.5 L	263	9.9	9.2	164	278	254	206	188	431	394	431	394	263
208	20.0 R	263	9.9	7.6	164	166	152	103	94	234	214	224	205	195
209	30.0 R	263	9.9	6.3	164	149	136	72	66	171	156	157	144	219
210	9.7 R	264	10.0	9.2	164	262	240	192	176	397	363	391	362	241
211	20.5 L	262	10.0	7.5	164	180	165	101	92	225	206	215	197	161
212	29.5 L	261	9.9	6.1	164	150	137	68	62	164	150	151	138	139
213	10.5 R	263	14.6	14.3	304	270	247	190	174	410	375	420	384	164
214	19.5 R	263	14.8	12.8	304	177	162	103	94	236	216	238	218	104
215	29.5 R	263	14.7	11.2	304	155	142	77	70	174	159	162	148	81
216	9.5 L	263	14.6	14.2	304	284	260	203	186	423	387	422	386	166
217	18.7 L	262	14.7	12.7	304	165	151	103	94	227	208	225	206	99
218	28.5 L	263	14.8	10.6	304	140	128	83	76	162	148	150	137	79

*R is right; L is left.

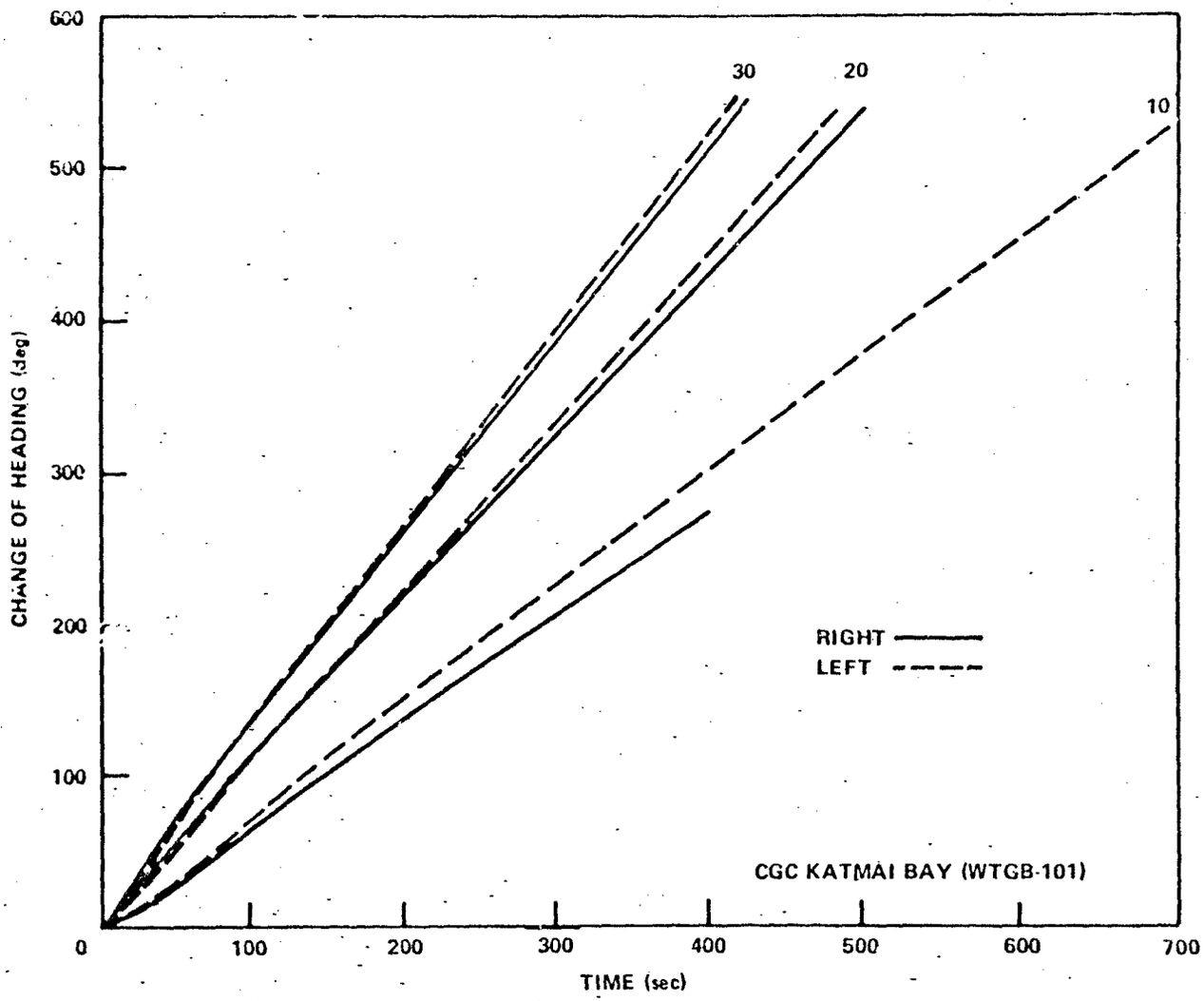


Figure 2 - Change of Heading Curves for 10, 20, and 30 Degrees Left and Right Rudder Turns from an Approach Speed of 5 Knots

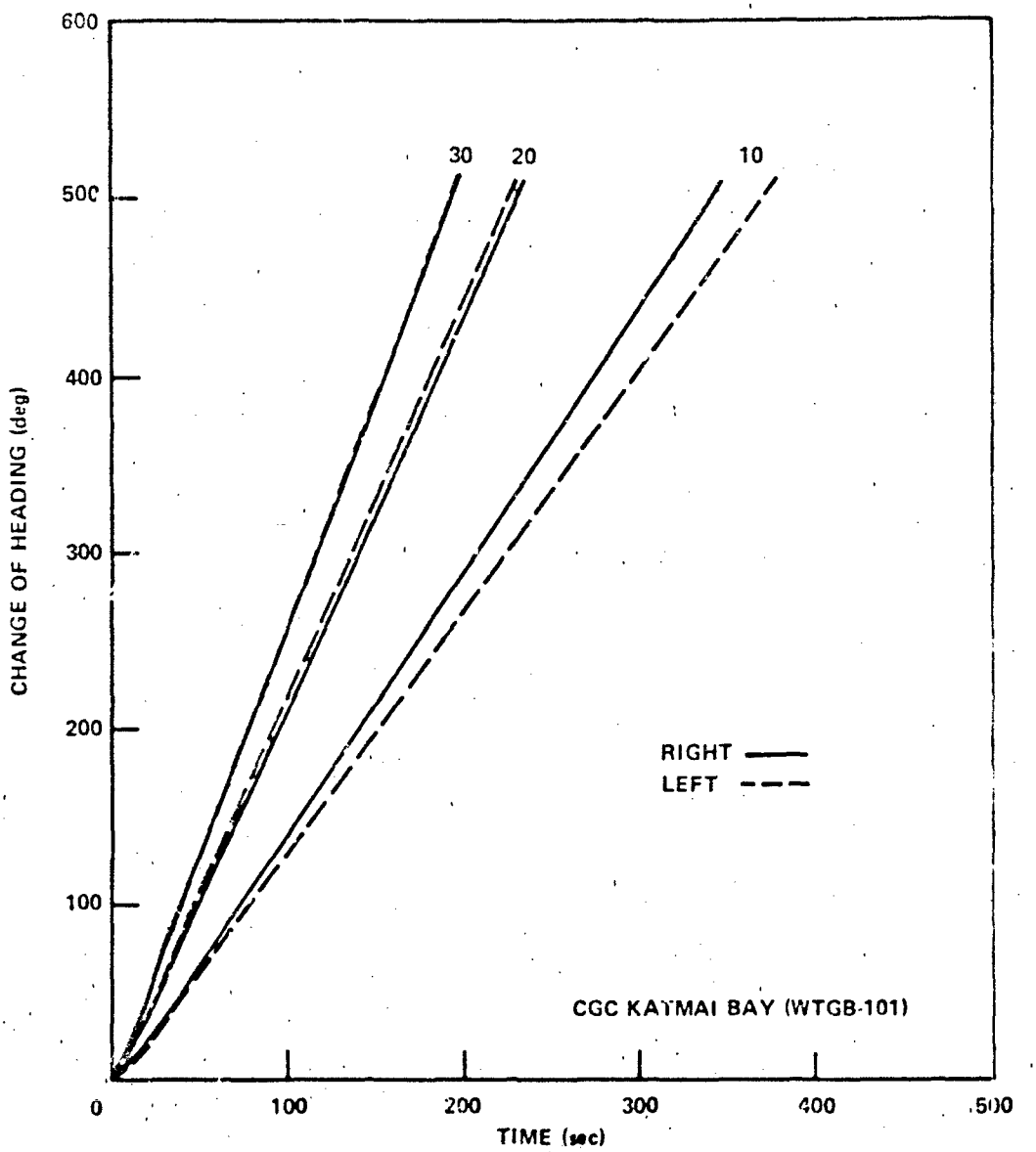


Figure 3 - Change of Heading Curves for 10, 20, and 30 Degrees Left and Right Rudder Turns from an Approach Speed of 10 Knots

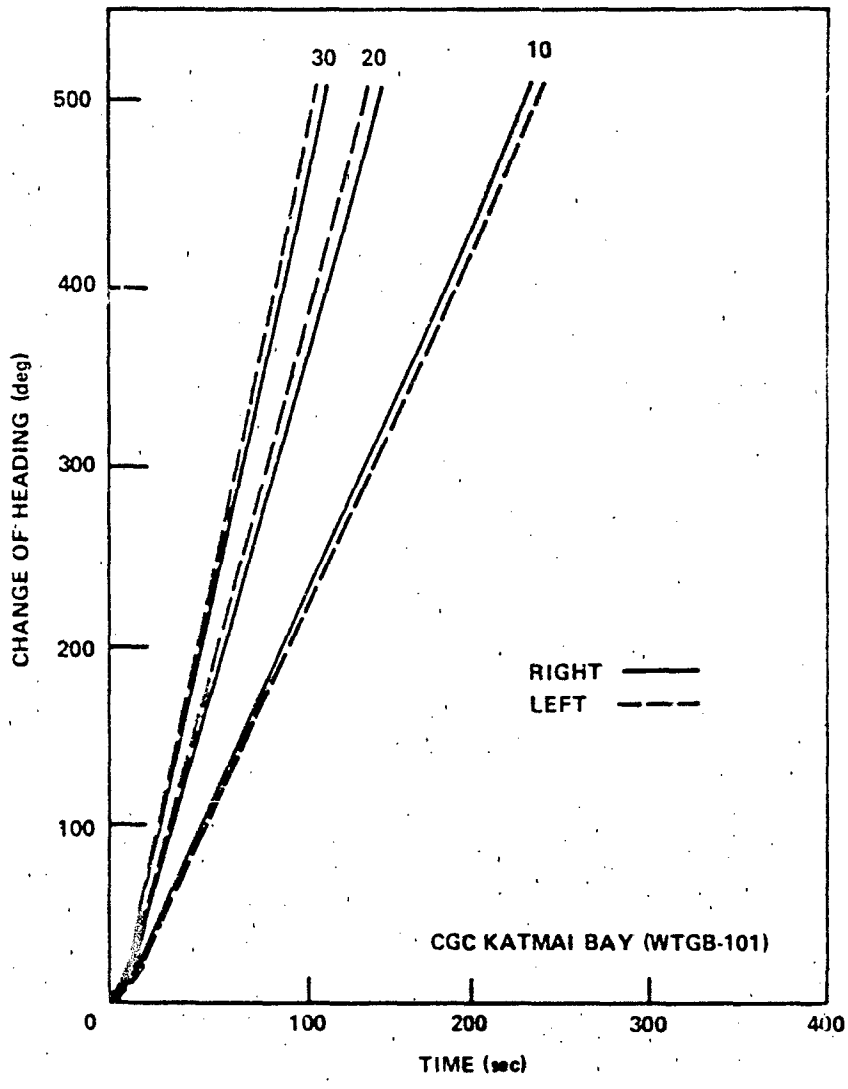


Figure 4 - Change of Heading Curves for 10, 20, and 30 Degrees Left and Right Rudder Turns from an Approach Speed of 14.7 Knots

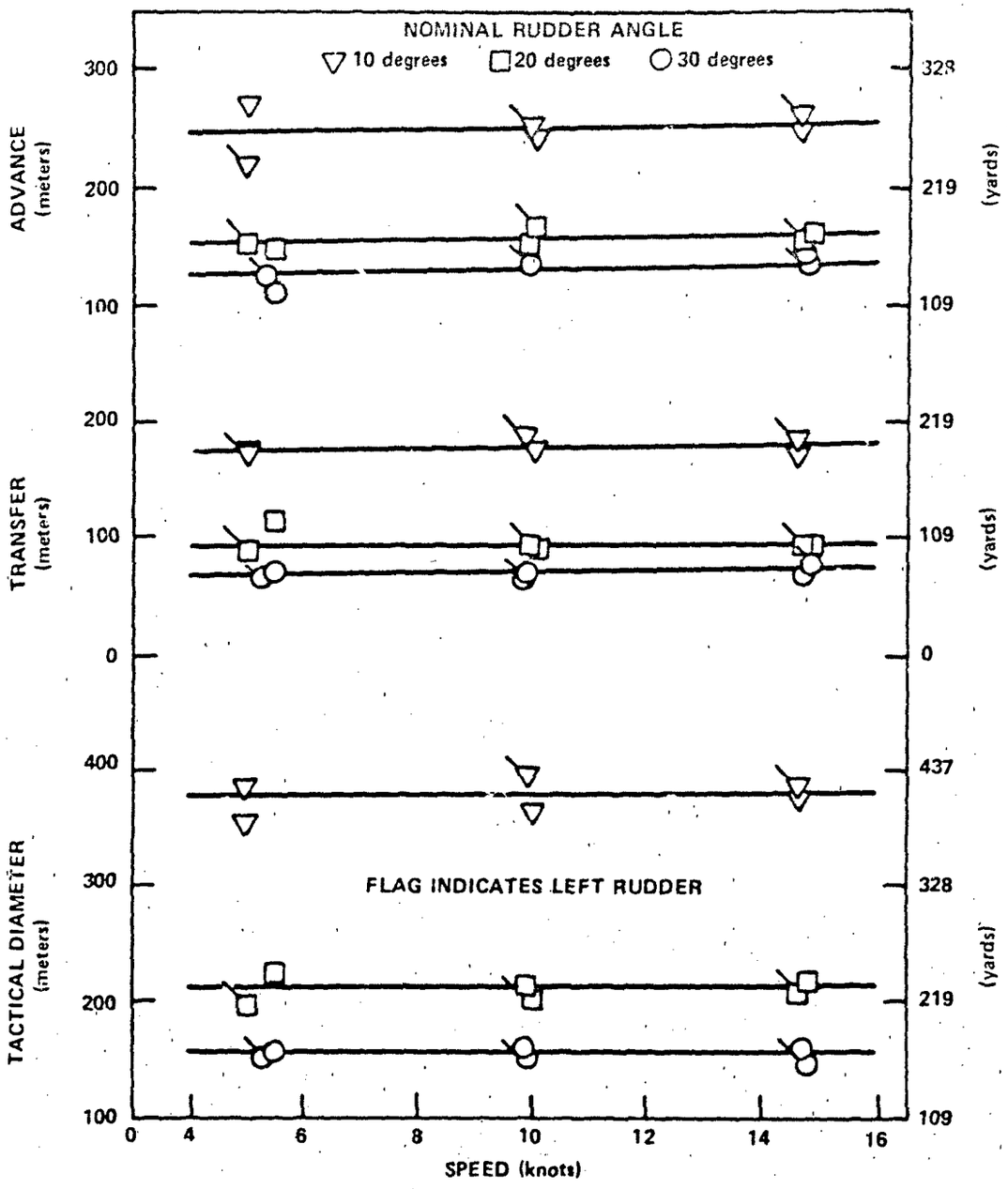


Figure 5 - CGC KATMAI BAY (WTGB-101), Advance, Transfer, and Tactical Diameter

DECELERATION TRIALS

Deceleration trial runs were interspersed with the tactical circles so that drift data taken from the circles could be used to correct the deceleration trial data. The deceleration runs were made by approaching the trial course parallel to the baseline at the desired speed and recording data during the steady approach. At execute, full astern power was applied to the propulsion shaft and tracking data, rpm, and heading were recorded until the ship was dead in the water. The results of these trials are presented in Figure 6. The curves for Run 301 are dashed at the end of the run. Data were not obtained at the low end of this curve because the tracking dating was not rapid enough to get another data point between the 17.5-second point and the dead in the water point. The dashed portion of the curve is an extrapolation from the existing data. From an approach speed of 12.8 knots, KATMAI BAY came dead in the water in 40 seconds and had a stopping distance of 175 yards (160 meters).

A reversal from 13.4 knots astern to full power ahead was made on the final day of the trials. The results of this maneuver are presented in Figure 7. The ship became dead in the water in 35 seconds and was going at a speed of 13 knots ahead within 70 seconds. The total distance covered in this maneuver from 13.4 knots astern to 13.0 knots ahead was 307 yards (281 meters). The distance from full astern execute to dead in the water was 166 yards (152 meters).

Two other reversals were conducted from full power ahead to full power astern. Both of these runs were terminated before the ship attained any appreciable asternway. The results obtained from these decelerations are presented as Figure 8 and the plots are terminated at the point where the ship became dead in the water. KATMAI BAY came to a stop within 44 to 47 seconds after the execute command was given. In that period, the ship traveled a distance of 208 to 219 yards (190 to 200 meters). The approach speed for these two runs was a little greater than the deceleration runs presented in Figure 6, thus the stopping distance was a little longer. Shaft rpm for Runs 401 and 403 tracked exactly until 18 seconds after execute. Run 403 then dropped in rpm, compared to Run 401, from 18 to 27

RUN NO.	APPROACH SPEED (khots)	REACH (meters)	TIME IN SECONDS TO DEAD IN THE WATER
301	5.0	36	20.5
302	7.8	69	25.5
303	10.0	104	32.0
304	12.8	160	40.0

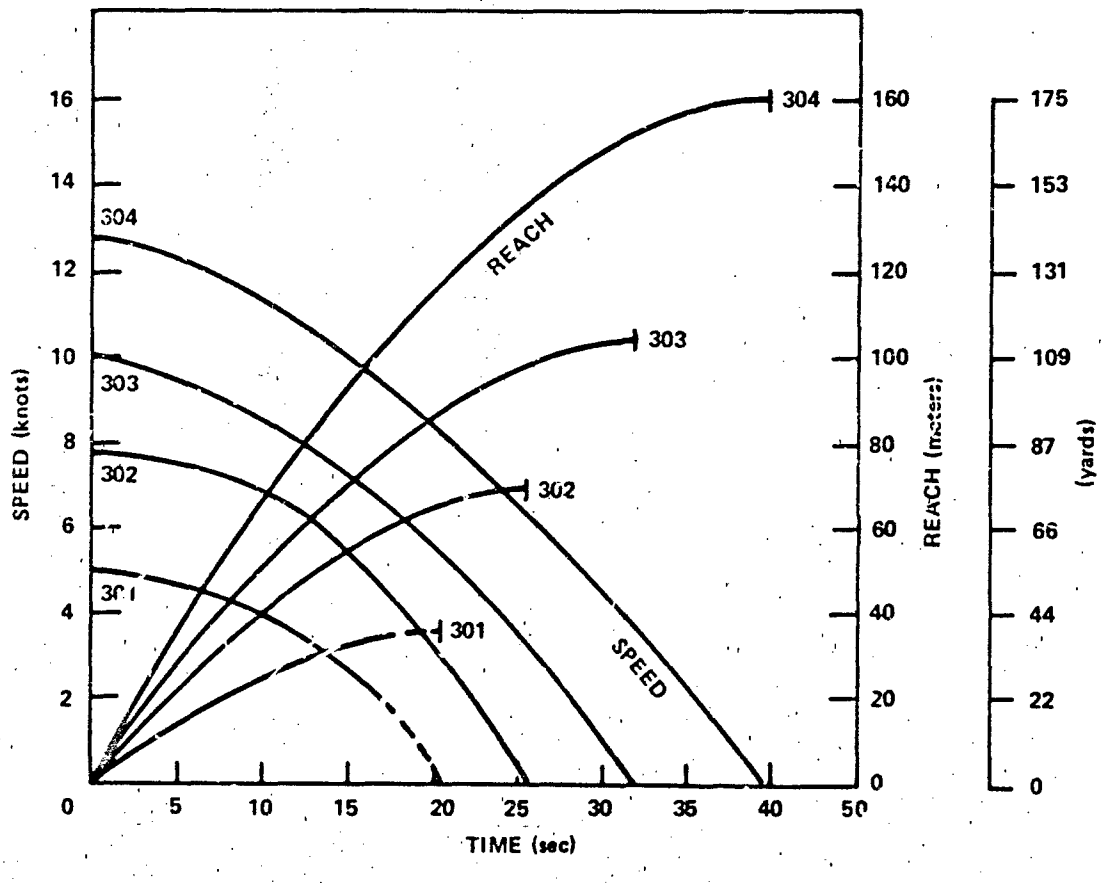


Figure 6 - CGC KATMAI BAY (WTGB-101) Deceleration Characteristics Using Full Astern Power

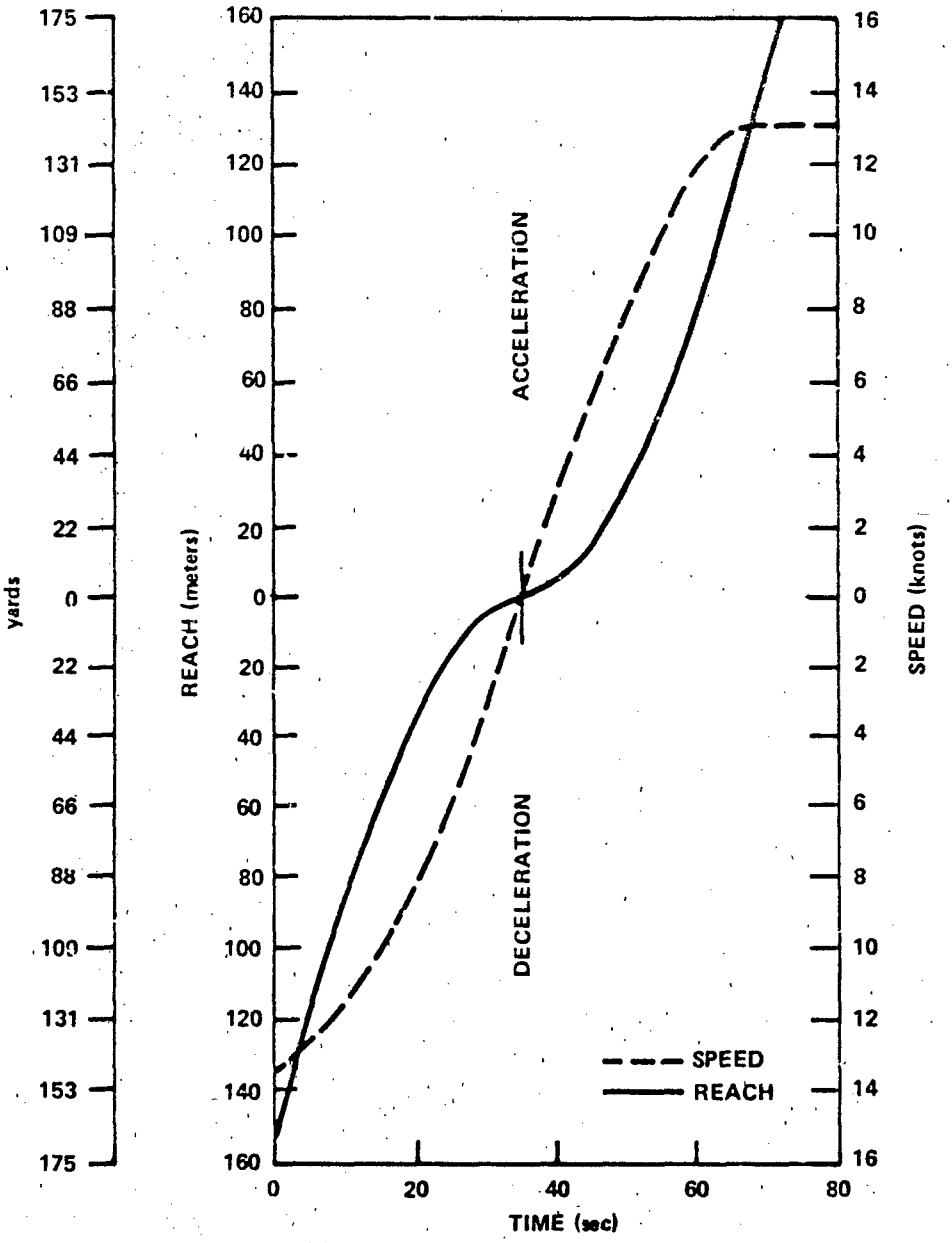


Figure 7 - CGC KATMAI BAY (WTGB-101) Reversal from 13.4 Knots Astern to Full Power Ahead Speed

RUN NO.	APPROACH SPEED (knots)	REACH (meters)	TIME IN SECONDS TO DEAD IN THE WATER
401	14.8	192	44.0
403	14.7	208	46.5

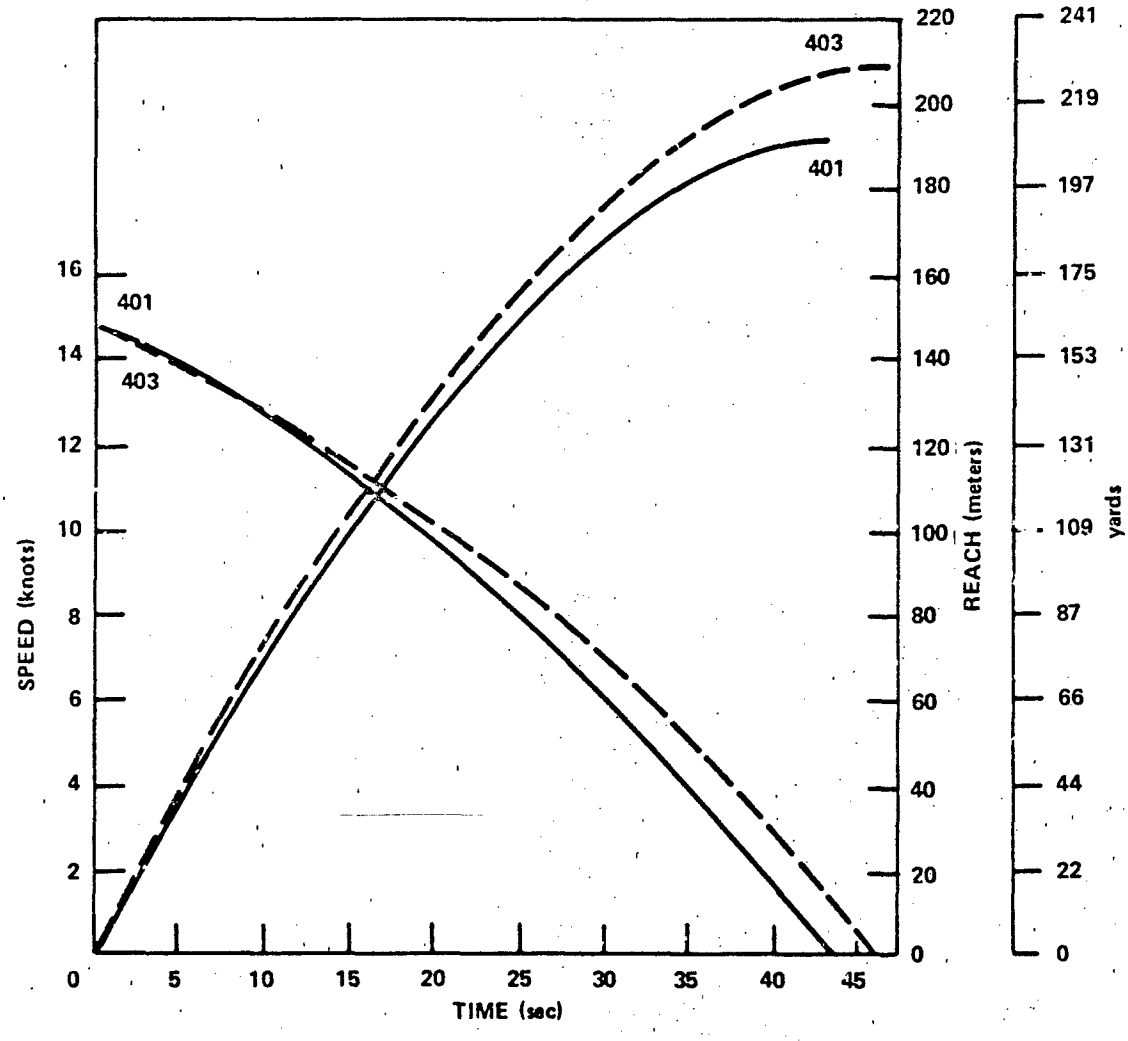


Figure 8 - CGC KATMAI BAY (WTGB-101) Deceleration from Full Ahead Power Using Full Power Astern

seconds of the run, then rose a little above that of Run 401 until the end of the run. This apparently caused the difference in stopping distance between Runs 401 and 403. It must be noted that approach headings for the two runs were in opposite directions. Winds were very light (approximately 4 to 6 knots), and even though wind direction would either aid or impair the ship's progress, it is not likely that the wind would contribute significantly to the deceleration distances.

It might be noted that fishtailing the rudder (moving the rudder hard left and right) during a deceleration run was not tried. When not confined to a narrow channel, this technique may shorten stopping distance.

BUBBLER SYSTEM SPEED TRIALS

It was known that when air was emitted from the forward bubblers, an astern thrust was imparted to the ship. An attempt was made to determine the speed KATMAI BAY would attain in the astern direction while being driven by the forward bubblers. The procedure used to do this was to bring the ship dead in the water, turn the forward bubblers on, and then allow the ship to get up to speed under bubbler power. The mini-ranger tracking equipment was used to track the ship's motion and speed was calculated from X, Y position plots. While the ship was going astern, it made a circle to the port with the helmsman instructed to keep the rudder amidships. It is not known how accurately the rudder position was matched to the indicator. However if the rudder was amidships, then the air emission from the bubbler manifolds must not have developed equal thrust on the starboard and port sides.

The average speed that the ship traveled during the bubbler run was 1.1 knots. Apparent speed variations for the 10-second periods sampled were from 0.7 to 1.7 knots. This variation is due to range equipment accuracy and the short distance traveled in 10 seconds. Samples taken at different 10-second interval starting points indicate that the average is accurate to plus or minus 1 to 2 tenths of a knot. In the future, it would probably be better to run in the ahead direction at a given rpm and then determine speed with and without the bubblers in operation.

CONCLUSIONS

The speed, tactical, and maneuvering trials conducted on KATMAI BAY are considered very successful in that weather conditions were ideal, instrumentation worked very well, and the ship performed very well. The repeatability of speed and rpm data taken during opposite runs of the rpm/speed trials is remarkedly good and these data are considered applicable to the Coast Guard's 140-foot WTGB under these trial conditions. Examples of the tracking data are included in this report as Appendix A. A perusal of the drift corrected circle plots will indicate that the tracking data are very consistent and reliable. The tactical and maneuvering data are also considered representative of the 140-foot WTGB Class.

From the results of these trials, it is concluded that:

1. A speed of 14.7 knots can be attained at 303.7 rpm.

2. The smallest tactical diameter attained during this trial was 162 yards (148 meters) with a 30-degree rudder angle.

3. Tactical diameters are essentially the same for left and right rudder angles.

4. Tactical diameters, transfer, and advance for a given rudder angle are nearly unaffected by ship speed.

5. The minimum stopping distance from full power ahead is 208 yards (190 meters).

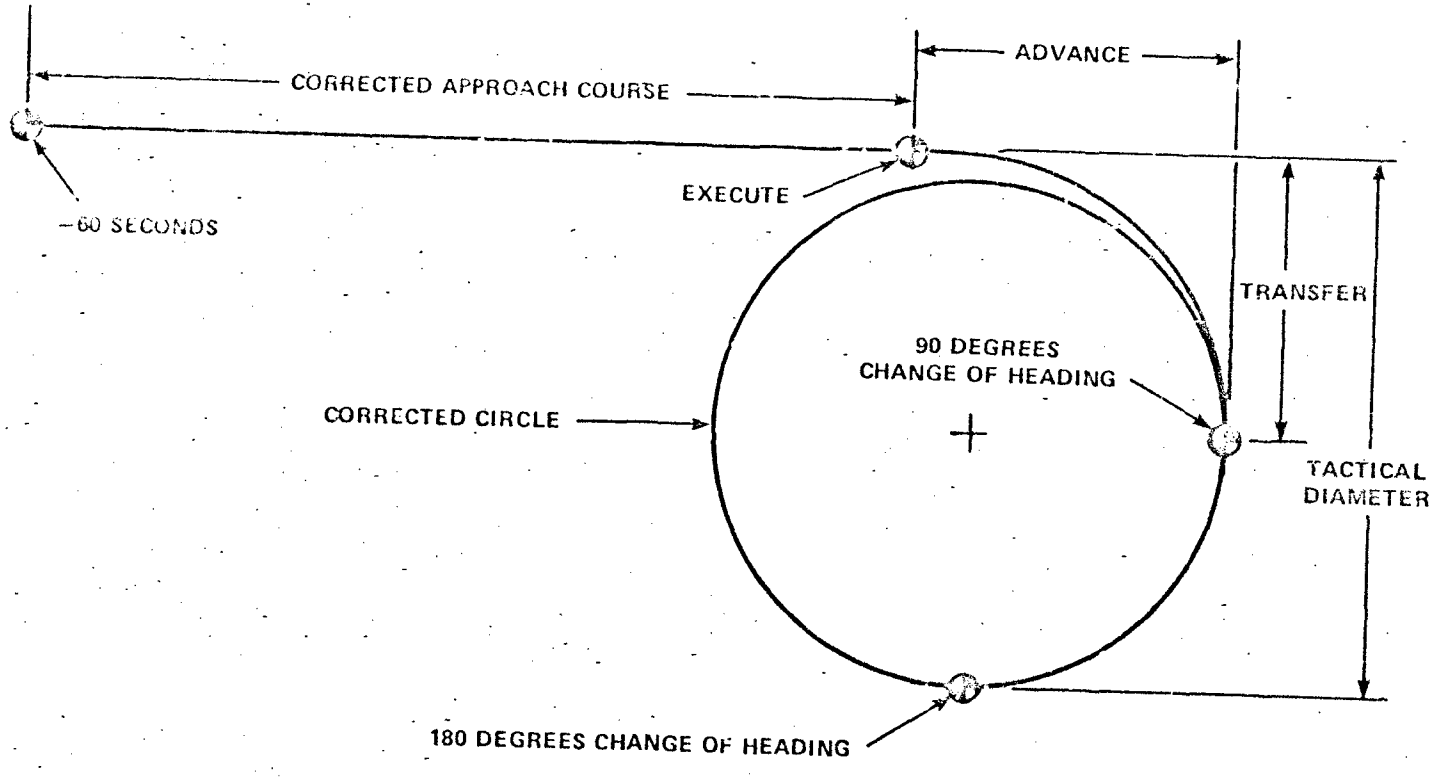
6. The stopping distance from full power astern is 166 yards (152 meters).

ACKNOWLEDGMENTS

The authors would like to express their appreciation to Commander Richard White, the Commanding Officer of KATMAI BAY and to Lieutenant Jonathon Embler, the Executive Officer, who had command of the ship during these trials. Their cooperation and that of the crew during the trial period was outstanding. The ship handling contributed greatly to the expeditious and accurate collection of trial data.

APPENDIX A

DIAGRAM SHOWING MEASUREMENTS USED TO DESCRIBE A TURNING CIRCLE MANEUVER


ADVANCE
CORRECTED APPROACH COURSE
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TRANSFER
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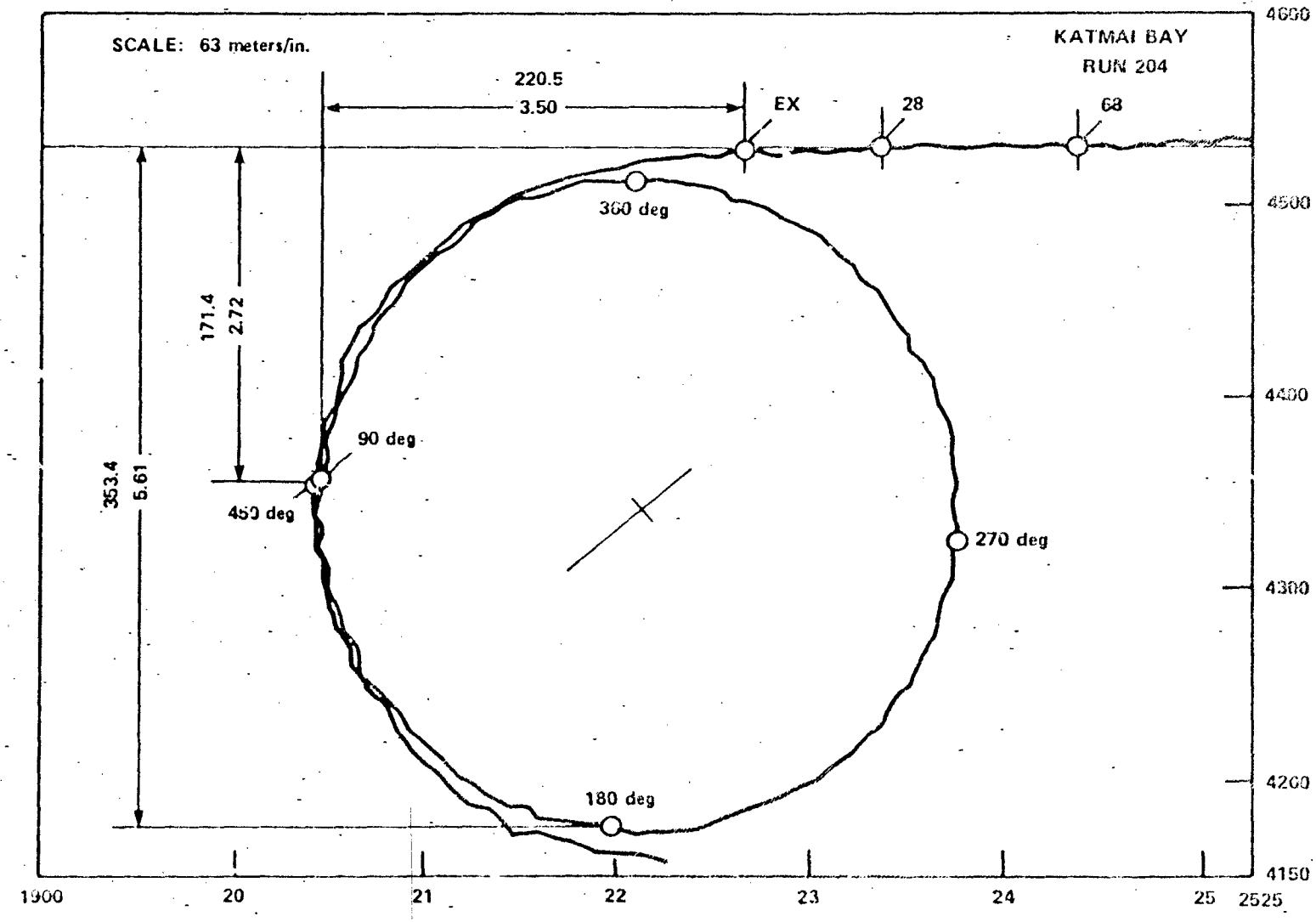
CHANGE OF HEADING
CORRECTED CIRCLE
TACTICAL
DIAMETER
180 DEGREES CHANGE OF HEADING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KATMAI BAY
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3.50
EX
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68
360 deg
90 deg
450 deg
270 deg
180 deg
171.4
2.72
353.4
5.61
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4500
4400
4300
4200
4150
1900
20
21
22
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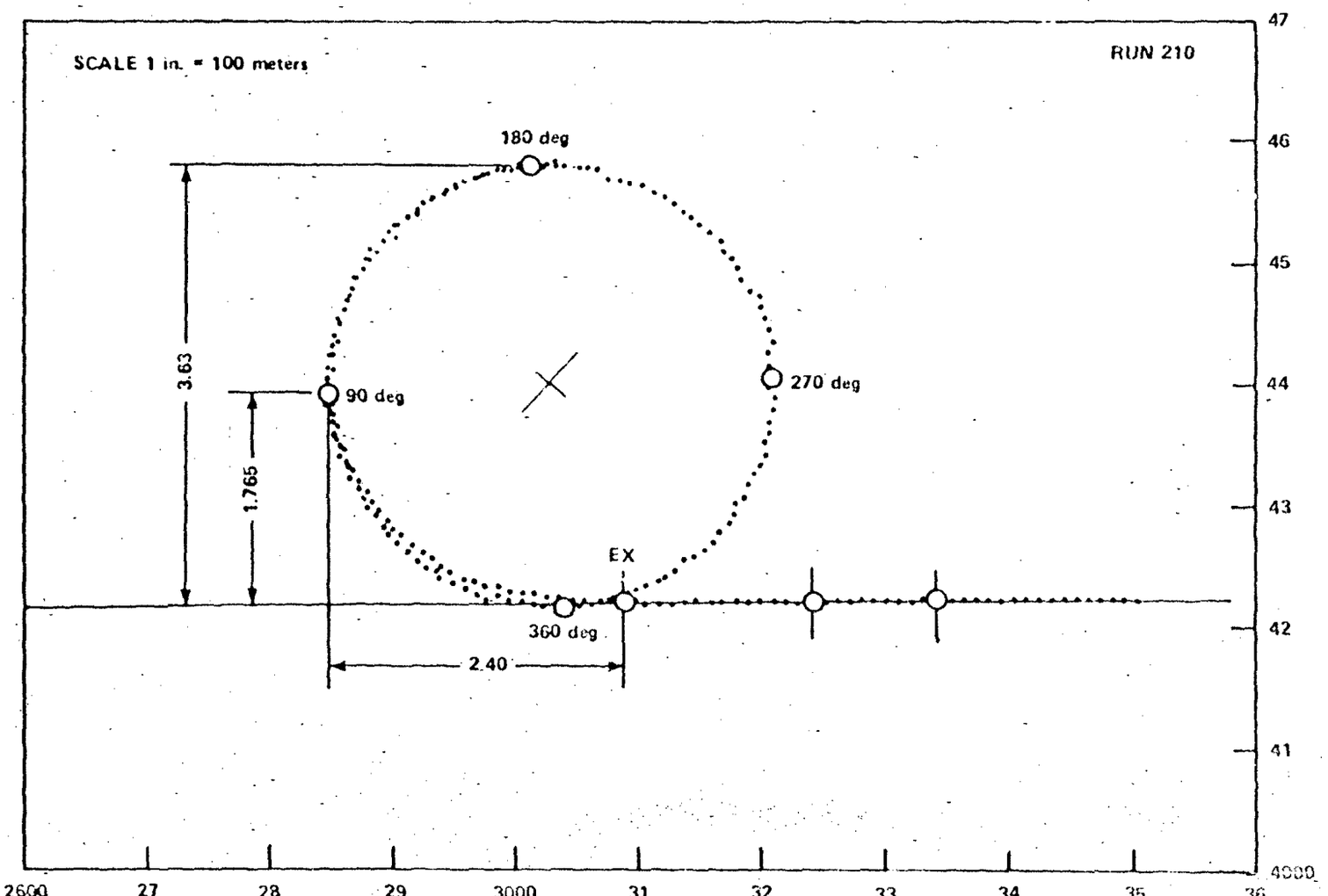
25
2525


SCALE 1 in. = 100 meters
RUN 210
180 deg
90 deg
270 deg
360 deg
EX
3.63
1.765
2.40
47
46
45
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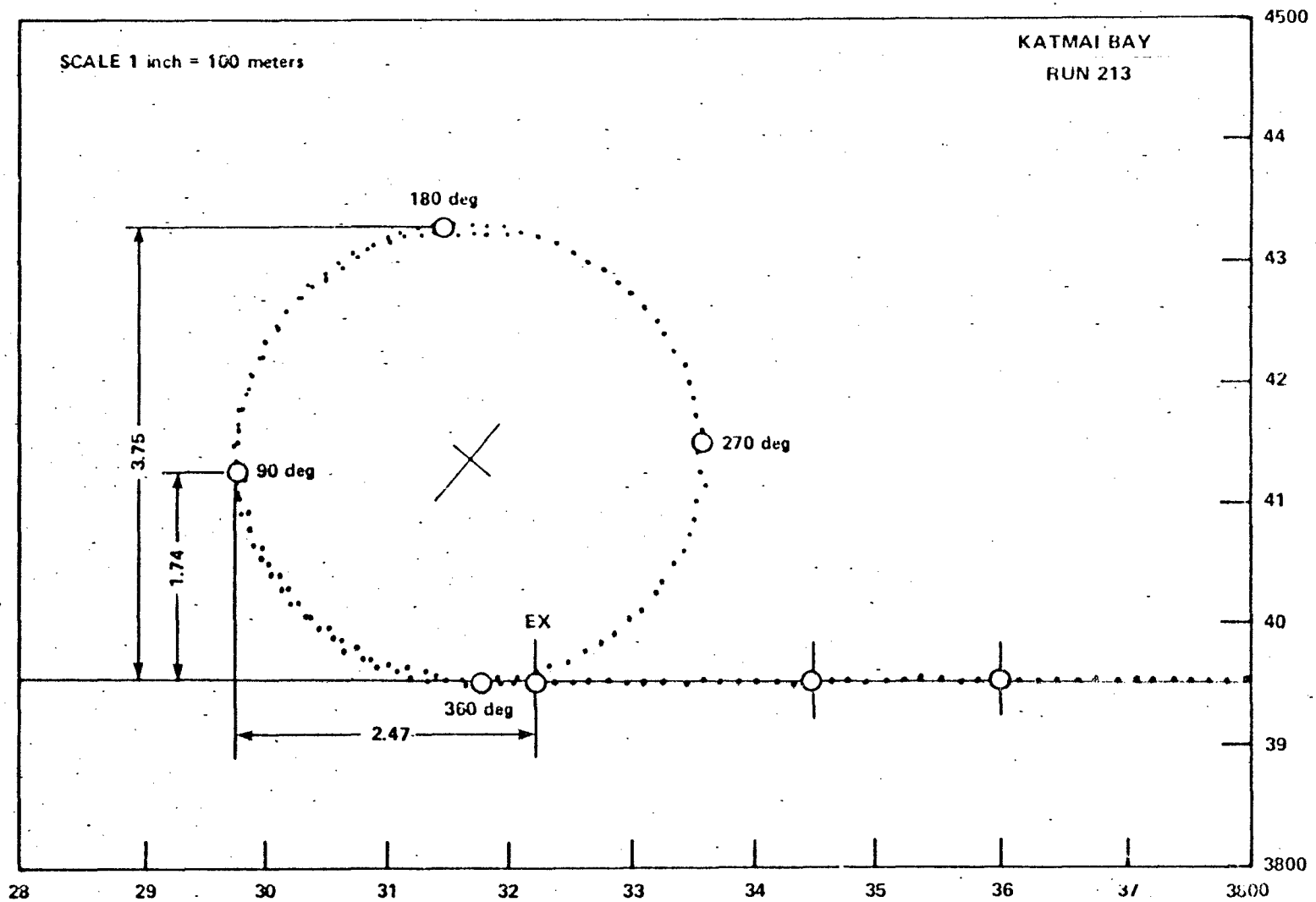
SCALE 1 inch = 100 meters
KATMAI BAY
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90 deg
270 deg
360 deg
EX
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1.74
2.47
4500
44
43
42
41
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