(2)

Carderock Division
Naval Surface Warfare Center
Bethesda, MD 20084-5000

CARDEROCKDIV-92/008 May 1992
Ship Hydromechanics Department
Research and Development Report

USS SCOUT (MCM 8) Results of Standardization, Locked and Trailed Shaft Trials

by

Michael L. Klitsch
Wayne P. Liu

Approved for public release; distribution is unlimited.

UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY 2b. DECLASSIFICATION / DOWNGRADING SCHEDULE	3. DISTRIBUTION / AVAILABILITY OF REPORT Approved for public release; distribution is unlimited.
4. PERFORMING ORGANIZATION REPORT NUMBER(S) CARDEROCKDIV-92/008	5. MONITORING ORGANIZATION REPORT NUMBER(S)
6a. NAME OF PERFORMING ORGANIZATION Carderock Division, Naval Surface Warfare Center 6b. OFFICE SYMBOL (If applicable) Code 1523	7a. NAME OF MONITORING ORGANIZATION Naval Sea Systems Command
6c. ADDRESS (City, State, and Zip Code) Bethesda, MD 20084-5000	7b. ADDRESS (City, State, and Zip Code) Crystal City, VA 20362
8a. NAME OF FUNDING / SPONSORING ORGANIZATION NAVSEA 8b. OFFICE SYMBOL (If applicable) PMS 303	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c. ADDRESS (City, State, and Zip Code) Naval Sea Systems Command, PMS 303 Crystal City, VA 20362	10. SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO.: SCN PROJECT NO.: TASK NO.: WORK UNIT ACCESSION NO.: DN210660

11. TITLE (Include Security Classification)
USS SCOUT (MCM 8) Results of Standardization, Locked Shaft, and Trailed Shaft Trials

12. PERSONAL AUTHOR(S)
Klitsch, Michael L. and Liu, Wayne P.

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
Final	FROM ______ TO ______	1992 May	79

16. SUPPLEMENTARY NOTATION

17. COSATI CODES		
FIELD	GROUP	SUB-GROUP

18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
USS SCOUT (MCM 8), Ship's Speed, Standardization Trial, Locked Shaft, Trailed Shaft, Shaft Power, Shaft Torque

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

Standardization, locked and trailed shaft, acceleration and deceleration, and fuel economy trials were conducted on USS SCOUT (MCM 8) to evaluate the performance of the ship equipped with Isotta Fraschini diesel engines and Voith fluid drive couplings. The results of the acceleration and deceleration trials and the fuel economy trials are the subject of separate reports.

Standardization results from SCOUT showed a maximum speed of 14.21 kn achieved with an average shaft speed of 175.2 r/min, a total shaft torque of 67,800 lb-ft (91,900 N-m), a total shaft horsepower of 2,260 (1,690 kW), and a displacement of 1,293 tons (1,314 t). The average propeller pitch for this condition was 110%.

This 110% pitch was found to be the optimum driving pitch as it was the only condition where maximum torque and shaft speed could both be achieved.

(Continued on reverse side)

20. DISTRIBUTION / AVAILABILITY OF ABSTRACT ☐ UNCLASSIFIED/UNLIMITED ☒ SAME AS RPT ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION UNCLASSIFIED
22a. NAME OF RESPONSIBLE INDIVIDUAL Michael L. Klitsch	22b. TELEPHONE (Include Area Code) 301-227-1870 22c. OFFICE SYMBOL Code 1523

DD Form 1473, JUN 86 Previous editions are obsolete.

SECURITY CLASSIFICATION OF THIS PAGE
UNCLASSIFIED

(Block 19 Continued)

Trailed shaft operations resulted in about 1 kn greater speeds than locked shaft operations when driving at similar pitch and shaft speeds. The trailing shaft propeller pitch was set at 120% to provide optimum windmilling characteristics.

All trials were conducted at the Atlantic Underwater Testing and Evaluation Center (AUTEC), Andros Island, Bahamas on 14 through 17 June 1991 in excellent sea conditions.

CONTENTS

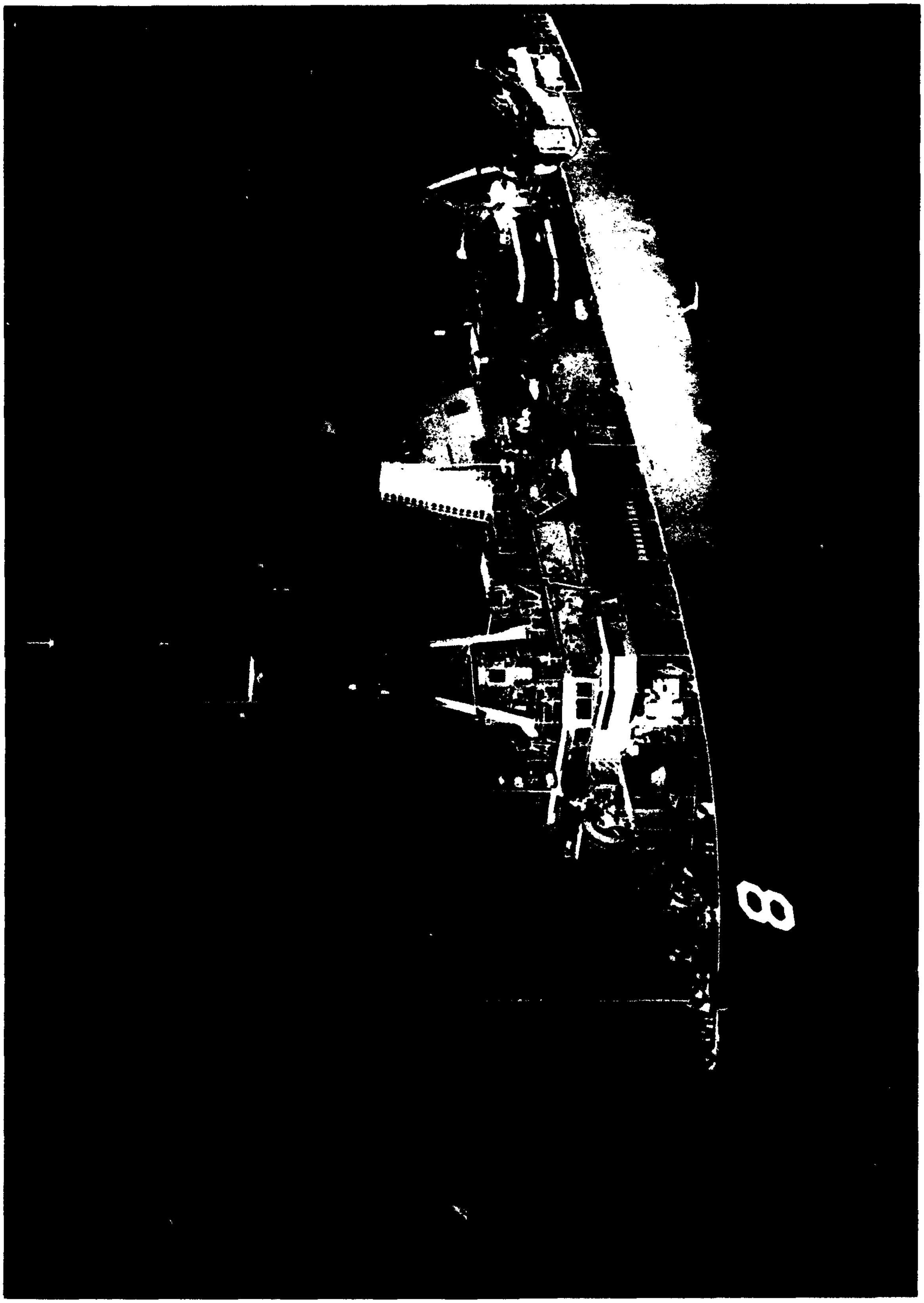
FIGURES

FIGURES (Continued)

TABLES

TABLES (Continued)

THIS PAGE INTENTIONALLY LEFT BLANK



USS SCOUT (MCM 8)

ABSTRACT

Standardization, locked and trailed shaft, acceleration and deceleration, and fuel economy trials were conducted on USS SCOUT (MCM 8) to evaluate the performance of the ship equipped with Isotta Fraschini diesel engines and Voith fluid drive couplings. The results of the acceleration and deceleration trials and the fuel economy trials are the subject of separate reports.

Standardization results from SCOUT showed a maximum speed of 14.21 kn achieved with an average shaft speed of 175.2 r/min, a total shaft torque of 67,800 lb-ft (91,900 N-m), a total shaft horsepower of 2,260 (1,690 kW), and a displacement of 1,293 tons (1,314 t). The average propeller pitch for this condition was 110%.

This 110% pitch was found to be the optimum driving pitch as it was the only condition where maximum torque and shaft speed could both be achieved.

Trailed shaft operations resulted in about 1 kn greater speeds than locked shaft operations when driving at similar pitch and shaft speeds. The trailing shaft propeller pitch was set at 120% to provide optimum windmilling characteristics.

All trials were conducted at the Atlantic Underwater Testing and Evaluation Center (AUTEC), Andros Island, Bahamas on 14 through 17 June 1991 in excellent sea conditions.

ADMINISTRATIVE INFORMATION

As of January 1992, the David Taylor Research Center (DTRC) became the Carderock Division, Naval Surface Warfare Center (CARDEROCKDIV, NSWC). However, throughout this report CARDEROCKDIV, NSWC will be referred to as DTRC. The trials described herein were requested by the Naval Sea Systems Command (NAVSEA), PMS 303. This work was authorized by Work Request N0002491WR21362 of 26 March 1991. The trials discussed in this report were conducted by David Taylor Research Center (DTRC) representatives and funded under DTRC Work Unit 1523-618.

INTRODUCTION

The information contained within this report was previously reported in a report of higher classification.*

Standardization, locked and trailed shaft, acceleration and deceleration, and fuel economy trials were conducted on USS SCOUT (MCM 8) at AUTEC, Andros Island, Bahamas, on 14 through 17 June 1991. The objective of the SCOUT standardization, locked and trailed shaft trials was to determine the

---

* Klitsch, Michael L. and Liu, Wayne P., David Taylor Research Center, as reported in DTRC-91/022, a report of higher classification.

speed/powering relationship of USS AVENGER (MCM 1) class ships equipped with the Isotta-Fraschini engines. Acceleration/deceleration trials on SCOUT evaluated the acceleration and deceleration characteristics of AVENGER class ships equipped with the fluid drive couplings. Fuel economy characteristics of the Isotta Fraschini engines were also evaluated. The acceleration/deceleration trials and the fuel economy trials are discussed in separate reports.

Isotta Fraschini diesel engines and Voith fluid drive couplings have been installed on MCM 3 and follow-on ships of the AVENGER class of minesweepers. These ships are powered by four Isotta Fraschini diesel engines; each engine has 6 cylinders, a maximum speed of 1800 r/min and is rated at 600 bhp (450 kW). The fluid drive couplings allow a maximum propeller shaft speed of 176 r/min and have about a 2% speed loss at top speed when compared to mechanical couplings.

Waukesha diesel engines and mechanical drive couplings were installed on MCM 1 and 2. The Waukesha engines are rated at 600 bhp (450 kW) and 2,000 r/min. The mechanical drive couplings allowed a maximum shaft speed of 180 r/min. Performance trials have previously been conducted on USS AVENGER (MCM 1) and those results are reported in a document of higher classification.*

USS SCOUT (MCM 8) is the eighth ship of the USS AVENGER (MCM 1) class of U.S. Navy mine countermeasure ships. SCOUT was built by Peterson Builders, Inc., Sturgeon Bay, Wisconsin. The ship's keel was laid on 8 June 1987 and the ship was commissioned on 15 December 1990. SCOUT is driven by two Bird-Johnson controllable pitch propellers and is powered by four Isotta Fraschini diesel engines (two engines per shaft). The ship has Voith fluid drive couplings. SCOUT's design displacement is 1,310 tons (1,330 t). Detailed information regarding the ship and propeller shaft characteristics of SCOUT are shown in Table 1. Table 2 lists SCOUT's principal propeller characteristics.

This report contains only results of the MCM 8 standardization and locked and trailed shaft trials. The main text of the report is divided into the following four sections:

- Instrumentation,
- Trial Conditions,
- Trial Procedures, and
- Results.

---

* Boboltz, David A., David Taylor Research Center, as reported in DTRC-90/002, a report of higher classification.

* Lapeyre, J.P., David Taylor Research Center, as reported in DTRC-90/018, a report of higher classification.

Standardization trial results are presented first followed by the results of the locked and trailed shaft trials. Conclusions and recommendations are also presented. This report also contains several detailed appendices which are referenced in the text.

INSTRUMENTATION AND DATA COLLECTION

Trial data were collected from DTRC instrumentation and existing ship signals. These signals and their accuracies are listed in Table 3. The block diagram of the routing of the signals is shown in Fig. 1. A description of the DTRC instrumentation and existing ship signals can be found in Appendix A.

As shown in Fig. 1, trial signals were routed from their respective sources to either synchro to analog (S/A) converters, frequency to voltage (F/V) converters, or amplifiers. The signals were then channeled into a Hewlett Packard data acquisition unit (HP 3852A). This unit converted analog signals to digital signals. The digital signals from the data acquisition unit were then recorded on 3.5 in. (8.9 cm) disc storage drives (HP 9122) and analyzed with a Hewlett Packard computer (HP 300). Hard copy printouts of the data analysis were provided with an HP line printer.

Figure 1 shows a Global Positioning System (GPS) which was interfaced with DTRC instrumentation during the trials. This system was installed by DTRC on an experimental basis for the purpose of evaluating it for future tracking applications. GPS position and speed data were collected during the trials whenever adequate satellite coverage was present.

TRIAL LOCATION AND CONDITIONS

Trials were conducted on SCOUT 14 through 17 June 1991 at AUTEC, Andros Island, Bahamas using a Motorola Falcon 484 pulse radar system. A diagram of the pulse radar tracking area at AUTEC is shown in Fig. 2. Geodetic specifics of the tracking site at AUTEC are presented in Appendix B.

Sea states during the trial were observed to be ideal and were between 0 and 1. True wind speeds were less than 15 kn and generally from an easterly direction. Trial site seawater temperature and specific gravity were relatively constant each day of the trials and were measured to be 82°F (28°C) and 1.026, respectively. Table 4 presents the various trial conditions observed on the tracking area during the trial period.

The average ship displacement and trim during each day of the trials was determined by using draft readings, water temperature, specific gravity, and ship's fuel tank readings. As shown below the displacement and trim of SCOUT during the trials was observed to be:

	Standardization		Lock/Trail	
Date	15 June 1991		16 June 1991	
Trim by Stern, ft (m)	1.3	(0.40)	1.4	(0.43)
Displacement, ton (t)	1,293	(1,314)	1,285	(1,306).

Table 4 contains a more detailed list of the trial conditions. The details of determining ship's displacement for each day of the trials can be found in Appendix C.

Both propellers were cleaned of barnacles by divers in the water at Nassau, Bahamas 13 June 1991. Upon completion of the propeller cleaning, DTRC divers inspected the propellers and took hull and propeller roughness readings. The diver inspection and roughness measurements showed the hull and propellers to be in satisfactory condition for the trials. The diver inspection and the roughness measurements are discussed in Appendix E.

GENERAL TRIAL PROCEDURES

The standardization and locked and trail shaft trials were conducted on a pulse radar tracking range to determine ship's position. Each maneuver was commenced after steady approach conditions were established; this ensured validity of comparison for data analysis. Shaft torque, shaft speed, ship speed, and position were monitored during the buildup for each run.

The DTRC Trial Director was informed by the Officer of the Deck when ship's heading and shaft speed had been brought to the scheduled values. Rudder movements were minimized at this time. The Trial Director and/or computer operator were then responsible for verifying those conditions with DTRC instrumentation. Ship speed was utilized as the final indicator of steady conditions since shaft speed stabilized well before the ship's momentum. The rate of ship speed change was monitored with shipboard DTRC tracking equipment.

After conditions were steadied, each maneuver was conducted with the basic commands of COMEX, EXECUTE, and FINEX. These commands were given by the trial director and the corresponding actions were quickly implemented by the Officer of the Deck. Described below are the general actions associated with each command.

COMEX initiated DTRC data collection. Steady approach conditions were maintained for one minute after this command.

EXECUTE signaled, for some maneuvers, the start of the transient portion of the run. EXECUTE marked the point of engine order change for acceleration/decelerations runs and rudder deflection for tactical turns. For the standardization and locked and trailed shaft runs, approach conditions were maintained for three more minutes when EXECUTE was called.

Time zero was defined as EXECUTE for all maneuvers.

FINEX marked the conclusion of the run and data collection. The criterion for FINEX varied with each maneuver.

More detailed descriptions of the procedures, such as approach conditions, FINEX criterion, pitch control modes, and definitive diagrams of each maneuver, are found in Appendix F.

PRESENTATION AND DISCUSSION OF RESULTS

Results of the trials on USS SCOUT (MCM 8) are presented below with graphical and tabulated data used to support discussions. Discussions are ordered as follows: standardization trials are followed by the locked and trailed shaft trials.

STANDARDIZATION

SCOUT standardization trials were conducted on 15 June 1991 at a displacement of 1,293 ton (1,314 t) . These trials evaluated speed/powering characteristics at 92%, 103% (design), 110%, and 120% propeller pitch. All standardization runs were conducted with

- All four engines on line,
- Both shafts driving, and
- Manual control for pitch scheduling.

The results of the standardization trials conducted on SCOUT are graphically presented in Figs. 3 through 6 and are tabulated in Tables 5 through 10.

Standardization Figures

Figures 3 and 4 represent the English and metric Standardization curves and show the shaft speed, and torque and power required to achieve a particular ship speed at each propeller pitch. Figures 5 and 6 represent English and metric plots of torque versus shaft speed for each propeller pitch. These figures will be used to support discussions on the following observations:

- Optimum pitch and
- Propulsion efficiency.

Optimum Pitch. Figures 5 and 6 show that the optimum driving propeller pitch was 110%. Output at the 92% and 103% pitch conditions could achieve design shaft speed (176 r/min) but without fully developing design torque (34,400 ft-lb [46,600 N-m]). Conversely output at the 120% condition achieved design torque without developing design shaft speed. Note that 110% was the only condition where both design shaft speed and design torque were reached. This explains the higher speed and power output at the 110% pitch condition. By adjusting the design pitch of the program control mode to 110% instead of 100%, more ship speed and shaft power can be extracted from the engines. This observation is in agreement with the standardization conclusions of Ref. 1.

Propulsion Efficiency. The power curves in Figs. 3 and 4 show that 120% pitch results in less efficient propulsion than observed at the 92%, 103%, and 110% conditions. Note that data collected at 120% fall on a different and distinct power curve. The three data points at 120% pitch show that SCOUT requires more power to attain a given speed than it would when operating in the 92% to 110%

propeller pitch range. The average shaft speed and torque curves of Figs. 3 and 4 show that a given speed and power can be achieved by a higher torque and lower shaft speed condition (over pitch condition) or by a lower torque and a higher shaft speed condition (under pitch condition). For the conditions tested this statement holds true for propeller pitch ranges between 92% and 110%, but not for 120%.

Standardization Data Tables

Standardization trials data are tabulated in Tables 5 through 10. English and metric standardization data, with both shafts driving at an average propeller pitch of 103%, are listed in Tables 5 and 6, respectively. English and metric standardization data, with both shafts driving at an average propeller pitch of 110%, are listed in Tables 7 and 8, respectively. English and metric standardization data, with both shafts driving at an average propeller pitch of 120% and 92%, are listed in Tables 9 and 10, respectively.

Each table contains the true wind speed and direction, shaft speed, shaft torque, shaft power, propeller pitch, and ship's speed. Data plotted in Figs. 3 through 6 are tabulated as spot averages. The spot average could consist of either a two-pass spot (where the data of two reciprocal passes is averaged) or a three-pass spot (where the mean of means method is used on three reciprocal passes). These two- or three-pass spot averages are required to eliminate the effects of wind, waves, and current.

Standardization data table (Tables 5 through 10) contents and headings are discussed below to further clarify the results and will conclude the discussion on standardization trial results. The following specifics will be addressed:

- Maximum Conditions,
- Ship's Speed,
- Propeller Pitch,
- Shaft Torque, and
- Data Repeatability.

Maximum Conditions. Tables 5 through 10 show that the maximum speed/powering conditions attained for SCOUT, at each of the four propeller pitches tested, are as follows:

Pitch, %	92	103	110	120
Top Speed, kn	13.12	13.90	14.21	13.88
Maximum Shaft Speed, r/min	175.7	175.3	175.2	161.6
Total Shaft Torque, lb-ft	49,600	60,700	67,800	67,600
Total Shaft Power, shp	1,660	2,030	2,260	2,080
Total Shaft Torque, N-m	67,300	82,300	91,900	91,600
Total Shaft Power, kW	1,240	1,520	1,690	1,550.

The highest ship speed (14.21 kn) and total shaft power (2,260 shp [1,690 kW]) was attained at 110% pitch. Maximum power output was within 98.3% of the rated power output of 2,300 shp (1,720 kW). Note that the 110% setting provides 230 more shp (11% more) and 0.31 kn more speed than observed at the near design pitch of 103%.

Ship's Speed. The data tables have a range speed column and an EM Log speed column. The range speed is the speed over the ground for each pass and the speed through the water for the data spot. The EM Log speed is the speed through the water.

The spot average range speed and the spot average EM Log speed show reasonable correlation. This topic is further discussed in Appendix A.

Propeller Pitch. The propeller pitch output signal used to present the data shown in the tables was calibrated pierside by divers. Propeller pitch variations due to temperature changes and shaft thrust were negligible for these trials. A more in depth discussion of the propeller pitch is included in Appendix D.

Shaft Torque. Torque was obtained by Wireless Data Corporation (WDC) torsionmeters installed by DTRC personnel. These were temporary trial torsionmeters and operated satisfactorily throughout the trials period.

Data Repeatability. Repeatability of the speed/powering data can be seen in Tables 5 and 6. Runs 2130S, 2140N and 2150S were conducted 24 hours after runs 1130S, 1140N, and 1150S. Both data spots represent full power conditions at 103% pitch. Note that speed and powering data from each spot are nearly identical and are practically indistinguishable on Figs. 3 and 4.

LOCKED AND TRAILED SHAFT TRIALS

SCOUT locked and trailed shaft trials were conducted on 16 June 1991 at a displacement of 1,285 tons (1,306 t) . These trials were conducted with: two engines on the driving shaft andprogram control for pitch scheduling.

Speed/powering characteristics were evaluated at the following single shaft driving conditions:

Configuration	Port shaft	Starboard shaft
A (design)	Driving - 105%	Trailing - 8%
B	Driving - 119%	Trailing - 8%
C	Driving - 119%	Trailing - 120%
D	Driving - 119%	Locked - 120%.

The results of the locked and trail shaft trials conducted on SCOUT are graphically presented in Figs. 7 and 8 and are tabulated in Tables 11 and 12.

Locked and Trailed Shaft Figures

Maximum Conditions. The maximum speed/powering conditions achieved for each of the four configurations are presented below:

Configuration	A	B	C	D
Driving Prop Pitch, %	105	119	119	119
Trailing Prop Pitch, %	8*	8*	120	-
Locked Prop Pitch, %	-	-	-	120
Top Speed, kn	9.71	9.07	10.34	7.90
Max. Port Shaft Speed, r/min	170.2	152.0	151.9	128.6
Total Shaft Torque, lb-ft	35,400	34,400	32,400	24,800
Total Shaft Power, shp	1,150	1,000	940	610
Total Shaft Torque, N-m	48,000	46,600	43,900	33,600
Total Shaft Power, kW	860	750	700	450

* Starboard shaft was not windmilling at 8% trailing pitch.

Figures 7 and 8 show that the top speed of 10.34 kn was achieved in configuration C and that other configurations required more power to reach slower speeds. Configuration C drove at 119% pitch and trailed at 120% pitch; however, this configuration, along with the others evaluated, does not appear to offer the optimum locked/trailed shaft conditions. An optimum configuration can be deduced by comparing changes in ship speed, shaft speed, and torque resulting from different driving and locked/trailed shaft pitches.

Optimum Driving Pitch. The most efficient driving pitch observed in the locked or trailed shaft mode was 105%. Figure 7 shows that the design configuration A, by driving at 105%, developed more power and speed at its maximum condition than did configuration B when driving at 119%. The 105% driving pitch also developed design torque while achieving a shaft speed of 170.1 r/min (97.2% of design). By driving at a pitch slightly less than 105% (100% - 103%), the design shaft speed of 176 r/min and design torque will both likely be achieved during locked or trailed shaft operations. Note that this optimum driving pitch is less than the 110% observed during standardization with two shafts driving. This may be attributed to the difference in propeller inflows between single and twin shaft driving conditions.

Optimum Trailed Pitch. The most efficient trailing pitch in the trail shaft mode can be seen to be 120%. Figure 7 shows a large speed/power difference between configuration B, which trailed at the design trail pitch of 8%, and configuration C which trailed at 120%. While both configurations drove at 119% pitch, the effect of trailing at 120% results in a speed increase of about 1.3 kn. As shown in

Tables 11 and 12, the shaft does not windmill when trailing at 8%; by increasing the trailing pitch to 120%, the shaft windmills and ship speed is increased while the driving shaft develops less torque.

Locked Pitch. Locking a shaft at 120% pitch provides no significant difference in speed or power when compared to locking a shaft at the normal lock shaft pitch of 8%. Figure 7 shows that configuration B, which trails the shaft at 8% pitch (this was not enough pitch for the shaft to windmill making it an essentially locked shaft), produces the same speed/power characteristics as configuration D, which locks the shaft at 120%. It was noted that during the locked shaft trials with the propeller pitch at 120%, shaft torque on the locked shaft was insignificant as it never exceeded 6,000 lb-ft (8,100 N-m). The 6,000 lb-ft (8,100 N-m) load represents less than 20% of the design limit.

Locked and Trailed Shaft Trial Data Tables

Locked and trailed shaft trials data, English and metric units, are presented in Tables 11 and 12, respectively. Each table contains the true wind speed and direction, shaft speed, shaft torque, shaft power, propeller pitch, and ship's speed. The data for each pass are listed and the spot average for the corresponding passes is listed.

Locked or trailed shaft data for total shaft power, total shaft torque, and average shaft speed consist solely of measurements from the driving shaft. Further discussion on the measurement of table specifics such as propeller pitch, ship speed, and shaft torque can be found in the standardization section.

CONCLUSIONS

1. Standardization trials showed that:
   a. The maximum speed and powering conditions achieved during two shaft/four engine operations were the following:

• Top speed, kn	14.21	
• Maximum average shaft speed, r/min	175.2	
• Total shaft torque, ft-lb (N-m)	67,800	(91,900)
• Total shaft power, shp (kW)	2,260	(1,690)
• Displacement, tons (t)	1,293	(1,314)
• Propeller pitch, %	110	

   b. The optimum pitch for two shaft/four engine operations is 110%. This pitch represents the only condition at which maximum torque and maximum shaft speed was achieved.
   c. 110% propeller pitch delivers 11% more power and 0.31 kn more speed at Ahead Flank than the near design pitch of 103%.

d. 120% propeller pitch results in off-peak propulsion efficiency and delivers less ship speed when compared to the 92%, 103%, and 110% pitches for the same power.

2. Lock and Trail shaft trials showed that:

a. Maximum speed for trail shaft trials was achieved at the following conditions:

• Driving pitch (port), %	119	
• Trailing pitch (starboard), %	120	
• Top speed, kn	10.34	
• Maximum average shaft speed, r/min	151.9	
• Total shaft torque, ft-lb (N-m)	32,400	(43,900)
• Total shaft power, shp (kW)	940	(700)
• Displacement, tons (t)	1,285	(1,306)

b. The most efficient driving pitch observed was 105% . Design torque and 170.1 r/min (97.2% of design shaft speed) were achieved at this condition.

c. The optimum trailing pitch was 120%. This pitch allowed the shaft to windmill; this increased ship speed by about 1 kn throughout the speed range when compared to similar driving conditions with less pitch on the trailing shaft. Trailing a shaft at 8% pitch did not windmill the shaft.

d. No appreciable difference in speed/powering was found between runs conducted with a shaft locked at 120% pitch and a shaft trailed at 8% pitch (8% pitch was not enough pitch for the shaft to windmill making it an essentially locked shaft).

RECOMMENDATIONS

The following recommendations are made for obtaining the maximum performance on SCOUT:

1. Set the program control design pitch for two shaft /four engine operations at 110% for optimum speed and power characteristics.
2. Avoid operating at 120% propeller pitch as it delivers off-peak speed/powering characteristics.
3. Set the driving shaft pitch at 105% during locked or trailed shaft operations.
4. Set the trailed shaft pitch at 120% in order to windmill the shaft during trailed shaft operations.
5. Set the locked shaft pitch at any convenient value as it has little impact on locked shaft speed/powering characteristics.

ACKNOWLEDGMENTS

DTRC would like to thank the crew of USS SCOUT (MCM 8) for their valuable assistance in the performance of the trials. The authors would like to thank Messrs. Lowry Hundley, Steve Intolubbe, Donald Drazin, Andrew Kilpatrick, Edward Whitmore, and Donald Ace for their efforts and support during the trial and the report preparation period.

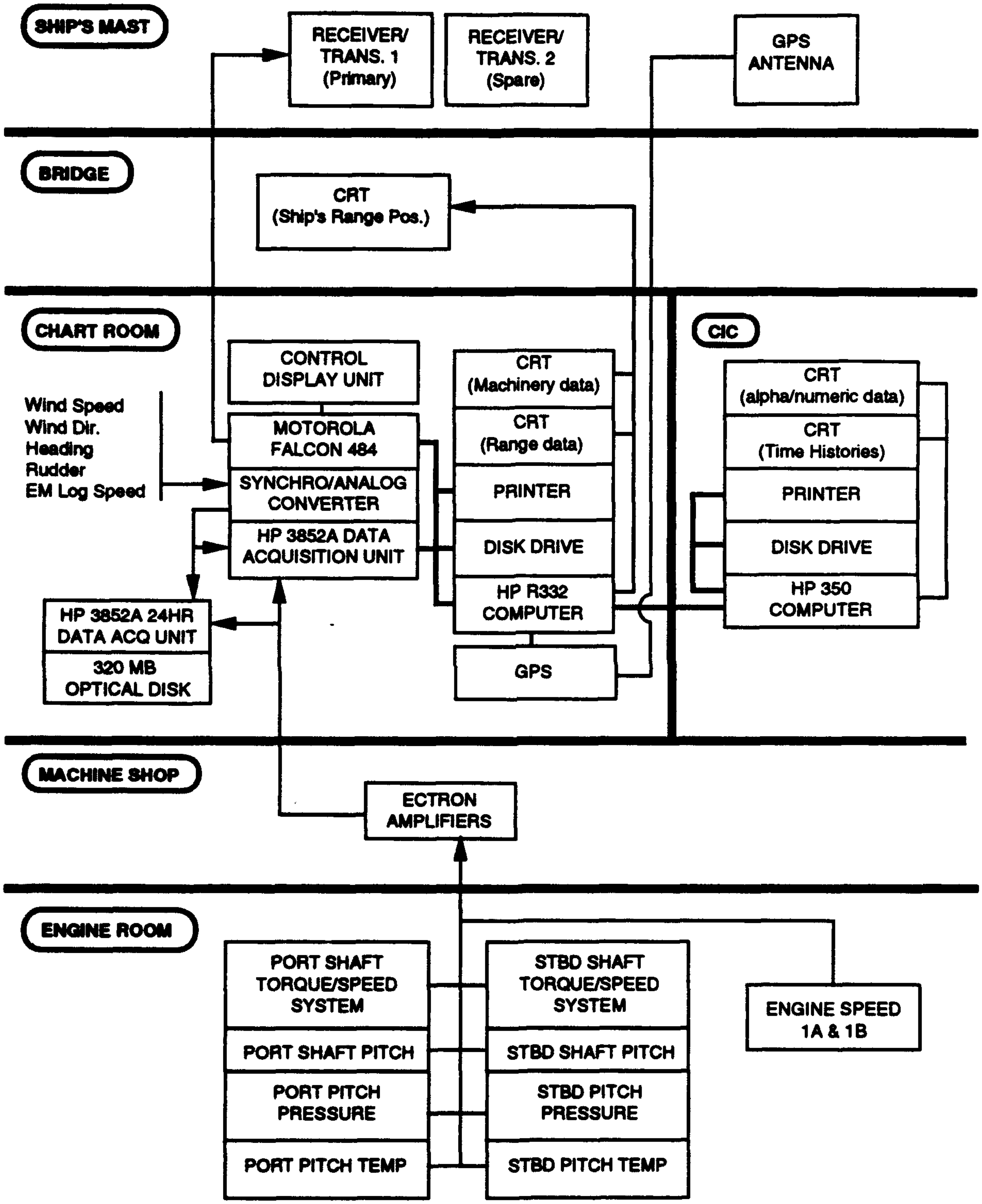


Fig. 1. USS SCOUT (MCM 8) instrumentation block diagram.

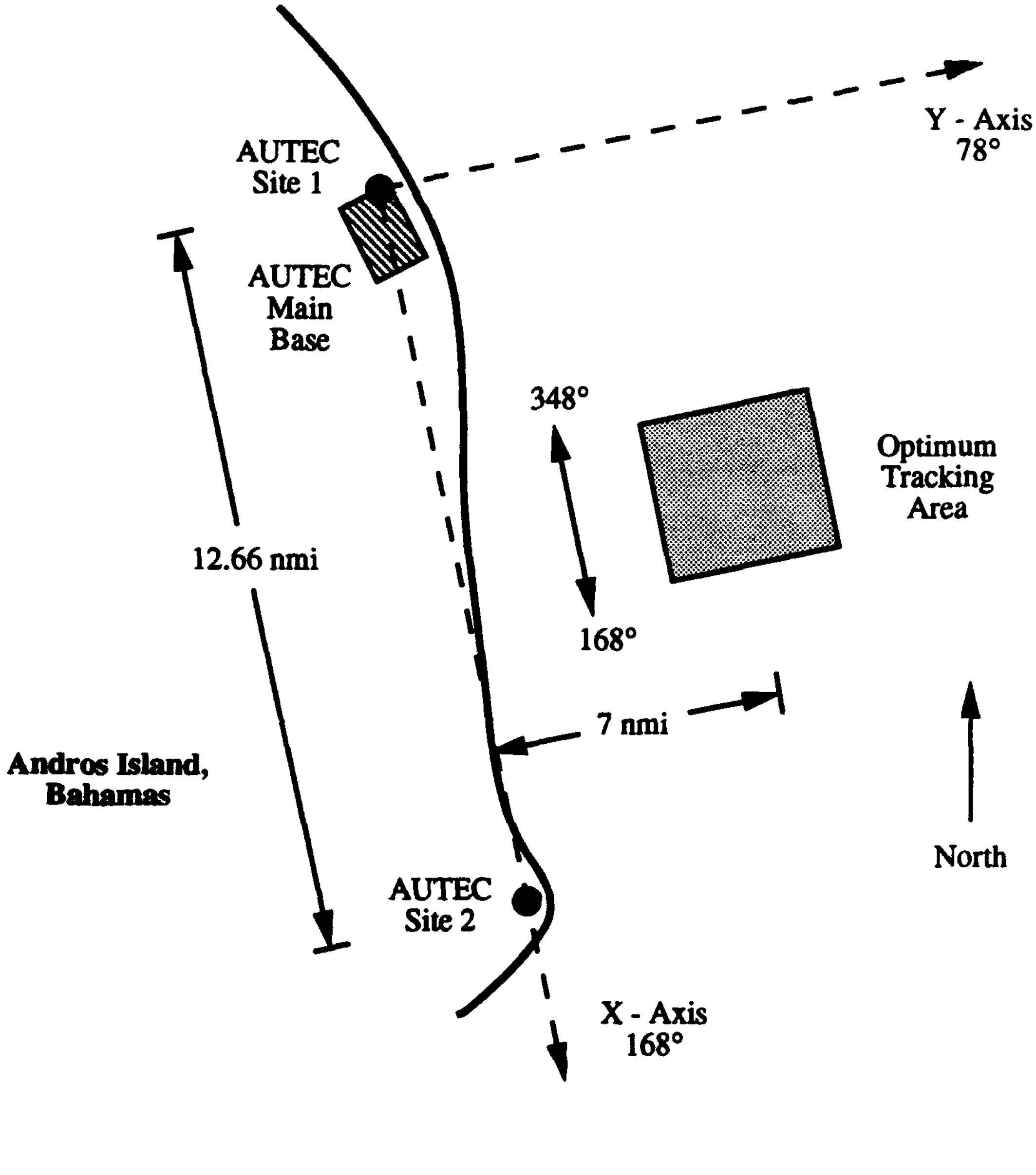


Fig. 2. Tracking range, AUTEC, Andros Island, Bahamas.

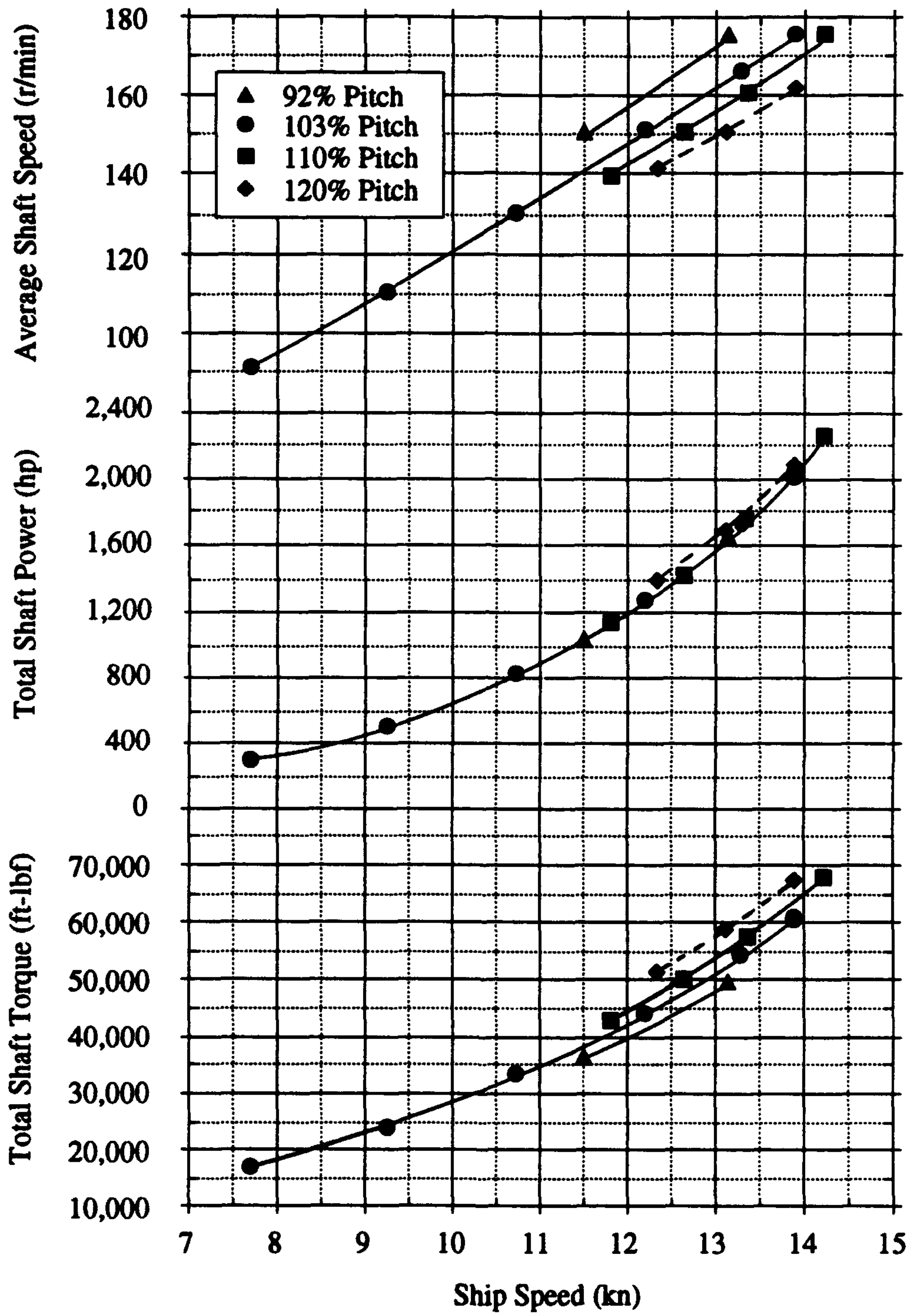


Fig. 3. USS SCOUT (MCM 8) standardization trial results - 1,293 tons (English units).

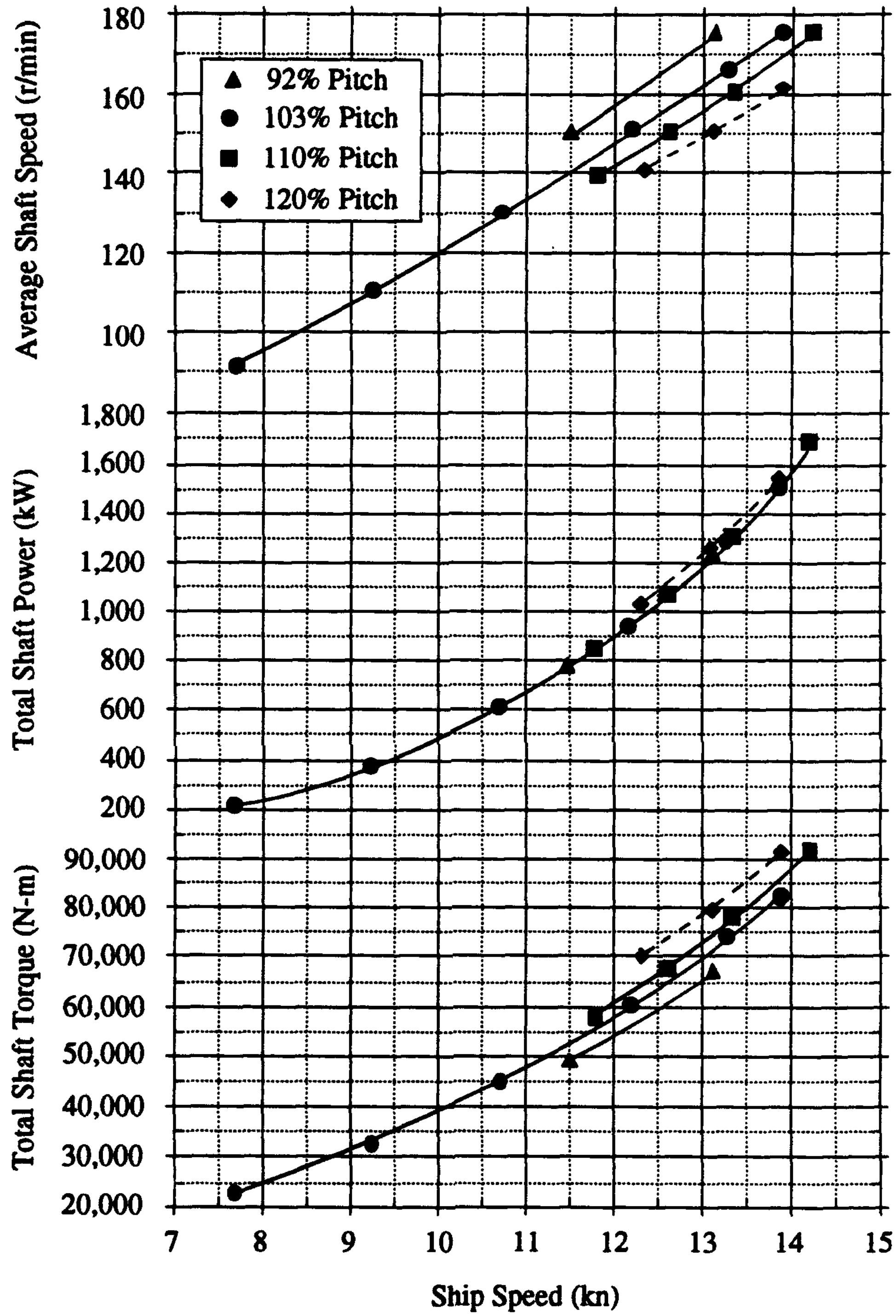


Fig. 4. USS SCOUT (MCM 8) standardization trial results - 1,314 tonnes (metric units).

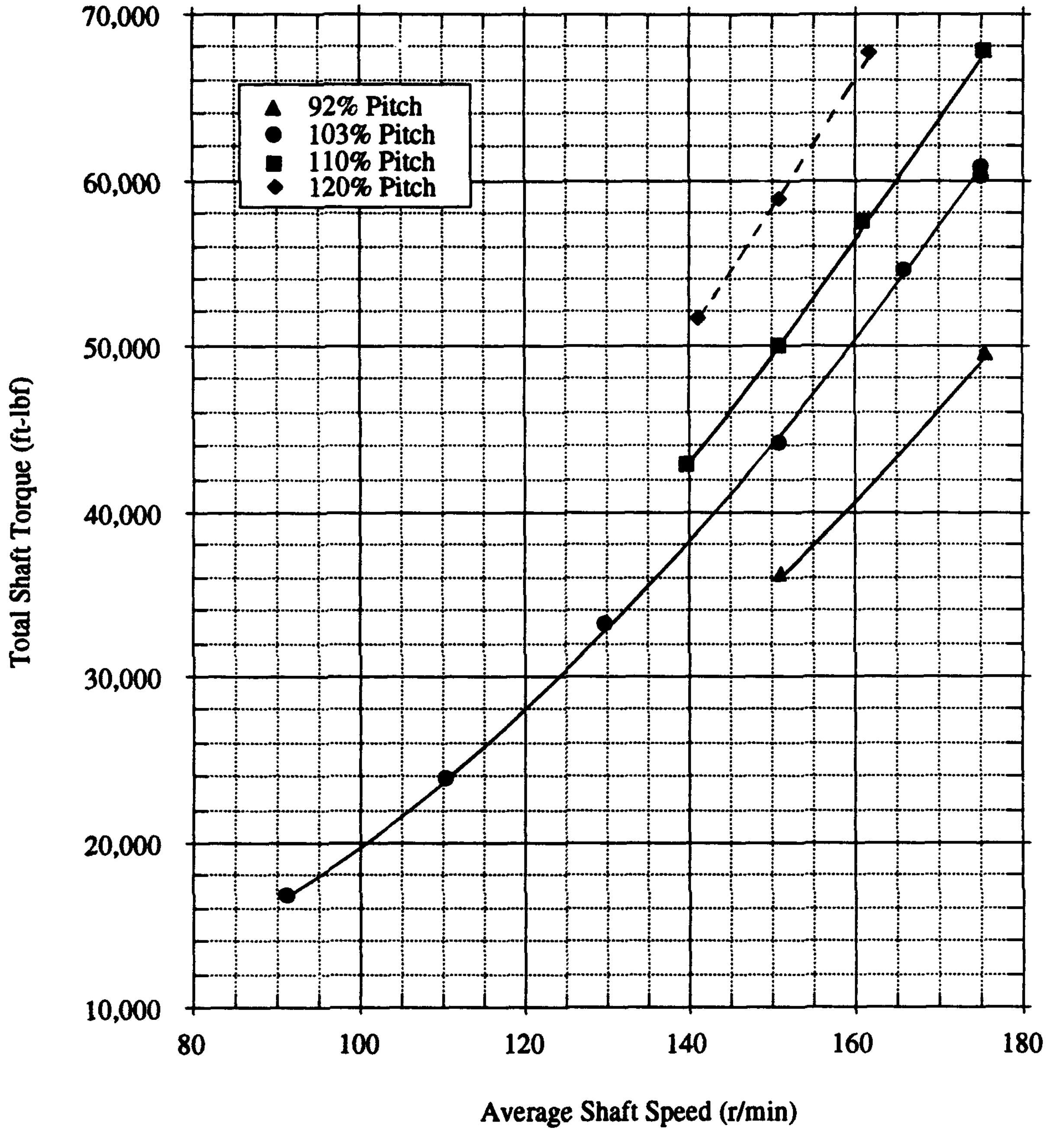


Fig. 5. USS SCOUT (MCM 8) torque versus shaft speed for standardization trial results - 1,293 tons (English units).

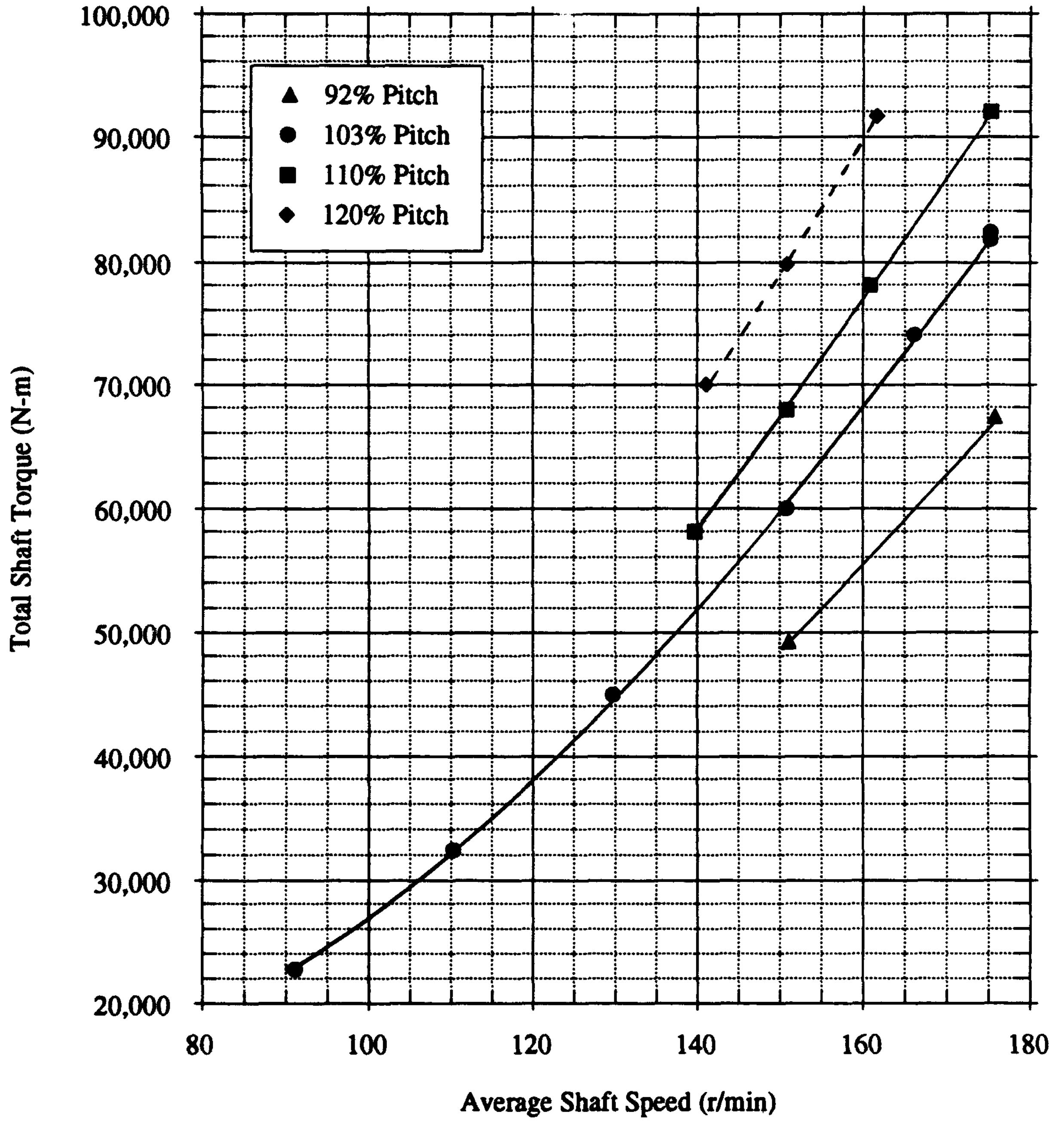


Fig. 6. USS SCOUT (MCM 8) torque versus shaft speed for standardization trial results - 1,314 tonnes (metric units).

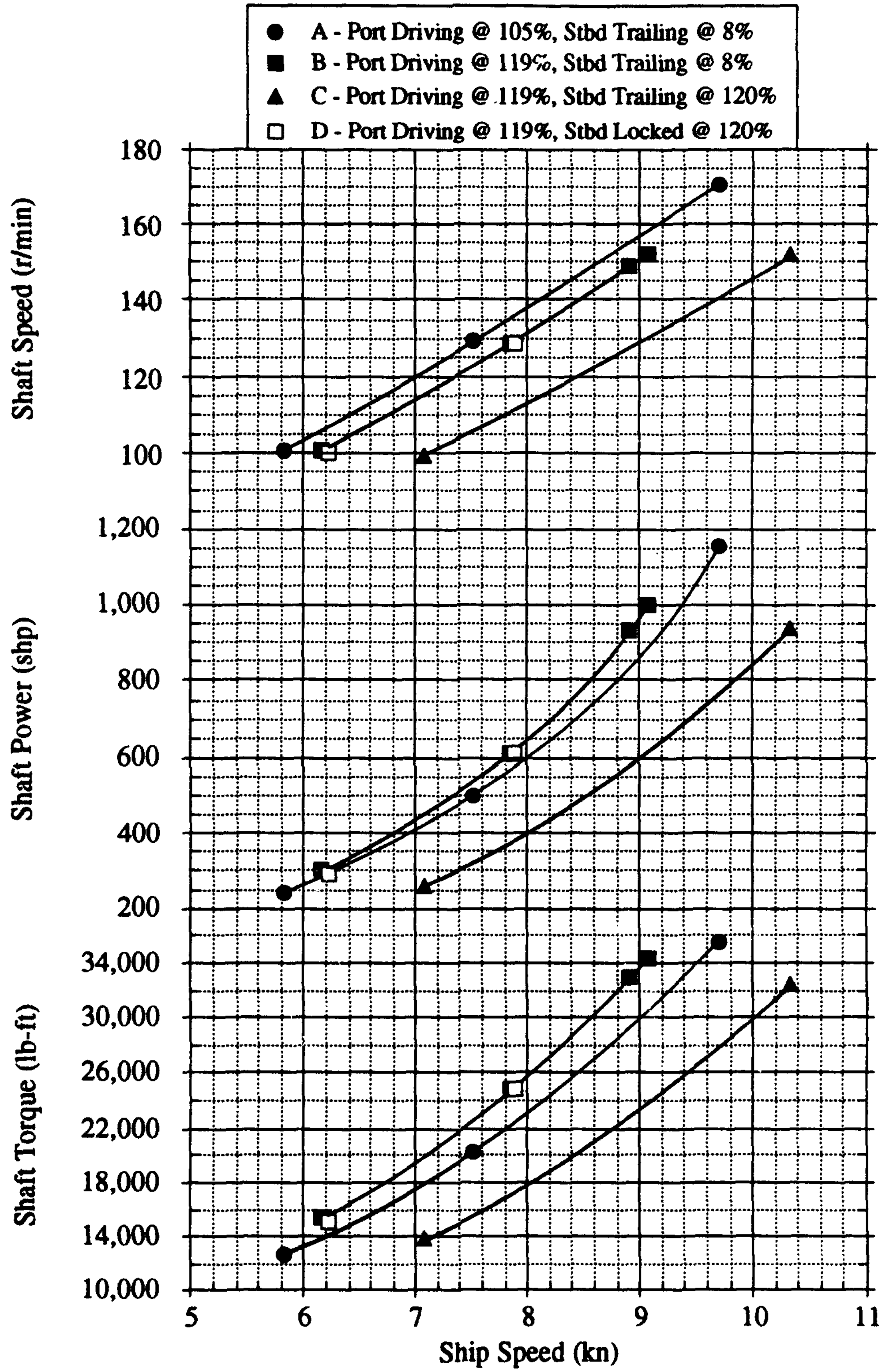


Fig. 7. USS SCOUT (MCM 8) locked and trailed shaft trial results - 1,285 tons (English units).

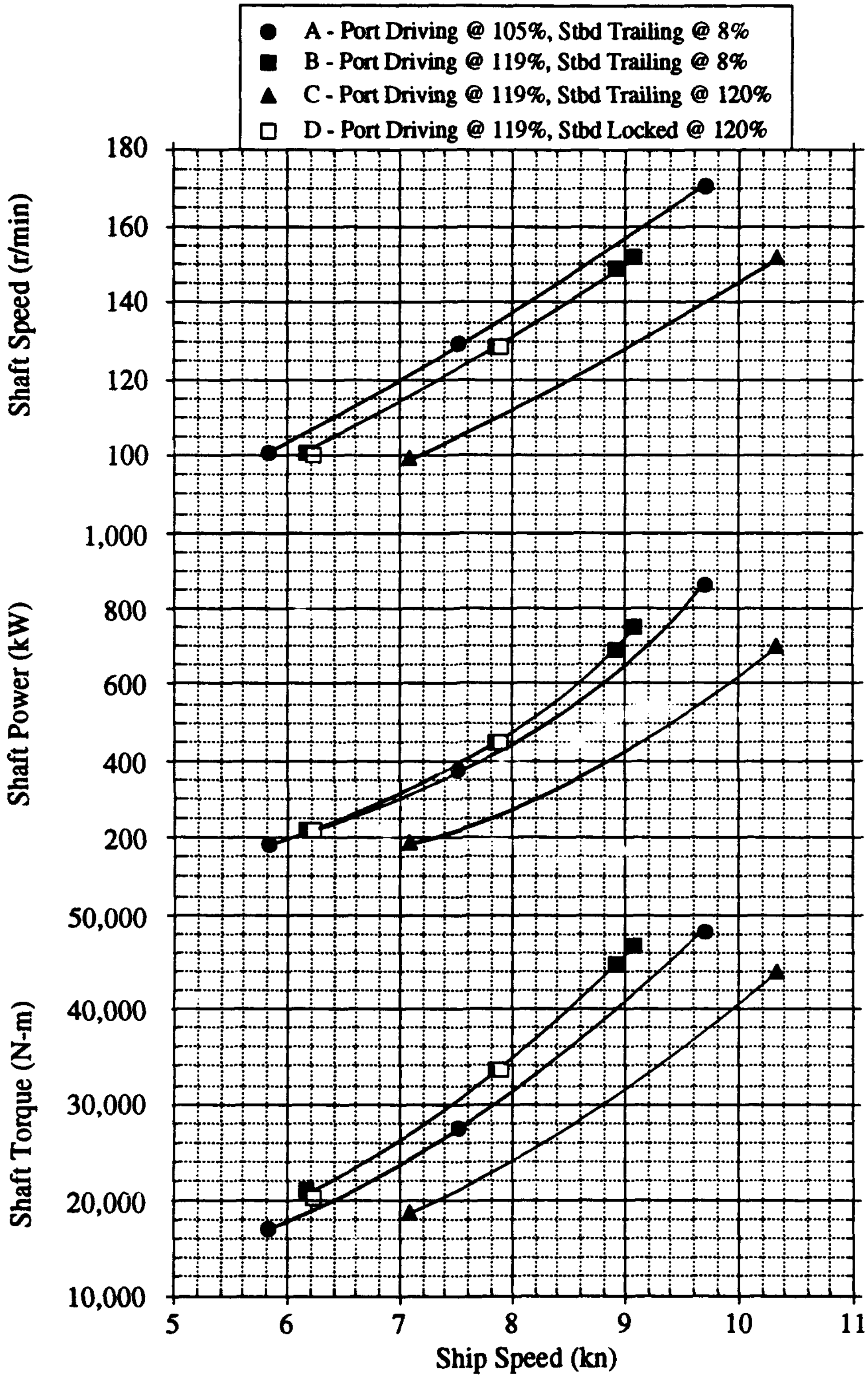


Fig. 8. USS SCOUT (MCM 8) locked and trailed shaft trial results - 1,306 tonnes (metric units).

Table 1. USS SCOUT (MCM 8) principal ship and propeller shaft characteristics.

Ship Characteristics		
Length Overall (LOA), ft (m)	224.00	(68.28)
Length Between Perpendiculars (LBP), ft (m)	205.50	(62.64)
Beam, Maximum at DWL, ft (m)	33.60	(10.24)
Design Displacement, ton (t)	1,310	(1,330)
Design Total Shaft Power, shp (kW)	2,300	(1,720)
Power Plant	4 Isotta Fraschini Diesel Engines	
Cylinders per Engine	6	
Engine Speed, r/min	1,800	
Engines per Shaft	2	
Design Power per Engine, bhp (kW)	600	450
Couplings		Voith Fluid Drive

Propulsion Shaft Characteristics		
Number of Propeller Shafts	2	
Design Shaft Torque, ft-lb (N-m)	34,400	(46,600)
Design Shaft Speed, r/min	176	
Starboard Shaft Outside Diameter, in. (cm)	13.508	(34.310)
Starboard Shaft Inside Diameter, in. (cm)	12.301	(31.244)
Starboard Shaft Modulus of Rigidity, lb/in^2 (kPa)	6,450,000	(44,470,000)
Port Shaft Outside Diameter, in. (cm)	13.485	(34.252)
Port Shaft Inside Diameter, in. (cm)	12.295	(31.229)
Port Shaft Modulus of Rigidity, lb/in^2 (kPa)	6,530,000	(45,020,000)

Table 2. USS SCOUT (MCM 8) principal propeller characteristics.

Number of Propellers	2	
Manufacturer	Bird-Johnson Company	
Material	Ni-Al Bronze	
NAVSEA Drawing Number	5844409	
Direction of Shaft Rotation (Port)	Inboard	
Direction of Shaft Rotation (Starboard)	Inboard	
Serial Number (Port)	0492	
Serial Number (Starboard)	0493	
Number of Blades	5	
Propeller Diameter, ft (m)	7.0	(2.13)
P/D at 0.7R	1.780	
Design Pitch at 0.7R, ft (m)	12.46	(3.80)
Maximum Ahead Pitch, ft (m)	14.96	(4.56)
Maximum Astern Pitch, ft (m)	6.22	(1.90)
Chord at 0.7R, in. (cm)	33.924	(862)
Expanded Area, ft^2 (m^2)	29.03	(2.70)
Disc Area, ft^2 (m^2)	38.48	(3.58)
Projected Area ft^2 (m^2)	22.70	(2.11)
Projected Area / Disc Area	0.590	
Total Weight of Hub with Blades (dry), lb (kg)	4,553.4	(2,065.4)
Oil Weight to Fill Hub, lb (kg)	120	(54.4)
Total Weight (wet) less Buoyancy, lb (kg)	3,941.4	(1,787.8)

Table 3. USS SCOUT (MCM 8) measurement accuracies.

Measurement	Source	Calibration Source	Resolution *	Accuracy
Steady Ship Speed	Pulse-Radar System	Surveyed Baseline	0.01 kn	± 0.05 kn
Instantaneous Speed	Pulse-Radar System	Surveyed Baseline	0.1 kn	± 0.5 kn
Shaft Torque 1645 System	Deflection Sensor	Deflection Calibration Stand	0.02 % **	± 1.5 % **
Shaft Speed	Infrared Light Sensor	Electronic Oscillator	0.1 r/min	± 0.5 r/min
Wind Speed	Anemometer (DC Generator)	Wind Tunnel	0.1 kn	± 0.5 kn
Wind Direction	Anemometer (Synchro Transmitter)	Visual Alignment	0.1°	± 1° (± 5° Alignment)
Rudder Angle	Synchro Transmitter	Rudder Quadrant	0.1°	± 0.25°
Ship Heading	Gyrocompass	Gyrocompass	0.1°	± 0.25°
Steady EM Log Speed	Synchro Transmitter	Standardization Trials	0.05 kn	± 0.25 kn ***
Propeller Pitch	Shaped Potentionmeter	Diver Measurements	1 % of Design	± 2 % of Design
Displacement	Draft Marks	Visual Observations	± 1 in.(2.5 cm)	± 15 tons (15 t)

* Least detectable change in measurement.
** At full scale, the units are ft-lb (N-m).
*** When calibrated.

Table 4. USS SCOUT (MCM 8) standardization and locked and trailed shaft trial conditions.

Item	Standardization Trial		Locked and Trailed Shaft Trials	
Trial Date	15 June 1991		16 June 1991	
Time of Day	0800 to 1900		0800 to 1800	
Trial Location	AUTEC, Bahamas		AUTEC, Bahamas	
Displacement, tons (t)	1,293	(1,314)	1,285	(1,306)
Ship Trim by Stern, ft (m)	1.3	(0.40)	1.4	(0.43)
Seawater Temperature	81°F	(27°C)	83°F	(28°C)
Seawater Specific Gravity	1.026		1.026	
Sea State	0 to 1		0 to 1	
Air Temperature	87°F	(31°C)	86°F	(30°C)
Avg True Wind Speed, kn	12		6	
True Wind Direction	060° - 109°		321° - 057°	

Table 5. USS SCOUT (MCM 8) standardization trial results, both shafts driving, 103% pitch, 15 June 1991 (English units).

Run No.	True Wind Spd (kn)	True Wind Dir (deg)	Shaft Speed Stbd (r/min)	Shaft Speed Port (r/min)	Shaft Torque, 1645 System Stbd (ft-lbf)	Shaft Torque, 1645 System Port (ft-lbf)	Shaft Power Stbd (hp)	Shaft Power Port (hp)	Propeller Pitch Stbd (% des)	Propeller Pitch Port (% des)	Ship's Speed EM Log (kn)	Ship's Speed Range (kn)	Average Shaft Spd (r/min)	Total Torque (ft-lbf)	Total Power (hp)
1160N	12.7	96	91.1	91.3	8,500	8,100	150	140	102	104	7.5	7.91	91.2	16,600	290
1170S	11.4	93	90.9	91.3	8,700	8,100	150	140	102	104	7.9	7.50	91.1	16,800	290
Avg									102	104	7.7	7.70	91.2	16,700	290
1010N	12.2	96	110.5	110.6	12,100	11,600	260	240	102	105	9.0	9.40	110.6	23,700	500
1020S	10.6	101	110.4	110.4	12,400	11,600	260	240	102	105	9.6	9.09	110.4	24,000	500
Avg									102	105	9.3	9.25	110.5	23,800	500
1040S	9.7	99	129.8	129.9	17,000	16,200	420	400	102	105	11.0	10.55	129.8	33,200	820
1050N	12.5	92	129.9	129.9	16,800	16,200	420	400	102	105	10.5	10.88	129.9	33,000	820
Avg									102	105	10.8	10.72	129.8	33,100	820
1070N	13.5	99	151.0	151.3	22,500	21,500	650	620	102	103	12.1	12.35	151.2	44,000	1,270
1080S	9.5	109	151.0	151.1	22,900	21,500	660	620	102	103	12.5	12.06	151.0	44,400	1,280
1090N	12.2	99	151.0	151.1	22,600	21,200	650	610	102	103	12.1	12.33	151.0	43,800	1,260
Avg									102	103	12.3	12.20	151.0	44,100	1,270
1100N	13.8	98	165.7	166.6	27,400	27,000	860	860	102	105	13.3	13.41	166.2	54,400	1,720
1110S	9.8	101	165.5	166.6	27,500	27,200	870	860	102	105	13.8	13.17	166.0	54,700	1,730
Avg									102	105	13.6	13.29	166.1	54,500	1,720
1130S	9.2	95	175.2	175.3	31,100	30,000	1,040	1,000	102	104	14.3	13.77	175.2	61,100	2,040
1140N	13.4	91	175.3	175.4	30,600	29,900	1,020	1,000	102	104	13.9	14.06	175.4	60,500	2,020
1150S	10.2	100	175.2	175.3	30,800	29,800	1,030	1,000	102	104	14.2	13.70	175.2	60,600	2,030
Avg									102	104	14.1	13.90	175.3	60,700	2,030
2130S	7.8	64	175.3	175.3	30,200	30,000	1,010	1,000	100	105	14.2	13.59	175.3	60,200	2,010
2140N	10.6	62	175.3	175.3	30,100	30,400	1,010	1,010	100	105	13.9	14.21	175.3	60,500	2,020
2150S	6.4	60	175.3	175.3	29,800	30,100	1,000	1,000	100	105	14.2	13.53	175.3	59,900	2,000
Avg*									100	105	14.0	13.89	175.3	60,200	2,010

* This spot was conducted on 16 June 1991 as a check on the repeatability of the data.

Table 6. USS SCOUT (MCM 8) standardization trial results, both shafts driving, 103% pitch, 15 June 1991 (metric units).

Run No.	True Wind Spd (kn)	True Wind Dir (deg)	Shaft Speed Stbd (r/min)	Shaft Speed Port (r/min)	Shaft Torque, 1645 System Stbd (N-m)	Shaft Torque, 1645 System Port (N-m)	Shaft Power Stbd (kW)	Shaft Power Port (kW)	Propeller Pitch Stbd (% des)	Propeller Pitch Port (% des)	Ship's Speed EM Log (kn)	Ship's Speed Range (kn)	Average Shaft Spd (r/min)	Total Torque (N-m)	Total Power (kW)
1160N	12.7	96	91.1	91.3	11,500	11,000	110	100	102	104	7.5	7.91	91.2	22,500	210
1170S	11.4	93	90.9	91.3	11,800	11,000	110	100	102	104	7.9	7.50	91.1	22,800	210
Avg									102	104	7.7	7.70	91.2	22,600	210
1010N	12.2	96	110.5	110.6	16,400	15,700	190	180	102	105	9.0	9.40	110.6	32,100	370
1020S	10.6	101	110.4	110.4	16,800	15,700	190	180	102	105	9.6	9.09	110.4	32,500	370
Avg									102	105	9.3	9.25	110.5	32,300	370
1040S	9.7	99	129.8	129.9	23,000	22,000	310	300	102	105	11.0	10.55	129.8	45,000	610
1050N	12.5	92	129.9	129.9	22,800	22,000	310	300	102	105	10.5	10.88	129.9	44,800	610
Avg									102	105	10.8	10.72	129.8	44,900	610
1070N	13.5	99	151.0	151.3	30,500	29,200	480	460	102	103	12.1	12.35	151.2	59,700	940
1080S	9.5	109	151.0	151.1	31,000	29,200	490	460	102	103	12.5	12.06	151.0	60,200	950
1090N	12.2	99	151.0	151.1	30,600	28,700	480	450	102	103	12.1	12.33	151.0	59,300	930
Avg									102	103	12.3	12.20	151.0	59,900	940
1100N	13.8	98	165.7	166.6	37,100	36,600	640	640	102	105	13.3	13.41	166.2	73,700	1,280
1110S	9.8	101	165.5	166.6	37,300	36,900	650	640	102	105	13.8	13.17	166.0	74,200	1,290
Avg									102	105	13.6	13.29	166.1	74,000	1,280
1130S	9.2	95	175.2	175.3	42,200	40,700	780	750	102	104	14.3	13.77	175.2	82,900	1,530
1140N	13.4	91	175.3	175.4	41,500	40,500	760	750	102	104	13.9	14.06	175.4	82,000	1,510
1150S	10.2	100	175.2	175.3	41,800	40,400	770	750	102	104	14.2	13.70	175.2	82,200	1,520
Avg									102	104	14.1	13.90	175.3	82,300	1,520
2130S	7.8	64	175.3	175.3	40,900	40,700	750	750	100	105	14.2	13.59	175.3	81,600	1,500
2140N	10.6	62	175.3	175.3	40,800	41,200	750	750	100	105	13.9	14.21	175.3	82,000	1,500
2150S	6.4	60	175.3	175.3	40,400	40,800	750	750	100	105	14.2	13.53	175.3	81,200	1,500
Avg*									100	105	14.0	13.89	175.3	81,700	1,500

* This spot was conducted on 16 June 1991 as a check on the repeatability of the data.

Table 7. USS SCOUT (MCM 8) standardization trial results, both shafts driving, 110% pitch, 15 June 1991 (English units).

Run No.	True Wind Spd (kn)	True Wind Dir (deg)	Shaft Speed Stbd (r/min)	Shaft Speed Port (r/min)	Shaft Torque, 1645 System Stbd (ft-lbf)	Shaft Torque, 1645 System Port (ft-lbf)	Shaft Power Stbd (hp)	Shaft Power Port (hp)	Propeller Pitch Stbd (% des)	Propeller Pitch Port (% des)	Ship's Speed EM Log (kn)	Ship's Speed Range (kn)	Average Shaft Spd (r/min)	Total Torque (ft-lbf)	Total Power (hp)
1210N	13.5	94	140.1	139.3	21,900	20,800	590	550	110	111	11.7	12.05	139.7	42,700	1,140
1220S	10.5	92	140.2	139.3	22,200	21,000	590	560	110	111	12.1	11.53	139.8	43,200	1,150
Avg									110	111	11.9	11.79	139.8	42,900	1,140
1240S	9.8	96	150.5	150.9	25,400	24,800	730	710	110	111	13.0	12.36	150.7	50,200	1,440
1250N	12.4	92	150.5	151.0	25,100	24,800	720	710	110	111	12.5	12.89	150.8	49,900	1,430
1260S	8.6	94	150.5	150.9	25,400	24,700	730	710	110	111	13.0	12.35	150.7	50,100	1,440
Avg									110	111	12.8	12.62	150.8	50,000	1,430
1270N	14.5	89	161.0	160.7	29,300	28,300	900	860	110	111	13.2	13.52	160.8	57,600	1,760
1280S	11.4	85	161.0	160.6	29,500	28,000	900	860	110	111	13.8	13.16	160.8	57,500	1,760
1290N	14.7	86	161.1	160.7	29,200	28,200	900	860	110	111	13.2	13.52	160.9	57,400	1,760
Avg									110	111	13.5	13.34	160.8	57,500	1,760
1300S	12.3	83	175.0	175.2	34,600	33,400	1,150	1,120	110	111	14.6	13.97	175.1	68,000	2,270
1310N	15.3	87	175.1	175.2	34,300	33,500	1,140	1,120	110	111	14.1	14.46	175.2	67,800	2,260
1320S	10.6	84	175.1	175.1	34,300	33,300	1,140	1,110	110	111	14.6	13.93	175.1	67,600	2,250
Avg									110	111	14.4	14.21	175.2	67,800	2,260

Table 8. USS SCOUT (MCM 8) standardization trial results, both shafts driving, 110% pitch, 15 June 1991 (metric units).

Run No.	True Wind Spd (kn)	True Wind Dir (deg)	Shaft Speed Stbd (r/min)	Shaft Speed Port (r/min)	Shaft Torque, 1645 System Stbd (N-m)	Shaft Torque, 1645 System Port (N-m)	Shaft Power Stbd (kW)	Shaft Power Port (kW)	Propeller Pitch Stbd (% des)	Propeller Pitch Port (% des)	Ship's Speed EM Log (kn)	Ship's Speed Range (kn)	Average Shaft Spd (r/min)	Total Torque (N-m)	Total Power (kW)
1210N	13.5	94	140.1	139.3	29,700	28,200	440	410	110	111	11.7	12.05	139.7	57,900	850
1220S	10.5	92	140.2	139.3	30,100	28,500	440	420	110	111	12.1	11.53	139.8	58,600	860
Avg									110	111	11.9	11.79	139.8	58,100	850
1240S	9.8	96	150.5	150.9	34,400	33,600	540	530	110	111	13.0	12.36	150.7	68,000	1,070
1250N	12.4	92	150.5	151.0	34,000	33,600	540	530	110	111	12.5	12.89	150.8	67,600	1,070
1260S	8.6	94	150.5	150.9	34,400	33,500	540	530	110	111	13.0	12.35	150.7	67,900	1,070
Avg									110	111	12.8	12.62	150.8	67,800	1,070
1270N	14.5	89	161.0	160.7	39,700	38,400	670	640	110	111	13.2	13.52	160.8	78,100	1,310
1280S	11.4	85	161.0	160.6	40,000	38,000	670	640	110	111	13.8	13.16	160.8	78,000	1,310
1290N	14.7	86	161.1	160.7	39,600	38,200	670	640	110	111	13.2	13.52	160.9	77,800	1,310
Avg									110	111	13.5	13.34	160.8	78,000	1,310
1300S	12.3	83	175.0	175.2	46,900	45,300	860	840	110	111	14.6	13.97	175.1	92,200	1,700
1310N	15.3	87	175.1	175.2	46,500	45,400	850	840	110	111	14.1	14.46	175.2	91,900	1,690
1320S	10.6	84	175.1	175.1	46,500	45,100	850	830	110	111	14.6	13.93	175.1	91,600	1,680
Avg									110	111	14.4	14.21	175.2	91,900	1,690

Table 9. USS SCOUT (MCM 8) standardization trial results, both shafts driving, 120% and 92% pitch, 15 June 1991 (English units).

Run No.	True Wind Spd (kn)	True Wind Dir (deg)	Shaft Speed Stbd (r/min)	Shaft Speed Port (r/min)	Shaft Torque, 1645 System Stbd (ft-lbf)	Shaft Torque, 1645 System Port (ft-lbf)	Shaft Power Stbd (hp)	Shaft Power Port (hp)	Propeller Pitch Stbd (% des)	Propeller Pitch Port (% des)	Ship's Speed EM Log (kn)	Ship's Speed Range (kn)	Average Shaft Spd (r/min)	Total Torque (ft-lbf)	Total Power (hp)
1470S	9.6	72	140.7	141.6	26,100	25,400	700	680	120	120	12.7	12.12	141.2	51,500	1,380
1480N	13.0	77	140.7	141.6	26,100	25,600	700	690	120	120	12.1	12.52	141.2	51,700	1,390
Avg									120	120	12.4	12.32	141.2	51,600	1,390
1410N	12.8	83	150.6	151.1	29,900	29,000	860	830	120	120	12.9	13.33	150.8	58,900	1,690
1420S	9.5	78	150.7	151.1	30,000	28,900	860	830	120	120	13.5	12.88	150.9	58,900	1,690
Avg									120	120	13.2	13.11	150.8	58,900	1,690
1440N	14.2	78	161.7	161.7	34,400	33,400	1,060	1,030	120	120	13.7	14.01	161.7	67,800	2,090
1450S	10.0	69	161.7	161.4	34,500	33,000	1,060	1,010	120	120	14.3	13.73	161.6	67,500	2,070
1460N	13.1	70	161.7	161.4	34,400	33,200	1,060	1,020	120	120	13.7	14.05	161.6	67,600	2,080
Avg									120	120	14.0	13.88	161.6	67,600	2,080
1530S	9.2	71	150.8	151.0	18,500	17,800	530	510	90	93	11.9	11.12	150.9	36,300	1,040
1540N	10.8	83	150.8	151.1	18,500	17,800	530	510	90	93	11.4	11.86	151.0	36,300	1,040
Avg									90	93	11.6	11.49	151.0	36,300	1,040
1550S	9.3	88	175.6	175.7	25,200	24,300	840	810	90	93	13.6	12.84	175.6	49,500	1,650
1560N	13.1	67	175.6	175.8	25,200	24,400	840	820	90	93	13.0	13.39	175.7	49,600	1,660
Avg									90	93	13.3	13.12	175.7	49,600	1,660

Table 10. USS SCOUT (MCM 8) standardization trial results, both shafts driving, 120% and 92% pitch, 15 June 1991 (metric units).

Run No.	True Wind Spd (kn)	True Wind Dir (deg)	Shaft Speed Stbd (r/min)	Shaft Speed Port (r/min)	Shaft Torque, 1645 System Stbd (N-m)	Shaft Torque, 1645 System Port (N-m)	Shaft Power Stbd (kW)	Shaft Power Port (kW)	Propeller Pitch Stbd (% des)	Propeller Pitch Port (% des)	Ship's Speed EM Log (kn)	Ship's Speed Range (kn)	Average Shaft Spd (r/min)	Total Torque (N-m)	Total Power (kW)
1470S	9.6	72	140.7	141.6	35,400	34,400	520	510	120	120	12.7	12.12	141.2	69,800	1,030
1480N	13.0	77	140.7	141.6	35,400	34,700	520	10	120	120	12.1	12.52	141.2	70,100	1,030
Avg									120	120	12.4	12.32	141.2	70,000	1,030
1410N	12.8	83	150.6	151.1	40,500	39,300	640	620	120	120	12.9	13.33	150.8	79,800	1,260
1420S	9.5	78	150.7	151.1	40,700	39,200	640	620	120	120	13.5	12.88	150.9	79,900	1,260
Avg									120	120	13.2	13.11	150.8	79,800	1,260
1440N	14.2	78	161.7	161.7	46,600	45,300	790	770	120	120	13.7	14.01	161.7	91,900	1,560
1450S	10.0	69	161.7	161.4	46,800	44,700	790	750	120	120	14.3	13.73	161.6	91,500	1,540
1460N	13.1	70	161.7	161.4	46,600	45,000	790	760	120	120	13.7	14.05	161.6	91,600	1,550
Avg									120	120	14.0	13.88	161.6	91,600	1,550
1530S	9.2	71	150.8	151.0	25,100	24,100	400	380	90	93	11.9	11.12	150.9	49,200	780
1540N	10.8	83	150.8	151.1	25,100	24,100	400	380	90	93	11.4	11.86	151.0	49,200	780
Avg									90	93	11.6	11.49	151.0	49,200	780
1550S	9.3	88	175.6	175.7	34,200	32,900	630	600	90	93	13.6	12.84	175.6	67,100	1,230
1560N	13.1	67	175.6	175.8	34,200	33,100	630	610	90	93	13.0	13.39	175.7	67,300	1,240
Avg									90	93	13.3	13.12	175.7	67,300	1,240

Table 11. USS SCOUT (MCM 8) locked and trailed shaft trial results, 16 June 1991 (English units).

Run No.	True Wind Spd (kn)	True Wind Dir (deg)	Shaft Speed Stbd (r/min)	Shaft Speed Port (r/min)	Shaft Torque, 1645 System Stbd (ft-lbf)	Shaft Torque, 1645 System Port (ft-lbf)	Shaft Power Stbd (hp)	Shaft Power Port (hp)	Propeller Pitch Stbd (% des)	Propeller Pitch Port (% des)	Ship's Speed EM Log (kn)	Ship's Speed Range (kn)	Average Shaft Spd (r/min)	Total Torque (ft-lbf)	Total Power (hp)
1810N	7.8	57	-	99.9	-	15,000	-	290	120	119	6.2	6.23	99.9	15,000	290
1820S	6.1	57	-	99.9	-	14,900	-	280	120	119	6.5	6.20	99.9	14,900	280
Avg*			-	99.9	-	15,000	-	290	120	119	6.4	6.22	99.9	15,000	290
1840S	5.9	65	-	128.6	-	24,600	-	600	120	119	8.2	7.80	128.6	24,600	600
1850N	9.8	69	-	128.6	-	24,900	-	610	120	119	7.8	8.00	128.6	24,900	610
Avg*			-	128.6	-	24,800	-	610	120	119	8.0	7.90	128.6	24,800	610

* These were the only locked shaft runs conducted.

Run No.	True Wind Spd (kn)	True Wind Dir (deg)	Shaft Speed Stbd (r/min)	Shaft Speed Port (r/min)	Shaft Torque, 1645 System Stbd (ft-lbf)	Shaft Torque, 1645 System Port (ft-lbf)	Shaft Power Stbd (hp)	Shaft Power Port (hp)	Propeller Pitch Stbd (% des)	Propeller Pitch Port (% des)	Ship's Speed EM Log (kn)	Ship's Speed Range (kn)	Average Shaft Spd (r/min)	Total Torque (ft-lbf)	Total Power (hp)
2610N	8.0	300	-	100.8	-	12,500	-	240	7	105	6.1	6.02	100.8	12,500	240
2620S	7.5	281	-	100.4	-	12,500	-	240	7	105	6.0	5.64	100.4	12,500	240
Avg**			-	100.6	-	12,500	-	240	7	105	6.1	5.83	100.6	12,500	240
2650S	7.0	269	-	128.9	-	20,200	-	500	8	105	7.5	7.32	128.9	20,200	500
2660N	5.0	285	-	129.1	-	20,200	-	500	8	105	7.6	7.73	129.1	20,200	500
Avg**			-	129.0	-	20,200	-	500	8	105	7.6	7.53	129.0	20,200	500
2630S	9.6	266	-	169.5	-	35,200	-	1,140	7	105	9.7	9.44	169.5	35,200	1,140
2640N	5.1	290	-	170.8	-	35,500	-	1,150	7	105	10.0	9.98	170.8	35,500	1,150
Avg**			-	170.2	-	35,400	-	1,150	7	105	9.8	9.71	170.2	35,400	1,150

** These runs are the normal trailed shaft ship operations.

Table 11. (Continued)

Run No.	True Wind Spd (kn)	True Wind Dir (deg)	Shaft Speed Stbd (r/min)	Shaft Speed Port (r/min)	Shaft Torque, 1645 System Stbd (ft-lbf)	Shaft Torque, 1645 System Port (ft-lbf)	Shaft Power Stbd (hp)	Shaft Power Port (hp)	Propeller Pitch Stbd (% des)	Propeller Pitch Port (% des)	Ship's Speed EM Log (kn)	Ship's Speed Range (kn)	Average Shaft Spd (r/min)	Total Torque (ft-lbf)	Total Power (hp)
1610S	3.8	321	-	100.7	-	15,300	-	290	7	119	6.4	6.07	100.7	15,300	290
1620N	2.7	66	-	100.8	-	15,400	-	300	7	119	6.3	6.25	100.8	15,400	300
1630S	2.7	113	-	100.7	-	15,400	-	300	7	119	6.4	6.12	100.7	15,400	300
Avg			-	100.8	-	15,400	-	300	7	119	6.4	6.17	100.8	15,400	300
1640N	2.4	40	-	128.7	-	24,900	-	610	7	119	7.9	7.88	128.7	24,900	610
1650S	0.4	129	-	128.5	-	24,800	-	610	7	119	8.0	7.84	128.5	24,800	610
Avg			-	128.6	-	24,800	-	610	7	119	8.0	7.86	128.6	24,800	610
1672N	4.8	65	-	148.6	-	33,000	-	930	8	119	9.0	9.15	148.6	33,000	930
1680S	3.3	79	-	148.7	-	33,000	-	930	8	119	9.2	8.73	148.7	33,000	930
1690N	5.3	59	-	148.7	-	33,000	-	930	8	119	8.9	9.08	148.7	33,000	930
Avg			-	148.7	-	33,000	-	930	8	119	9.1	8.92	148.7	33,000	930
1730S	4.3	77	-	152.0	-	34,300	-	990	8	119	9.3	8.85	152.0	34,300	990
1740N	6.7	69	-	151.9	-	34,500	-	1,000	8	119	9.1	9.29	151.9	34,500	1,000
Avg			-	152.0	-	34,400	-	1,000	8	119	9.2	9.07	152.0	34,400	1,000
1910S	5.5	71	39.7	99.8	-	13,800	-	260	120	119	7.3	6.86	99.8	13,800	260
1920N	6.8	67	39.4	99.7	-	14,000	-	270	120	119	7.0	7.29	99.7	14,000	270
Avg***			39.6	99.8	-	13,900	-	260	120	119	7.2	7.08	99.8	13,900	260
1940N	5.9	70	61.2	151.9	-	32,600	-	940	120	119	10.3	10.50	151.9	32,600	940
1950S	4.6	79	61.7	151.9	-	32,100	-	930	120	119	10.7	10.18	151.9	32,100	930
Avg***			61.5	151.9	-	32,400	-	940	120	119	10.5	10.34	151.9	32,400	940

*** These were the only trailed shaft runs where the shaft rotated.

Table 12. USS SCOUT (MCM 8) locked and trailed shaft trial results, 16 June 1991 (metric units).

Run No.	True Wind Spd (kn)	True Wind Dir (deg)	Shaft Speed Stbd (r/min)	Shaft Speed Port (r/min)	Shaft Torque, 1645 System Stbd (N-m)	Shaft Torque, 1645 System Port (N-m)	Shaft Power Stbd (kW)	Shaft Power Port (kW)	Propeller Pitch Stbd (% des)	Propeller Pitch Port (% des)	Ship's Speed EM Log (kn)	Ship's Speed Range (kn)	Average Shaft Spd (r/min)	Total Torque (N-m)	Total Power (kW)
1810N	7.8	57	-	99.9	-	20,300	-	220	120	119	6.2	6.23	99.9	20,300	220
1820S	6.1	57	-	99.9	-	20,200	-	210	120	119	6.5	6.20	99.9	20,200	210
Avg*			-	99.9	-	20,300	-	220	120	119	6.4	6.22	99.9	20,300	220
1840S	5.9	65	-	128.6	-	33,400	-	450	120	119	8.2	7.80	128.6	33,400	450
1850N	9.8	69	-	128.6	-	33,800	-	450	120	119	7.8	8.00	128.6	33,800	450
Avg*			-	128.6	-	33,600	-	450	120	119	8.0	7.90	128.6	33,600	450

* These were the only locked shaft runs conducted.

Run No.	True Wind Spd (kn)	True Wind Dir (deg)	Shaft Speed Stbd (r/min)	Shaft Speed Port (r/min)	Shaft Torque, 1645 System Stbd (N-m)	Shaft Torque, 1645 System Port (N-m)	Shaft Power Stbd (kW)	Shaft Power Port (kW)	Propeller Pitch Stbd (% des)	Propeller Pitch Port (% des)	Ship's Speed EM Log (kn)	Ship's Speed Range (kn)	Average Shaft Spd (r/min)	Total Torque (N-m)	Total Power (kW)
2610N	8.0	300	-	100.8	-	16,900	-	180	7	105	6.1	6.02	100.8	16,900	180
2620S	7.5	281	-	100.4	-	16,900	-	180	7	105	6.0	5.64	100.4	16,900	180
Avg**			-	100.6	-	16,900	-	180	7	105	6.1	5.83	100.6	16,900	180
2650S	7.0	269	-	128.9	-	27,400	-	370	8	105	7.5	7.32	128.9	27,400	370
2660N	5.0	285	-	129.1	-	27,400	-	370	8	105	7.6	7.73	129.1	27,400	370
Avg**			-	129.0	-	27,400	-	370	8	105	7.6	7.53	129.0	27,400	370
2630S	9.6	266	-	169.5	-	47,700	-	850	7	105	9.7	9.44	169.5	47,700	850
2640N	5.1	290	-	170.8	-	48,100	-	860	7	105	10.0	9.98	170.8	48,100	860
Avg**			-	170.2	-	48,000	-	860	7	105	9.8	9.71	170.2	48,000	860

** These runs are the normal trailed shaft ship operations.

Table 12. (Continued)

Run No.	True Wind Spd (kn)	True Wind Dir (deg)	Shaft Speed Stbd (r/min)	Shaft Speed Port (r/min)	Shaft Torque, 1645 System Stbd (N-m)	Shaft Torque, 1645 System Port (N-m)	Shaft Power Stbd (kW)	Shaft Power Port (kW)	Propeller Pitch Stbd (% des)	Propeller Pitch Port (% des)	Ship's Speed EM Log (kn)	Ship's Speed Range (kn)	Average Shaft Spd (r/min)	Total Torque (N-m)	Total Power (kW)
1610S	3.8	321	-	100.7	-	20,700	-	220	7	119	6.4	6.07	100.7	20,700	220
1620N	2.7	66	-	100.8	-	20,900	-	220	7	119	6.3	6.25	100.8	20,900	220
1630S	2.7	113	-	100.7	-	20,900	-	220	7	119	6.4	6.12	100.7	20,900	220
Avg			-	100.8	-	20,900	-	220	7	119	6.4	6.17	100.8	20,900	220
1640N	2.4	40	-	128.7	-	33,800	-	460	7	119	7.9	7.88	128.7	33,800	460
1650S	0.4	129	-	128.5	-	33,600	-	450	7	119	8.0	7.84	128.5	33,600	450
Avg			-	128.6	-	33,600	-	450	7	119	8.0	7.86	128.6	33,600	450
1672N	4.8	65	-	148.6	-	44,700	-	690	8	119	9.0	9.15	148.6	44,700	690
1680S	3.3	79	-	148.7	-	44,700	-	690	8	119	9.2	8.73	148.7	44,700	690
1690N	5.3	59	-	148.7	-	44,700	-	690	8	119	8.9	9.08	148.7	44,700	690
Avg			-	148.7	-	44,700	-	690	8	119	9.1	8.92	148.7	44,700	690
1730S	4.3	77	-	152.0	-	46,500	-	740	8	119	9.3	8.85	152.0	46,500	740
1740N	6.7	69	-	151.9	-	46,800	-	750	8	119	9.1	9.29	151.9	46,800	750
Avg			-	152.0	-	46,600	-	750	8	119	9.2	9.07	152.0	46,600	750
1910S	5.5	71	39.7	99.8	-	18,700	-	190	120	119	7.3	6.86	99.8	18,700	190
1920N	6.8	67	39.4	99.7	-	19,000	-	200	120	119	7.0	7.29	99.7	19,000	200
Avg***			39.6	99.8	-	18,800	-	190	120	119	7.2	7.08	99.8	18,800	190
1940N	5.9	70	61.2	151.9	-	44,200	-	700	120	119	10.3	10.50	151.9	44,200	700
1950S	4.6	79	61.7	151.9	-	43,500	-	690	120	119	10.7	10.18	151.9	43,500	690
Avg***			61.5	151.9	-	43,900	-	700	120	119	10.5	10.34	151.9	43,900	700

*** These were the only trailed shaft runs where the shaft rotated.

THIS PAGE INTENTIONALLY LEFT BLANK

APPENDIX A
INSTRUMENTATION

A description of the DTRC instrumentation and existing ship signals on SCOUT are discussed below. This section of the report is divided into the following subsections: introduction, ship's position, ship's speed by EM Log, heading and rudder, relative wind, propeller pitch, shaft torque, shaft speed, and shaft power.

INTRODUCTION

The measurements taken on each run during the trials were: ship's position, EM log speed, ship's heading, rudder position, relative wind speed, relative wind direction, propeller pitch, propeller pitch control system oil temperature and pressure, shaft torque, and shaft speed. Measurements were collected via a Hewlett Packard (HP) data acquisition unit and an HP computer. When appropriate, the measurements were converted to analog voltages prior to entering the data acquisition unit. The computer calculated the run averages as well as the maximum and minimum values. The data were also converted into engineering units and displayed in a hard copy format as output from a line printer. Figure 1 shows the data acquisition system used on SCOUT.

SHIP'S POSITION

Ship based DTRC pulse radar equipment (Motorola Falcon IV) tracked the ship's position with respect to two shore based reference points. Distances from the ship to each of the shore sites were used to calculate the ship's position on a coordinate system defined by the shore sites. A more complete description of the tracking range and coordinates can be found in Appendix B.

The Motorola Falcon system provided a real time display of ship position, and coupled with other computer driven equipment, supplied an instantaneous analysis of ship speed and maneuvering characteristics. Calibration of the tracking equipment is also described in Appendix B.

SHIP'S SPEED BY EM LOG

EM Log speed was recorded by tapping into the ship's EM Log synchro signal. The ship's EM Log measures speed by in water track. Therefore, the EM Log speed is the ship's speed through the water.

A plot of the ship's EM Log speed versus the range speed for each data spot is shown in Fig. A.1. The data for this graph are the spot average speeds and are thus a comparison of speed through the water.

HEADING AND RUDDER

Ship's heading and rudder position were recorded using ship's synchro signals. These three phase, 60-cycle, signals were converted to analog voltages using a synchro to analog (S/A) converter. The analog voltages were then sent to the computer via the data acquisition unit.

RELATIVE WIND

Relative wind speed and direction were recorded using a wind anemometer provided by DTRC. This anemometer was mounted on the ship's anchor light mast. Analog voltages from the anemometer were input to the computer as described above. Calculations were made, using the relative wind speed and direction along with the ship's speed and heading, to determine true wind speed and direction.

PROPELLER PITCH

Propeller pitch voltages were recorded using the analog signal from the shaped potentiometer located at the OD box. Propeller pitch voltage was calibrated against actual blade positions by divers in the water using a DTRC designed protractor and a Bird-Johnson pitch scale. An extensive description of this procedure and the calibration is included in Appendix D.

Propeller pitch control system hydraulic oil temperature data were collected by the ship's force reading the temperature gage on the hydraulic oil power module (HOPM) and with a DTRC installed wrap-around temperature gage on the return oil line. The analog voltages provided by each shaped potentiometer were input to the computer via the data acquisition unit.

It is noted that no synchronization problems between port and starboard shaft speed or pitch were observed during any acceleration or deceleration runs on SCOUT.

SHAFT TORQUE

Torque data were collected from the DTRC installed Wireless Data Corporation (WDC) 1645 torsionmeter system. These signals were provided to the computer via the data acquisition unit.

The WDC 1645 torsionmeter system is a strain gage bridge monitoring system. One system was mounted on each propulsion shaft on the spool spacer between a flexible coupling and the reduction gears. Two carrier rings were clamped on each spool section and were used to transmit the torque on the shaft to a sensor bar. The sensor bar is a sealed metal tube containing a strain gage bridge which produces a voltage directly proportional to the deflection of the bar. A stationary electronics unit provided voltage and current to drive the rotating electronics and strain gage bridge. The output of the bridge was provided to a rotating low power transmitter. The transmitter signal was received, demodulated, and conditioned by the stationary unit, thus producing an analog voltage proportional to torque. These voltages were provided to the computer via the data acquisition unit.

The spool spacer shaft section on SCOUT is made of a cast nonferrous copper alloy #953. Nonuniformity throughout the spool spacer due to the casting process, causes inconsistencies in the modulus of rigidity from shaft to shaft. Therefore, the modulus of rigidity for each spool spacer shaft section was determined from static load tests conducted at Peterson Builders, Inc. in March 1989.

The WDC torque measurement system was calibrated by subjecting the sensor bar to precise displacement increments. These displacements were related to shaft torque by known shaft properties such as outside diameter, inside diameter, and modulus of rigidity. These particular properties for the shaft sections where the WDC torque measurement systems were mounted are shown in Table 1.

SHAFT SPEED

Shaft rotational speed (r/min) was obtained using an infrared light sensor mounted adjacent to each shaft. A mylar band was wrapped around and secured to each shaft. Attached to this band were 60 equally-spaced pieces of reflective tape. As the shaft rotated, a pulse was generated each time a tape strip passed the sensor. The pulses were generated at a frequency directly proportional to shaft speed. This pulse train was converted to an analog voltage with a frequency to voltage (F/V) converter. These voltages were fed to the computer via the data acquisition unit.

SHAFT POWER

Shaft horsepower was determined from the measured shaft speed and shaft torque. It was calculated by multiplying the shaft speed (in r/min) by the shaft torque (in lb-ft) and dividing that result by the constant 5,252.

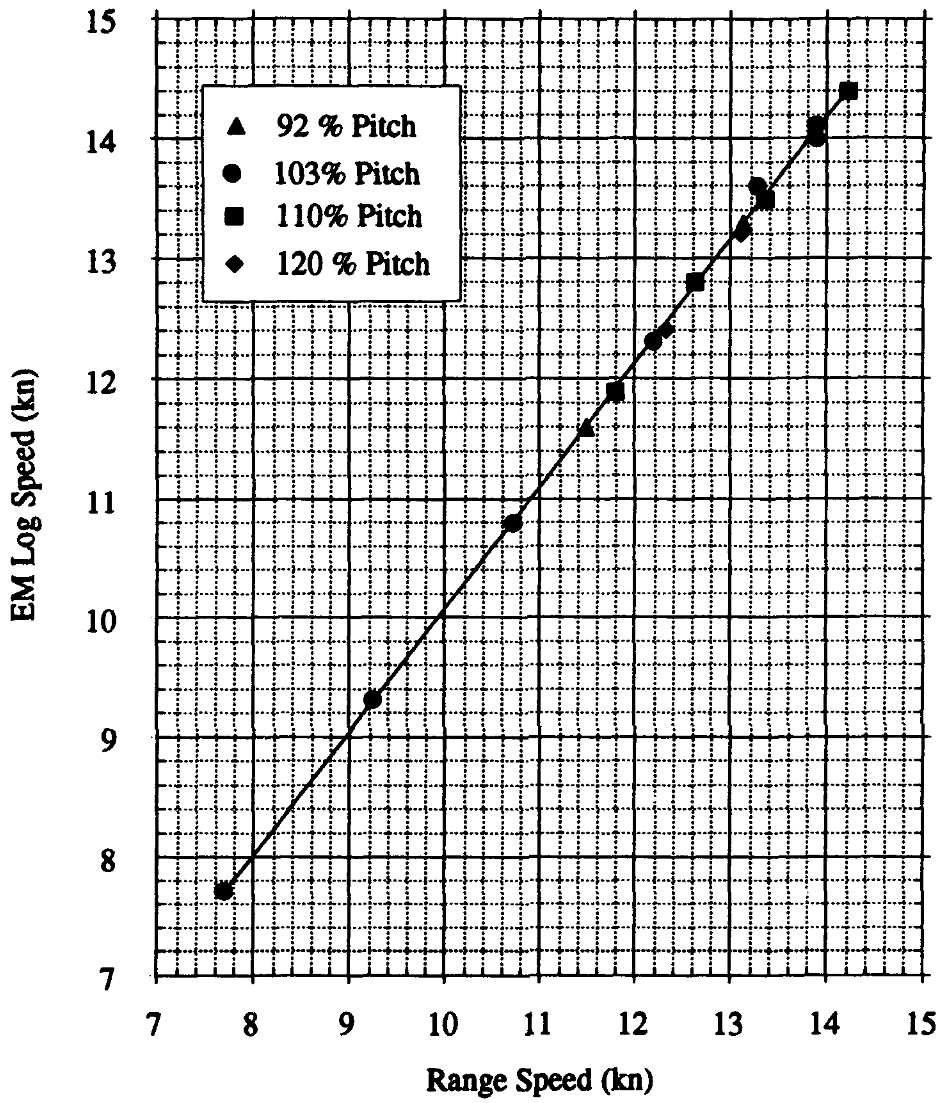


Fig. A.1. USS SCOUT (MCM 8) EM Log speed versus average range speed.

APPENDIX B
PULSE RADAR TRACKING RANGE AT AUTEC

Tracking for the Performance and Special Trials was accomplished with shipboard pulse radar equipment and two shore based reference sites located on Andros Island in the Bahamas. The range and the locations of the shore based transponders can be found on Fig. 2.

The total operating area of the trial site measured approximately 10 by 13 miles, with water depths of about 1000 fathoms. The optimum tracking zone is depicted on Fig. 2 as a rectangle with dimensions of 4 by 4 nautical miles. All runs requiring tracking were conducted about this rectangle. Geodetic data pertinent to the tracking range is shown below:

	Site 1	Site 2
Location	Andros Town	Salvador Point
Tower	Site 1 Instrumentation Tower	Site 2 Tracking Radar 2B Antenna
Latitude	24° 42' 22.4"	24° 29' 56.0"
Longitude	77° 45' 53.9"	77° 43' 8.1"
X Coordinate (yd)	0	25,640
Y Coordinate (yd)	0	0
Height (yd)	25	10.

These coordinate data were developed from tracking equipment calibrated between the surveyed towers at site 1 and site 2. The surveyed coordinate data, provided by range personnel, showed a known baseline distance of 25,640 yd between the two sites; this provided calibration data that was commensurate with the distances measured during the trials.

The true heading of the baseline was determined from coordinate data to be 168° / 348°. Approach courses for all runs which required tracking paralleled this heading.

For standardization runs, the speed of the ship over the ground was calculated using positional values from the range in the X direction only. As noted in Table 3, the speed has a resolution of 0.01 kn and an accuracy of ± 0.05 kn for these runs.

THIS PAGE INTENTIONALLY LEFT BLANK

APPENDIX C
DISPLACEMENT CALCULATIONS

The following discussion explains the procedure used for determining the displacement and trim of SCOUT during the standardization and locked and trailed shaft trials.

Accurate visual draft readings were taken on SCOUT on three occasions. The first was on the morning of 14 June 1991 at the pier at Nassau, Bahamas just prior to departure for trials. These readings are deemed reliable due to the calm water and slack lines from the ship to the pier. These readings yielded the highest displacement because SCOUT was fueled the previous evening. The second and third set of draft readings were taken in the open ocean off the coast of AUTEC as the AUTEC harbor area was too shallow for SCOUT's draft. The second set of readings were obtained on the morning of 17 June 1991 from a small boat circling SCOUT. The sea was fairly calm and these readings are deemed reasonably reliable. The last set of readings were obtained on the evening of 17 June 1991 in a similar manner to the morning readings. The sea was extremely calm (smooth as glass) and these readings are considered very reliable. Tables C.1 through C.3 contain the draft readings, and the subsequent calculations required to determine the displacement, for the three sets of draft readings obtained.

Draft readings were collected at other times throughout the trial period. However, they were considered to be very unreliable readings as the sea swells rolling past SCOUT's draft marks made it extremely difficult to "choose" a number for a particular reading.

Note that a draft reading error of ±1 in. can result in an error of ±15 tons in total displacement.

The specific gravity and temperature of the water were also needed to complete the displacement calculations. These measurements were taken at sea each day and did not vary from day to day. The hydrometer used to measure the specific gravity was calibrated so that the specific gravity of fresh water at 60° F is 1.000. Therefore, in order to calculate displacement, the measured value had to be corrected for a sea water temperature of 82° F. The corrected specific gravity is shown in the tables.

Ship's force determined displacement in the morning and evening of each day of the trials by tank soundings. These displacements were used to calculate a differential in displacement from the previous reading. The three sets of accurate DTRC obtained draft readings and the ship's force differentials were used to calculate displacements and trim for each day of the trials.

Table C.4 is a summary of SCOUT's displacement and trim throughout the trial. The first column lists the date and general time. The next column lists the ship's force determined differential in displacement. The third column lists the DTRC calculated displacements from Tables C.1, C.2, and C.3. The fourth column lists morning and evening displacements as determined from the previous two columns. The fifth column lists the average displacement for each day of the trials. The displacements for the trials were the following:

- Standardization trials, ton (t) 1,293 (1,314)
- Locked and Trailed Shaft, ton (t) 1,285 (1,306).

Finally, the table lists three columns for trim. The DTRC measured trim was obtained from the draft readings found in Tables C.1 through C.3. The trims were all down by the stern. Next, the estimated trim was interpolated from the measured trim. The last column lists the average trim for each day of the trials. The trims by the stern for each particular trial were the following:

- Standardization trials, ft (m) 1.3 (0.40)
- Locked and Trailed Shaft, ft (m) 1.4 (0.43).

Table C.1. USS SCOUT (MCM 8) standardization trial displacement calculations, 14 June 1991 morning.

Draft Readings					
	Port		Starboard		Average
	Fwd = 10.83 ft		Fwd = 11.08 ft	(3)	Fwd = 10.96 ft
(1)	Mid = 11.00 ft	(2)	Mid = 12.00 ft	(4)	Mid = 11.50 ft
	Aft = 11.67 ft		Aft = 12.58 ft	(5)	Aft = 12.12 ft

(6)	Specific Gravity of Water (Corrected for Water Temperature of 82° F)	1.023	
(7)	Specific Volume of Water = 35.955 / (6)	35.15	ft^3/ton
(8)	Forward Draft Mark to Ref. Line for Longitudinal Centers	87.0	ft
(9)	L.C.F. From Ref. Line at Draft (4) From Curves of Form (+ Aft, - Fwd)	15.6	ft
(10)	Forward Draft Mark to L.C.F. = (8) + (9)	102.6	ft
(11)	Forward Draft Mark to Midship Draft Mark	87.0	ft
(12)	Forward Draft Mark to After Draft Mark	195.5	ft
(13)	Trim Between Draft Marks = (5) - (3) (+ Aft, - Fwd)	1.2	ft
(14)	Calculated Draft at Midship Draft Marks = (3) + [(13)*(11)] / (12)	11.5	ft
(15)	Keel Deflection = (4) - (14) (+ Sag, - Hog)	0.0	ft
(16)	Calculated Draft at L.C.F. = (3) + [(13)*(10)] / (12)	11.6	ft
(17)	Equivalent Draft = (16) + 0.75 * (15)	11.6	ft
(18)	Displacement in Seawater at Draft (17) From Curves of Form	1,310	tons
(19)	List = 57.3 * [(2) - (1)] / 121.00 (+ Port, - Stbd)	0.47	deg
(20)	Final Displacement = (18) * [35 / (7)]	1,304	tons

Table C.2. USS SCOUT (MCM 8) locked and trailed shaft trial displacement calculations, 17 June 1991 morning.

Draft Readings

	Port		Starboard		Average
	Fwd = 10.66 ft		Fwd = 10.83 ft	(3)	Fwd = 10.75 ft
(1)	Mid = 10.83 ft	(2)	Mid = 11.75 ft	(4)	Mid = 11.29 ft
	Aft = 11.83 ft		Aft = 12.58 ft	(5)	Aft = 12.20 ft

(6)	Specific Gravity of Water (Corrected for Water Temperature of 82° F)	1.023	
(7)	Specific Volume of Water = 35.955 / (6)	35.15	ft^3/ton
(8)	Forward Draft Mark to Ref. Line for Longitudinal Centers	87.0	ft
(9)	L.C.F. From Ref. Line at Draft (4) From Curves of Form (+ Aft, - Fwd)	15.6	ft
(10)	Forward Draft Mark to L.C.F. = (8) + (9)	102.6	ft
(11)	Forward Draft Mark to Midship Draft Mark	87.0	ft
(12)	Forward Draft Mark to After Draft Mark	195.5	ft
(13)	Trim Between Draft Marks = (5) - (3) (+ Aft, - Fwd)	1.5	ft
(14)	Calculated Draft at Midship Draft Marks = (3) + [(13)*(11)] / (12)	11.4	ft
(15)	Keel Deflection = (4) - (14) (+ Sag, - Hog)	-0.1	ft
(16)	Calculated Draft at L.C.F. = (3) + [(13)*(10)] / (12)	11.5	ft
(17)	Equivalent Draft = (16) + 0.75 * (15)	11.4	ft
(18)	Displacement in Seawater at Draft (17) From Curves of Form	1,275	tons
(19)	List = 57.3 * [(2) - (1)] / 121.00 (+ Port, - Stbd)	0.44	deg
(20)	Final Displacement = (18) * [35 / (7)]	1,270	tons

Table C.3. USS SCOUT (MCM 8) trial displacement calculations, 17 June 1991 evening.

Draft Readings		
Port	Starboard	Average
Fwd = 10.50 ft	Fwd = 10.83 ft	(3) Fwd = 10.67 ft
(1) Mid = 10.83 ft	(2) Mid = 11.75 ft	(4) Mid = 11.29 ft
Aft = 11.92 ft	Aft = 12.58 ft	(5) Aft = 12.25 ft

(6)	Specific Gravity of Water (Corrected for Water Temperature of 82° F)	1.023	
(7)	Specific Volume of Water = 35.955 / (6)	35.15	ft^3/ton
(8)	Forward Draft Mark to Ref. Line for Longitudinal Centers	87.0	ft
(9)	L.C.F. From Ref. Line at Draft (4) From Curves of Form (+ Aft, - Fwd)	15.6	ft
(10)	Forward Draft Mark to L.C.F. = (8) + (9)	102.6	ft
(11)	Forward Draft Mark to Midship Draft Mark	87.0	ft
(12)	Forward Draft Mark to After Draft Mark	195.5	ft
(13)	Trim Between Draft Marks = (5) - (3) (+ Aft, - Fwd)	1.6	ft
(14)	Calculated Draft at Midship Draft Marks = (3) + [(13)*(11)] / (12)	11.4	ft
(15)	Keel Deflection = (4) - (14) (+ Sag, - Hog)	-0.1	ft
(16)	Calculated Draft at L.C.F. = (3) + [(13)*(10)] / (12)	11.5	ft
(17)	Equivalent Draft = (16) + 0.75 * (15)	11.4	ft
(18)	Displacement in Seawater at Draft (17) From Curves of Form	1,275	tons
(19)	List = 57.3 * [(2) - (1)] / 121.00 (+ Port, - Stbd)	0.44	deg
(20)	Final Displacement = (18) * [35 / (7)]	1,270	tons

Table C.4. USS SCOUT (MCM 8) summary of trial displacements and trim.

	DISPLACEMENT					TRIM			
June 1991	Ship's Force Determined Differential in Displacement From Previous Reading (ton)	DTRC Displacement as Calculated from Draft Readings in Tables B.1 - B.3 (ton)	Displacement as Determined from Differentials and Draft Readings (ton)	Average Displacement for this Day (ton)	Average Displacement for this Day (tonnes)	DTRC Measured Trim Down by Stern (ft)	Estimated Trim Down by Stern (ft)	Average Trim Down by Stern for this Day (ft)	Average Trim Down by Stern for this Day (m)
am of 14th	-	1,304	-			1.16	-		
pm of 14th	-	-	-			-	1.21		
am of 15th	-10	-	1,294			-	1.26		
pm of 15th	-3	-	1,291	1,293	1,314	-	1.31	1.3	0.40
am of 16th	-2	-	1,289			-	1.36		
pm of 16th	-8	-	1,281	1,285	1,306	-	1.41	1.4	0.43
am of 17th	-11	1,270	1,270			1.45	-		
pm of 17th	-7	1,270	1,263	1,267	1,287	1.58	-	1.5	0.46

APPENDIX D
PROPELLER PITCH CALIBRATION AND DETERMINATION

A description of the propeller pitch and the propeller pitch calibration on SCOUT is discussed below. This section of the report is divided into the following subsections: introduction, measuring propeller pitch by two methods, calibration settings, calibration temperatures, calibration data, setting propeller pitch, determining actual pitch, oil temperature considerations, and shaft thrust considerations.

INTRODUCTION

The starboard and port propellers on USS SCOUT (MCM 8) were calibrated by divers in the water at Nassau, Bahamas. The calibration, conducted on 11 and 12 June 1991, was performed to determine the relationship between the percent propeller pitch and the propeller pitch voltage signal.

The propeller pitch was measured in three distinct ways. The first method was to measure the axial distance between the leading and trailing edge of the blades at the 70% radius at design pitch. This distance was measured on all five blades of each propeller at design pitch (100%) to check the accuracy of the blade settings and the scribe mark alignments. The other two methods involved measuring the angular displacement of the blade palm of the propeller blade with respect to the hub. This angular displacement was measured with a Bird-Johnson circular pitch scale and with a DTRC fabricated protractor. The angular displacement readings of the DTRC protractor were used for the calibration data.

The voltage used to record the propeller pitch during the calibration and throughout the trials was obtained from the shaped potentiometer located at the oil distribution (OD) box.

MEASURING PROPELLER PITCH USING THE AXIAL DISTANCE METHOD

The propeller pitch calibration entailed measuring axial distances from a plane normal to the axis of the propeller shaft to the leading and trailing edges of each blade at 70% of the radius. The difference between the two measurements is the axial distance (Δ) between the leading and trailing edges. The ratio of the axial distance (Δ) to the blade chord length at the 70% radius (l) is the sine of the pitch angle as shown in Eq. D.1.

$$\phi = \sin^{-1}\left[\frac{\Delta}{l}\right] \qquad \text{(D.1)}$$

where ϕ = pitch angle

Δ = axial distance from leading edge to trailing edges at 70% radius in inches

l = blade chord length at the 70% radius in inches.

The blade chord length at the 70% radius (l) for SCOUT is 33.924 in.

The pitch angle (ϕ) calculated in Eq. D.1 was entered into Eq. D.2 to calculate the propeller pitch at the 70% radius.

$$P = 2\pi(0.70R)\tan\phi \qquad \text{(D.2)}$$

where P = propeller pitch at the 70% radius in feet

R = propeller radius in feet

ϕ = pitch angle.

The propeller radius for SCOUT is 3.5 ft. The ratio of this propeller pitch to the design pitch yields the percent propeller pitch. The design pitch is 12.46 ft.

The device, used to make the axial distance measurements, was designed and fabricated by DTRC. It was fastened to the propeller hub by divers.

This device is only accurate at the design pitch and meaningful measurements are only obtained from the device with the blades at design pitch. These data are used to verify that the blades on each propeller are at the same pitch relative to each other. This verification was conducted with the blades set on design pitch (as determined by the scribe mark alignments and the other two pitch measuring methods) and measurements taken on all five blades on each propeller. The results of the measurements indicated that there was no variation in the pitch from blade to blade on either propeller.

MEASURING PROPELLER PITCH USING THE ANGULAR DISPLACEMENT METHOD

The pitch angle can be determined from the angular displacement (ß) of the palm of the propeller blade with respect to the hub. This is a simple procedure because the propeller manufacturer (Bird-Johnson) stamps several marks on the hub and one mark on the blade palm. The mark on each blade palm is a short scribe perpendicular to the arc of the palm. Four labeled scribe marks (full astern, centerline, design, and full ahead) are on the hub near the blade palm opening. These four marks are perpendicular to the arc of the blade palm opening. The position of the scribe mark on the blade palm relative to the scribe marks on the hub determine the propeller pitch.

The MCM 1 class propeller blade palms can rotate a total of 66.12°. The center of this rotation is called the Centerline (C_L) and the pitch angle at this position is 11.117° in the ahead direction. The full ahead pitch setting is 33.06 degrees of rotation from C_L and the pitch angle is 44.18°. The design propeller pitch setting is 27.87 degrees of rotation from C_L and the pitch angle is 38.99°. The full astern pitch setting is 33.06 degrees of rotation from C_L and the pitch angle is 22.00° in the astern direction. Equation D.3 shows how the angular displacement (ß) yields the pitch angle (ϕ).

$$\phi = \beta + 11.117° \qquad \text{(D.3)}$$

where ß = rotation of the blade palm with respect to the hub in degrees
ϕ = pitch angle in degrees.

The pitch angle (ϕ) calculated in Eq. D.3 was entered into Eq. D.2 to calculate the propeller pitch at the 70% radius.

The angular displacement of the palm of the propeller blade with respect to the hub was measured with two different scales. The first was a Bird-Johnson circular pitch scale. This scale was inserted between the blade palm and hub and it yielded a direct readout of propeller pitch in feet. This scale could be read to the nearest 1/4 foot (or 2% pitch near design). The other scale was a DTRC fabricated protractor which gave the angle of rotation of the blade palm with respect to C_L (ß). This scale could be read to the nearest 1/2 degree (or 2% pitch near design). The angle measured with the DTRC protractor was inserted into Eq. D.3 to determine the pitch angle (ϕ). The pitch angle (ϕ) was then entered into Eq. D.2 to calculate the propeller pitch at the 70% radius.

The readings obtained with the DTRC protractor and the Bird-Johnson circular pitch scale corresponded very well. However, the divers taking the readings with the scales on the hub commented that the DTRC protractor was easier to read. Therefore, the readings obtained with the DTRC protractor were used for the calibration.

CALIBRATION SETTINGS

Each propeller was calibrated at a minimum of five different pitch settings. These pitch settings were all in the range of 80% to 120% ahead. Since the blades were found to have no variation in pitch relative to each other with the axial distance measuring device, measurements were taken on only two of the five blades at each pitch setting. The respective measurements were then averaged to yield a pitch in feet or angle of rotation for the particular pitch setting. These measurements were used in the above equations to calculate percent propeller pitch at each setting for each measurement method.

CALIBRATION TEMPERATURES

It was attempted to calibrate each propeller at two different hydraulic oil temperatures so that corrections could be made for any temperature variations in the system during the trials. The first calibration temperature was to be near the normal operating temperature of the system and the second one a little hotter. The starboard propeller was calibrated at 122°F and 129°F and the port propeller was calibrated at 125°F and 128°F. These calibration temperature differences were not significant enough to determine the effects of temperature variations on propeller pitch. The least squares fit of the lower temperature data were used for the calibration. For both propeller systems, the hydraulic oil temperatures during the trials remained near the calibration temperature. Therefore, temperature variation corrections were not necessary for any of the trial data.

Figure D.1 shows the percent propeller pitch as determined by the DTRC protractor versus the shaped potentionmeter voltage read by the computer for the starboard propeller. Figure D.2 shows the percent propeller pitch as determined by the DTRC protractor versus the shaped potentionmeter voltage read by the computer for the port propeller. These figures show that the temperature variations were insignificant relative to the accuracy of the propeller pitch measurements.

CALIBRATION DATA

Table D.1 lists the starboard propeller pitch calibration data and Table D.2 lists the port propeller pitch calibration data. The table includes the pitch as measured by the axial distance method at design pitch, propeller pitch in percent as measured with the Bird-Johnson pitch scale and the DTRC protractor, and shaped potentiometer voltage. The hydraulic oil temperature in the system was monitored by a DTRC gauge on the return line and by the temperature gauge on the HOPM. The voltage and temperature were read by the DTRC trial computer.

SETTING PROPELLER PITCH

The pitch of a controllable pitch propeller is controlled by the movement of a rigid steel control rod and piston mechanism inside the propeller shaft and hub. Linear motion of the control rod and piston causes the blades of the propeller to rotate, yielding different pitches for the propeller.

The controllable pitch propeller system operates with hydraulic oil. This oil flows constantly from the OD box down the shaft to the hub and returns to a sump. The sump is heated to maintain a nominal operating temperature in the system.

The position of the control rod and piston mechanism are controlled by a feedback voltage system. This voltage monitors the position of the control rod at the OD box. By adjusting the voltage, the control rod and piston mechanism can be moved to give a desired pitch. A constant voltage will hydraulically lock the control rod in place at the OD box.

DETERMINING ACTUAL PITCH (U)

The propeller pitch that is set by a constant voltage is subject to change when a ship is underway. This change occurs because the actual pitch of a controllable pitch propeller is affected by two factors:

the temperature of the hydraulic oil in the system, and the thrust on the propeller shaft. Each factor causes the position of the piston mechanism in the hub to change since the constant voltage locks the control rod in place at the OD box.

OIL TEMPERATURE CONSIDERATIONS

The propeller pitch system operates with the hydraulic oil at a nominal operating temperature. The temperature of the oil can be transient over time depending on such variables as the heater in the hydraulic oil sump, seawater flowing around the shaft and hub outside of the ship hull, and line shaft bearings. When the oil temperature is significantly different from the nominal operating temperature, the control rod is subject to thermal expansion or contraction. When the system is operating with a constant voltage, any change in length of the control rod due to temperature variations will occur in the hub. This causes movement of the piston mechanism in the hub which results in the pitch being changed while the feedback voltage remains constant.

The oil temperature on the starboard shaft during the trials was around 126°F ± 2°F. The oil temperature on the port shaft during the trials was around 127°F ± 1°F. These temperatures coincided very well with the calibration temperatures. Therefore, it was not necessary to make any corrections to the trial propeller pitch readings for temperature variations.

SHAFT THRUST CONSIDERATIONS

The thrust developed by the propeller of a ship underway puts a compression force on the shaft. This force causes the shaft to compress an amount that can be calculated by using Eq. D.3.

$$\partial = T/E * \sum_{i=1}^{N} L_i/A_i \qquad \text{(D.3)}$$

where ∂ = propeller shaft compression in inches
T = propeller shaft thrust in pounds
L = propeller shaft length in inches
A = propeller shaft cross-sectional area in square inches
E = modulus of elasticity in pounds per square inch.

This equation shows that the compression is directly proportional to the thrust. It is also dependent on shaft length, cross-sectional area, and material. The port and starboard propeller shafts on SCOUT are identical; however, the shafts have various sections. These various sections must be accounted for individually as shown in the equation.

The length of shaft which is subject to thrust compression is the length between the aft end of the thrust bearing and the forward flange of the propeller hub. Table D.3 lists the various shaft sections between these two shaft pieces, their lengths, outside diameters, inside diameters, cross-sectional areas, and length to area ratios. The total shaft length subject to shaft compression was found to be 50.61 ft. The summation of the individual length to area ratios for this shaft length were found to be 13.10 in^{-1}. The modulus of elasticity for the shaft material is 26,000,000 lb/in^2.

The maximum shaft thrust will cause the largest compression. Since the maximum shaft thrust (T_{max}) for SCOUT is 14,850 lb, the maximum shaft compression is 0.007 in. for either shaft. Note that the thrust was determined from model tests.

The maximum shaft compression in inches (∂_{max}) must be translated into a change in pitch in percent. This is accomplished by taking measurements on the brass pitch indicator plate on the OD box. These measurements show that the control rod moves 0.360 in. for pitch changes between 90% and 110%. This information is used in Eq. D.4 to determine the amount of pitch change that the maximum shaft compression can cause.

$$\beta_{max} = \partial_{max} * \frac{\Pi}{D} \qquad \text{(D.4)}$$

where β_{max} = maximum propeller pitch change in percent

∂_{max} = maximum propeller shaft compression in inches (from Eq. D.3)

Π = propeller pitch range in percent

D = distance of control rod movement in inches.

The maximum amount of pitch change is determined by Eq. D.4 with the following values; ∂_{max} = 0.007 in., Π = 110% - 90%, and D = 0.360 in. This yields β_{max} = 0.4% which is the maximum amount that the pitch can change on either shaft of SCOUT due to compression.

Table D.4 shows the values used in Eqs. D.3 and D.4 in more detail.

The action of the thrust force tends to push the shaft forward or into the ship. This force is not transmitted to the control rod and piston mechanism inside the shaft and the hub. The force causes (U) the hub to physically move forward while the control rod and piston mechanism remain fixed. This results in the pitch being decreased while the feedback voltage remains constant.

The maximum possible decrease in propeller pitch due to thrust is 0.4% on SCOUT. This will only occur at the maximum thrust condition. Therefore, the effects of thrust on the propeller pitch were considered negligible and were not taken into account.

FINAL PROPELLER PITCH COMMENTS

From the preceding discussion it is quite evident that the propeller pitch is the least accurately known measurement of the trials. However, a thorough investigation of the calibration data, hydraulic oil temperature data, and predicted shaft thrust data has lead to values of pitch as best as can be determined. It is important to note two conclusions about the propeller pitch data during the trials; (1) the hydraulic oil temperature variations were minimal and therefore corrections due to thermal expansion or contraction were deemed unnecessary, and (2) the effects of propeller shaft thrust were deemed minimal and therefore corrections were deemed unnecessary. Therefore, the propeller pitch values recorded in the tables are the values of pitch as best as can be determined.

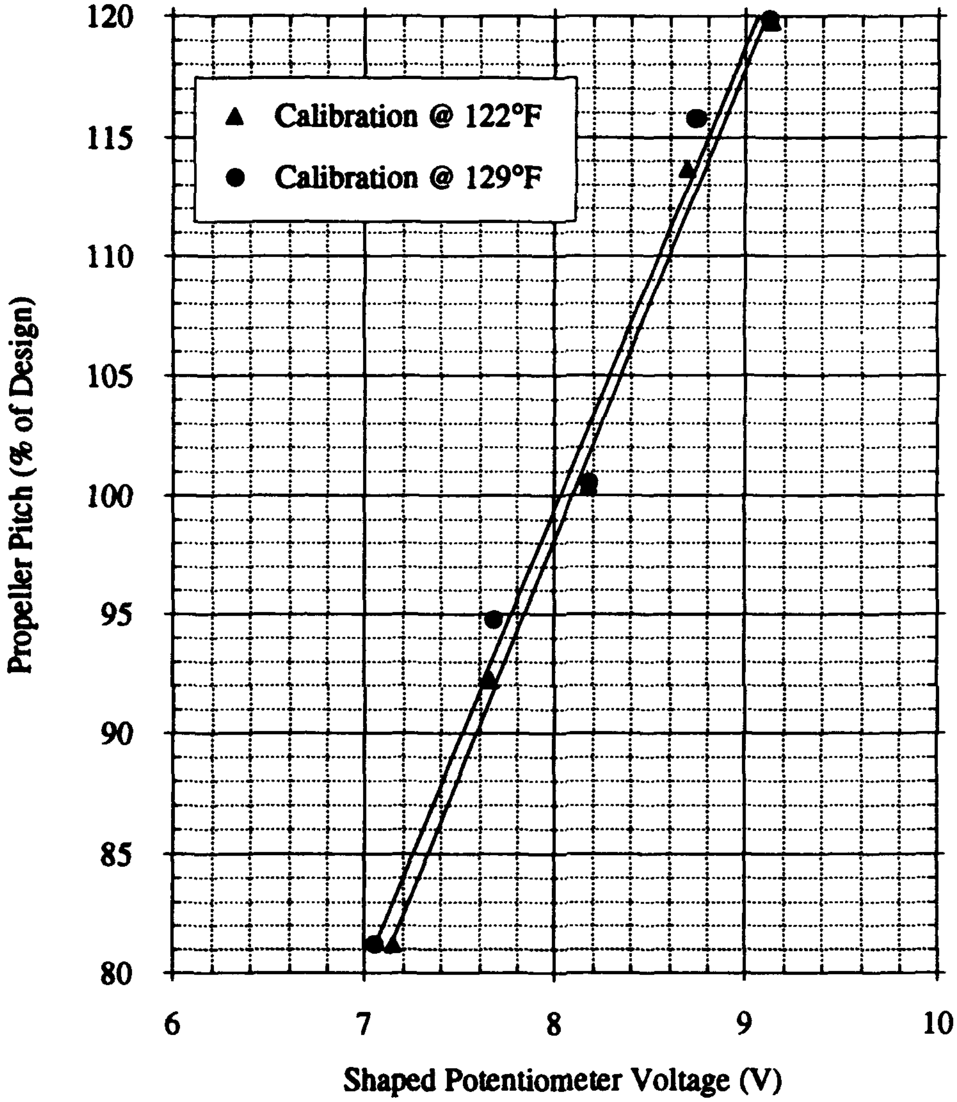


Fig. D.1. USS SCOUT (MCM 8) percent propeller pitch versus voltage for starboard propeller.

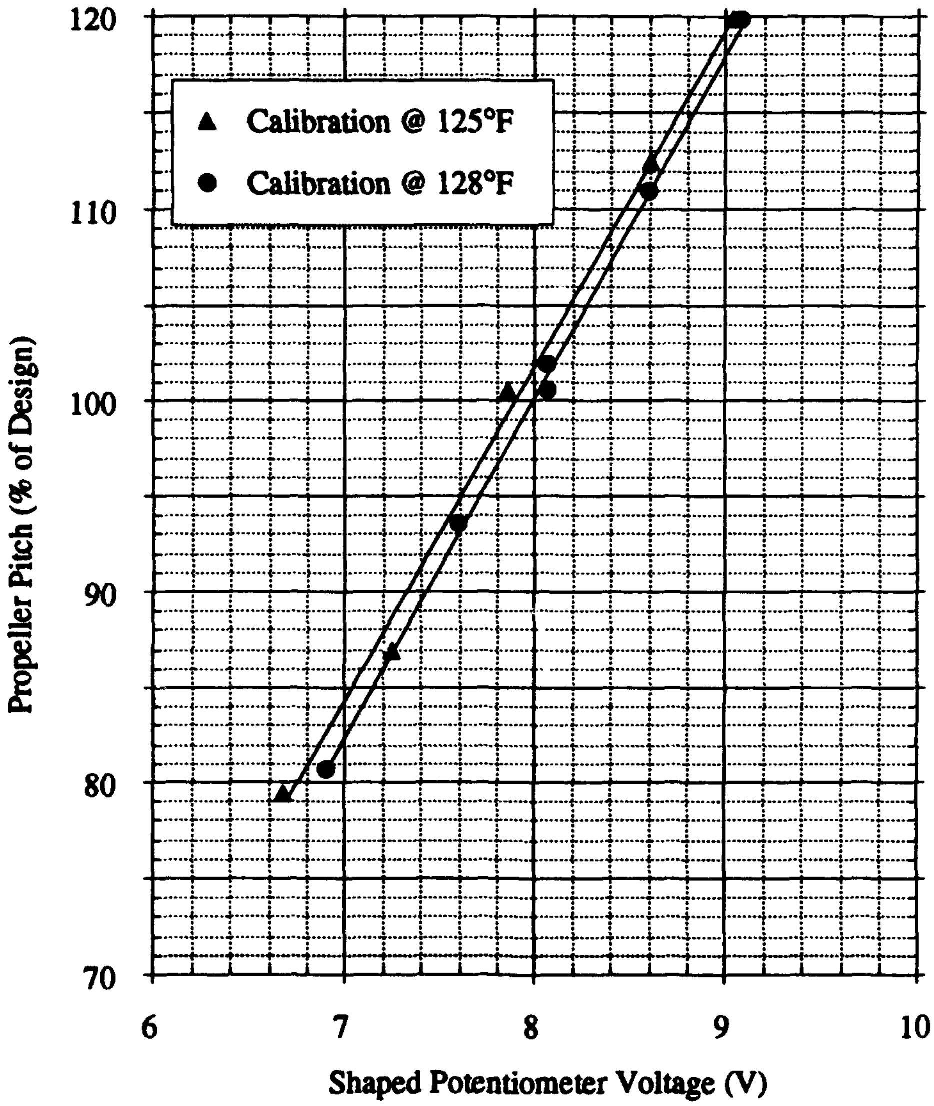


Fig. D.2. USS SCOUT (MCM 8) percent propeller pitch versus voltage for port propeller.

Table D.1. USS SCOUT (MCM 8) starboard propeller pitch calibration data.

11 June 1991, HOPM temperature = 122°

Scribe Mark Alignment	Axial Distance Method Pitch (%)	Bird-Johnson Pitch Scale Pitch (%)	DTRC Protractor Pitch (%)	Shaped Potentiometer Voltage
-	-	82.7	81.2	7.146
-	-	92.3	92.2	7.665
on the mark	105.2	100.0	100.5	8.180
-	-	109.2	113.7	8.690
on the mark	123.7	120.0	119.8	9.129

12 June 1991, HOPM temperature = 129°

Scribe Mark Alignment	Axial Distance Method Pitch (%)	Bird-Johnson Pitch Scale Pitch (%)	DTRC Protractor Pitch (%)	Shaped Potentiometer Voltage
-	-	81.5	81.2	7.059
-	-	93.1	94.7	7.685
on the mark	104.2	100.0	100.5	8.182
-	-	112.4	115.7	8.748
-	-	113.2	115.7	8.738
on the mark	-	120.0	119.8	9.123

Table D.2. USS SCOUT (MCM 8) port propeller pitch calibration data.

11 June 1991, HOPM temperature = 125°F

Scribe Mark Alignment	Axial Distance Method Pitch (%)	Bird-Johnson Pitch Scale Pitch (%)	DTRC Protractor Pitch (%)	Shaped Potentiometer Voltage
-	-	77.1	79.4	6.678
-	-	88.3	86.9	7.248
on the mark	99.8	100.0	100.5	7.860
-	-	112.4	112.5	8.609
on the mark	121.1	120.0	119.8	9.032

12 June 1991, HOPM temperature = 128°F

Scribe Mark Alignment	Axial Distance Method Pitch (%)	Bird-Johnson Pitch Scale Pitch (%)	DTRC Protractor Pitch (%)	Shaped Potentiometer Voltage
-	-	79.4	80.6	6.898
-	-	92.3	-	7.568
-	-	93.9	93.5	7.598
on the mark	99.3	100.0	100.5	8.075
-	-	102.3	101.9	8.070
-	-	112.4	110.9	8.593
on the mark	-	120.0	119.8	9.081

Table D.3. USS SCOUT (MCM 8) shaft length and cross-sectional area data.

Shaft Portion	Shaft Section Length L (ft)	Shaft Outside Diameter OD (in.)	Shaft Inside Diameter ID (in.)	Shaft Cross-sectional Area A (in^2)	Shaft Length/Area Ratio L/A (in^{-1})
Aft Thrust Bearing	0.09	16.25	2.50	202.49	0.006
	1.36	8.50	2.50	51.84	0.316
	0.30	17.32	2.50	230.78	0.015
	2.04	7.48	2.50	39.03	0.626
	2.79	8.75	2.50	55.22	0.607
	2.88	8.13	2.50	46.94	0.736
	0.28	13.75	2.50	143.58	0.024
	2.86	8.50	2.50	51.84	0.662
Stern Tube	13.25	7.50	2.50	39.27	4.049
Stern Tube	7.11	8.50	2.50	51.84	1.646
	0.28	13.75	2.50	143.58	0.024
	1.53	8.50	2.50	51.84	0.353
Propeller Shaft	9.64	7.50	2.50	39.27	2.945
Propeller Shaft	5.96	9.50	2.50	65.97	1.084
Fore Flange of Hub	0.25	22.75	2.50	401.58	0.007

Notes:
1. The port and starboard shafts on this class are identical.
2. Total shaft length from thrust bearing to hub: L = 50.61 (ft).
3. Summation of length over area ratio: L/A = 13.10 (in^{-1}).

Table D.4. USS SCOUT (MCM 8) pitch change due to shaft compression.

	Maximum Shaft Compression		
Equation D.3:	∂_{max}	=	$T_{max}/E * \sum_{i=1}^{N} L_i/A_i$
	$\sum_{i=1}^{N} L_i/A_i$	=	13.10 in^{-1}
	E	=	26,000,000 lb/in^2
	$1/E * \sum_{i=1}^{N} L_i/A_i$	=	5.0385×10^{-7} in/lb
	T_{max}	=	14,850 lb
	∂_{max}	=	0.007 in
	Maximum Pitch Change due to Maximum Thrust		
Equation D.4:	β_{max}	=	$\partial_{max} * \frac{\Pi}{D}$
	∂_{max}	=	0.007 in
	Π	=	110% - 90% = 20%
	D	=	0.360 in
	β_{max}	=	0.4%

THIS PAGE INTENTIONALLY LEFT BLANK

APPENDIX E
SURFACE ROUGHNESS SURVEY

A hull inspection and surface roughness survey were conducted on the USS SCOUT (MCM 8) on 13 June 1991 at Nassau, Bahamas This inspection and survey were carried out by DTRC divers. The roughness survey consisted of taking roughness measurements of SCOUT's hull, rudders, and propeller blades. SCOUT's underwater hull area has an ablative coating.

A British Ship Research Association (BSRA) Mark II Roughness Analyzer was used to collect roughness readings. The BSRA Analyzer was used to collect peak-to-trough roughness measurements at representative locations throughout the hull area as well as on the ship's two rudders and propellers. The BSRA Analyzer measures roughness in terms of mean apparent amplitude.

The BSRA Analyzer measures the maximum peak-to-trough height in micrometers (μm) for fifteen 50 mm sample lengths. These 15 sample lengths are taken over a total of 750 mm of a length of surface. These 15 sample lengths are known as one data length. The roughness reading for one data length is the average of the 15 sample lengths.

There were 18 roughness readings taken from the stern to the bow of the hull area. These readings were averaged to yield an overall hull roughness of 233 μm. The maximum value for the hull roughness was 471 μm. The minimum value for the hull roughness was 102 μm. The divers reported extensive cracks in the fiberglass along the keel and hull intersection. The divers also reported slime at the waterline. The divers reported that the hull was in satisfactory condition for the trials.

Full barnacle growth on both propellers was found and cleaned with a rotating scouring pad system on 13 June 1991. This evolution was conducted by Seaward Marine, Inc. After the cleaning, DTRC divers inspected the propeller blades and found them to be satisfactory. The DTRC divers did report that the blades had a wire brushed texture to them. Roughness readings were then taken on the cleaned propeller blades with the propeller trolley. Eight readings were taken on the starboard propeller blades and averaged together to yield an overall starboard propeller blade roughness of 188 μm. Seven readings were taken on the port propeller blades and averaged together to yield an overall port propeller blade roughness of 204 μm. The divers reported that the propellers were in satisfactory condition for the trials.

Surface roughness measurements were taken on both sides of each rudder. The divers reported that the inboard sides of each rudder had large areas of paint missing. However, the roughness readings were only taken on painted areas. A total of eight readings were taken on both rudders and averaged together to yield an overall rudder roughness of 200 μm. The divers reported that the rudders were in satisfactory condition for the trials.

Table E.1 lists the surface roughness data. It includes the name of the general area where the roughness readings were collected, the number of roughness readings taken, and the maximum, minimum, and average values of roughness for that area.

Table E.2 lists the surface roughness readings of USS AVENGER (MCM 1) and SCOUT for comparison purposes. It can be seen that the hull and rudders have similar values but the propellers on AVENGER were much smoother than those on SCOUT.

Table E.3 lists surface roughness data from several surface ships. This table shows the ship name, the dates that the roughness data were collected, and the number of days since the last hull cleaning. It lists the number of roughness readings taken over a general area of the ship and the average roughness for that area. The surface roughness data comparisons show SCOUT's roughness is comparable to other surface ships prior to standardization trials.

DTRC divers took underwater video and photographs of the hull and propellers. This visual documentation of SCOUT's underwater condition has been provided to NAVSEA, PMS 303.

Table E.1. USS SCOUT (MCM 8) surface roughness data. 13 June 1991.

General Area	No. of Readings Taken	Maximum (μm)	Minimum (μm)	Average (μm)
Hull	18	471	102	233
Rudders	8	231	161	200
Stbd Prop. Blades	8	255	87	188
Port Prop. Blades	7	307	130	204

Notes:
1. The underwater hull has an ablative coating.
2. Full barnacle growth on both propellers was cleaned with a rotating scouring pad system on 13 June 1991.
3. Propeller blades were measured with the BSRA propeller trolley.

Table E.2. USS SCOUT (MCM 8) and USS AVENGER (MCM 1) surface roughness data comparison.

General Area	USS AVENGER (MCM 1) No. of Readings Taken	USS AVENGER (MCM 1) Average (µm)	USS SCOUT (MCM 8) No of Readings Taken	USS SCOUT (MCM 8) Average (µm)
Hull	36	225	18	233
Rudders	7	178	8	200
Stbd Prop. Blades	4	89	8	188
Port Prop. Blades	4	107	7	204

Notes:
1. Full barnacle growth on both propellers was cleaned with a rotating scouring pad system on 13 June 1991.
2. Propeller blades on SCOUT were measured with the BSRA propeller trolley.

Table E.3. USS SCOUT (MCM 8) surface roughness data comparisons.

	USS WHIDBEY ISLAND (LSD 41) 3/24/85 to 3/27/85 Days since last cleaning = 0		USS VINCENNES (CG 49) 8/12/85 to 8/14/85 Days since last cleaning = 21		USS MIDWAY (CV 41) 8/22/86 to 8/24/86 Days since last cleaning = 0	
General Area	No. of Roughness Readings	Average Roughness (μm)	No. of Roughness Readings	Average Roughness (μm)	No. of Roughness Readings	Average Roughness (μm)
Hull	25	192	68	140	85	233
Rudders	4	257	4	250	14	194
Struts	6	293	7	169	12	380
Propeller Blades	8	72	-	-	30	118
Propeller Blades*	-	-	-	-	-	-

	USS MIDWAY (CV 41) 4/6/87 to 4/7/87 Days since last cleaning = 220		USS DEWEY (DDG 45) 5/7/87 to 5/9/87 Days since last cleaning = 13		USS THEODORE ROOSEVELT (CVN 71) 4/11/88 to 4/14/88 Days since last cleaning = 345	
General Area	No. of Roughness Readings	Average Roughness (μm)	No. of Roughness Readings	Average Roughness (μm)	No. of Roughness Readings	Average Roughness (μm)
Hull	35	210	11	370	62	264
Rudders	10	183	-	-	15	291
Struts	15	408	-	-	5	344
Propeller Blades	20	229	-	-	31	112
Propeller Blades*	-	-	-	-	10	206

	USS COPELAND (FFG 25) 11/8/88 to 11/9/88 Days since last cleaning = 0		USS COPELAND (FFG 25) 2/19/89 to 2/21/89 Days since last cleaning = 14		USNS WALTER S. DIEHL (T-AO 193) 6/6/89 Days since last cleaning = 417	
General Area	No. of Roughness Readings	Average Roughness (μm)	No. of Roughness Readings	Average Roughness (μm)	No. of Roughness Readings	Average Roughness (μm)
Hull	25	158	16	124	40	241
Rudders	4	136	-	-	8	245
Struts	9	634	-	-	9	376
Propeller Blades	8	47	14	67	-	-
Propeller Blades*	-	-	12	121	21	40

* Data were collected with the BSRA propeller trolley.

THIS PAGE INTENTIONALLY LEFT BLANK

APPENDIX F

SCHEMATIC OF SHIPS PATH DURING TRIAL MANEUVERS

The following text contains detailed descriptions of the procedures used for the standardization and locked and trailed shaft trials. A definitive diagram of these maneuvers is contained in this appendix.

Ship speed and propeller shaft powering values for each data point (data spot) plotted were routinely determined by conducting steady passes on the AUTEC tracking range. These passes were on reciprocal headings (348° - 168° true) with each pass about four minutes in duration (from COMEX to FINEX). A Williamson turn was conducted at the end of each pass to facilitate operating in the same body of water throughout a speed spot.

Each pass was initiated when ship and machinery conditions (torque and shaft speed) had steadied. During the pass, shipboard ranging equipment tracked the ship's movements relative to two shore-based reference points and recorded time and position data. Range data were then matched against the propeller shaft powering conditions to define the ship's powering characteristics for each pass.

Speed values for each pass were determined by the ranging equipment and represented speed over the ground (speed through the water plus wind and current). Speed values for each data spot represented, speed through the water; this value and the average powering characteristics for each spot were calculated by averaging data from the three passes with the data from the middle pass weighted twice. This procedure removed the effects of water current and wind on ship speed and is based on the assumption of a linear current versus time gradient throughout the duration of the spot. Unless otherwise noted, all references to ship speed imply spot speeds.

Effects due to current and wind were minimal and nonvarying relative to the time required to conduct a speed spot. Speed differentials were generally between 0.1 kn and 0.4 kn in the northerly direction throughout the trial period. This facilitated the use of two pass spots (the two passes were averaged together to yield the data spot) for many of the data points obtained on the standardization and locked and trailed shaft trials.

Figure F.1 diagrams the ship path and conduct of standardization and locked and trailed shaft passes.

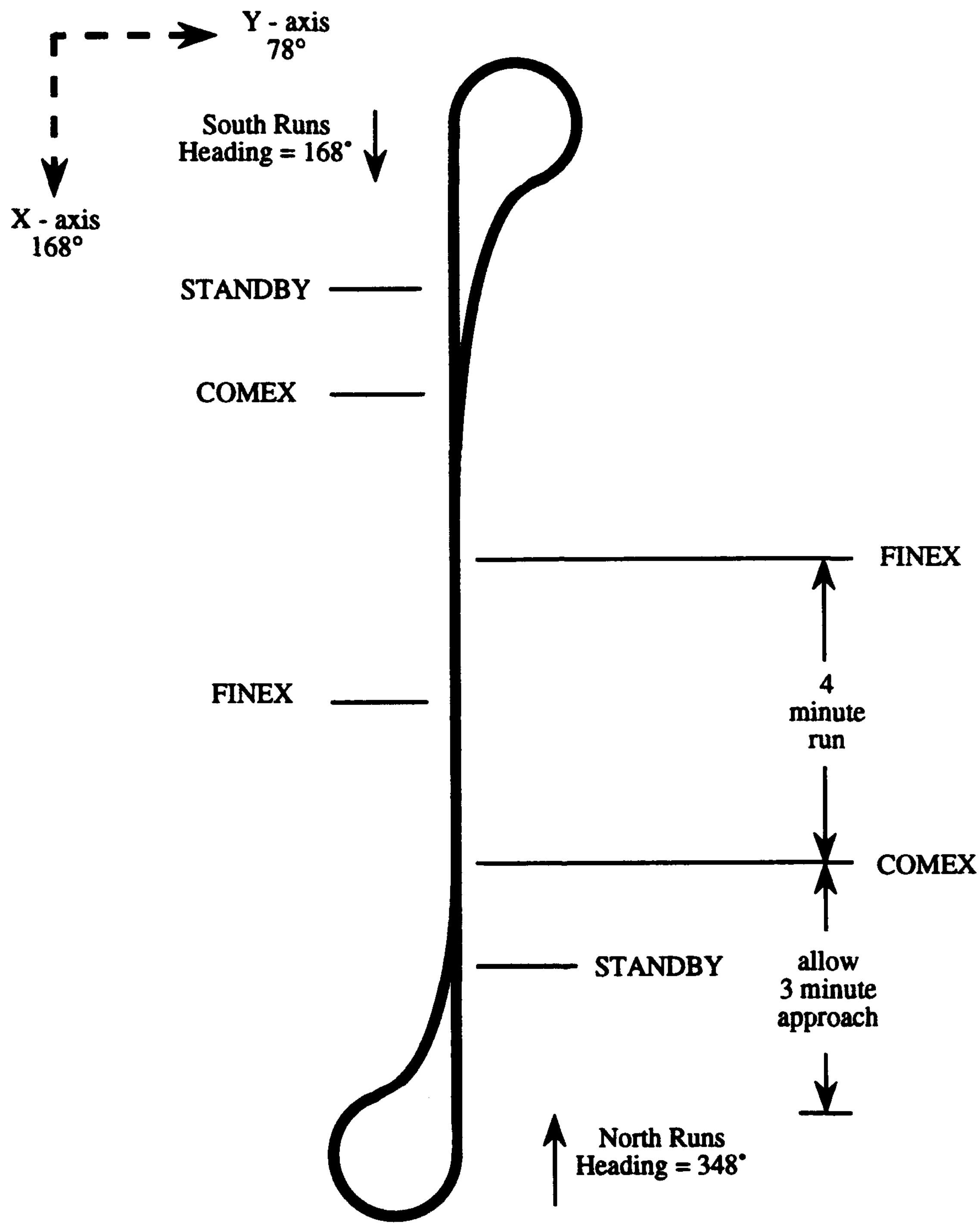


Fig. F.1. Ships path during a typical standardization, locked, or trailed shaft run.

INITIAL DISTRIBUTION

Copies			
13	NAVSEA		
		10	55W3
		2	MS 303
		1	56X1
2	SUPSHIP STURGEON BAY		
1	CO USS AVENGER (MCM 1)		
1	CO USS DEFENDER (MCM 2)		
1	CO USS SENTRY (MCM 3)		
1	CO USS CHAMPION (MCM 4)		
1	CO USS GUARDIAN (MCM 5)		
1	CO USS DEVASTATOR (MCM 6)		
1	CO USS PATRIOT (MCM 7)		
1	CO USS SCOUT (MCM 8)		
1	CO USS PIONEER (MCM 9)		
1	PCO USS WARRIOR (MCM 10)		
1	PCO USS GLADIATOR (MCM 11)		
12	DTIC		

CENTER DISTRIBUTION

Copies	Code	Name
2	15	Wm. B. Morgan
9	1504	V.J. Monacella
1	152	W.C. Lin
1	1521	W.G. Day
4	1523	R.J. Stenson
2	3411 (C)	Publications
1	342.1	TIC (C)
1	342.2	TIC (A)
5	3432	Reports Control