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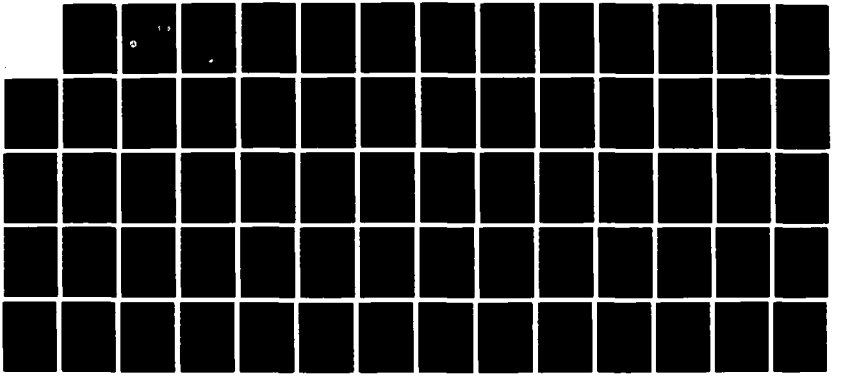

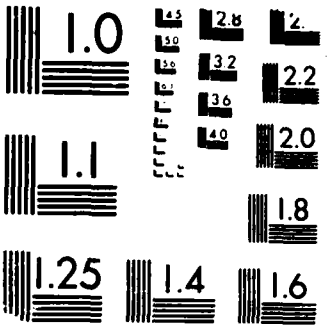

MICROCOPY RESOLUTION TEST CHART

NATIONAL BUREAU OF STANDARDS 1963-A

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Report No. CG-D-06-88

SURVEY OF TECHNOLOGY WITH POSSIBLE APPLICATIONS TO UNITED STATES COAST GUARD BUOY TENDERS

VOLUME II - LITERATURE ABSTRACTS

S. ALLEN (editor)
R. YOUNG
K. BITTING
C. KOHLER
R. WALKER
R. WYLAND
D. PIETRASZEWSKI

U.S. COAST GUARD RESEARCH AND DEVELOPMENT CENTER
AVERY POINT, GROTON, CONNECTICUT 06340-6096

FINAL REPORT
SEPTEMBER 1987

Prepared for:

U.S. Department Of Transportation
United States Coast Guard
Office of Engineering and Development
Washington, DC 20593

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SAMUEL F. POWEL, III
Technical Director
U.S. Coast Guard Research and Development Center
Avery Point, Groton, Connecticut 06340-6096

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16. Abstract

This report is divided into three volumes. Volume I, "Technology Assessment", contains state-of-the-art summaries and projected trends for major technology areas pertinent to buoy tender design. ~~Volume II,~~ "Literature Abstracts", contains an annotated bibliography of the citations obtained during the technology survey. Volume III, "Technology Characterization", contains a description of the relational model and documentation of the computerized database used for storage and analysis of buoy tender data.

Volumes I, II, and III are contained within separate binders due to size considerations. Detailed abstracts of Volumes I and III may be found within each volume. What follows is the abstract for only Volume II.

~~Volume II,~~ "Literature Abstracts", contains a bibliography of citations obtained in the technology survey. Citations include abstracts where available, and are organized by the following catagories:

1. foreign aids to navigation vessels
2. aids to navigation; foreign practices
3. offshore supply support/work vessels
4. hull forms for seakeeping
5. propulsion systems
6. weight handling systems
7. vessel automation, navigation, control and monitoring.

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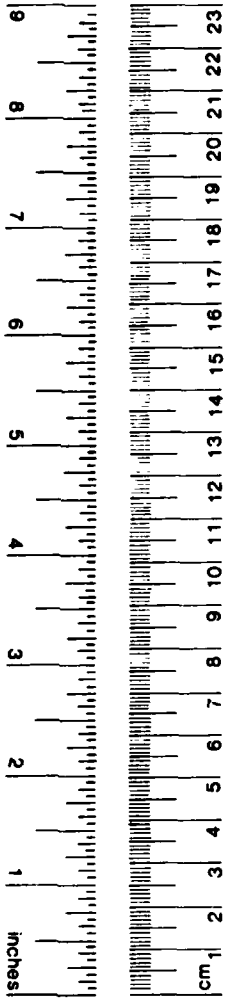
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

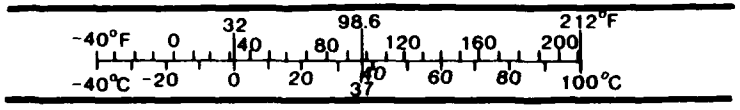
Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	* 2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (WEIGHT)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (EXACT)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

* 1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures. Price $2.25. SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (WEIGHT)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	0.125	cups	c
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (EXACT)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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1.0 INTRODUCTION

1.1 Background

Because of the advancing age of current U.S. Coast Guard buoy tenders of the WLB (180 foot) and WLM (157 foot) classes, the Commandant of the Coast Guard has initiated the WLB/WLM Capability Replacement Project within the Office of Acquisition (G-A). As part of this project, current technology pertinent to buoy tender design has been surveyed as task 205.06.4.1.

1.2 Objective

The objective of this survey is to compile, document and review the state-of-the-art in specific areas of marine technology that apply to buoy tending. Areas of technology identified by G-A which have been surveyed are:

- Foreign Aids to Navigation Vessels
- Aids to Navigation; Foreign Practices
- Offshore Supply/Support/Work Vessels
- Hull Forms for Seakeeping
- Propulsion Systems
- Weight Handling Systems
- Vessel Automation/Propulsion/Navigation/Control and Monitoring

1.3 Report Organization

This report is divided into three volumes. Volume I, "Technology Assessment", contains state-of-the-art summaries and projected trends for major technology areas pertinent to buoy tender design. Current status in each area is presented along with recent and projected changes.

Volume II, "Literature Abstracts, contains an annotated bibliography of the citations obtained during the survey.

Volume III, "Technology Characterization", contains a description of the relational model and documentation of the computerized database used for storage and analysis of buoy tender data.

1.4 Description of Literature Abstracts

Actual abstracts of citations obtained during the survey are included in Appendix A. Not all citations included in Appendix A have been referenced in Volume I Technology Assessment. The intent has been to include all relevant citations in areas which were researched. Abstracts are organized by each of the major technology areas listed in Section 1.2.

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AIDS TO NAVIGATION; FOREIGN PRACTICES

Antonides, L.J. **"The Buoy Tender BREEVEERTIEN"**, IALA Bulletin No. 65, 1976-1. (see Foreign Tenders Section for Abstract)

"A Sophisticated Buoy Tender for UK Port Authority," Small Ships, October 1983. (see Foreign Tenders Section for Abstract)

"BALTICA: built for heavy navaids servicing and icebreaking.", IALA Bulletin 1984/1.(see Foreign Tenders Section for Abstract)

Bish, Peter. **"Tangol Charlie"**, IALA Bulletin 1981/3, p. 21

Cope, Cpt S.T. **"A New Design for a Buoy Tender."** No citation. (Affil: AGA Navigation Aids, UK)

Chatterton, Howard. **"Buoytender - Looking Ahead."** IALA Bulletin No. 63, 1975-2/3, p. 1

Colin de Verdiere, G. **"Remodelling of the buoy tender GEORGES DE JOLY."** IALA Bulletin No. 80, 1980/4 (in French).

"New Tender for Tees," no citation. October 1983.

Noda, Horoaki. **"Buoy Tender MYOJO,"** IALA Bulletin No. 37, July 1968. p. 25. (see Foreign Tenders Section for Abstract)

"Patricia: Elegance and Efficiency in a New Diesel Electric Flagship for Trinity House," The Motor Ship, July 1982. (see Foreign Tenders Section for Abstract)

Smid, H., Siebeneicher, J., **"Multi-Functional Vessels Designed for Oil Recovery and Also Used for Buoy-Tending and Ice-Breaking,"** no citation. (Affil: Federal Ministry of Transport, Bonn, West Germany) (see Foreign Tenders Section for Abstract)

Vreeswijk, J.K. **"Efficiency in Buoyage Maintenance"** IALA Bulletin No. 72, 1977/4

Waas, H. **"Buoy Tender Walter Korte,"** Sixth International Technical Conference on Lighthouses and other Aids to Navigation, U.S. Coast Guard, Washington, DC, September 26, 1960. (see Foreign Tenders Section for Abstract)

Ward, N., **"The Use of Computer Modelling in Planning Marine Aids to Navigation,"** The Journal of Navigation, Vol. 39, No. 3, September 1986 (Affil: Trinity House)

Xiaoquian, Gu, **"Aids to Navigation in China."** IALA Bulletin 1986/4

FOREIGN AIDS TO NAVIGATION VESSELS

"A SOPHISTICATED BUOY TENDER FOR U.K. PORT AUTHORITY," Small Ships, October/November 1983

This 2-page article on the UK Port Authority buoy tender Wilton (loa 40.0 m, beam 9.25 m, draft 3.7 m) describes the unique propulsion arrangement; 1 x British Polar F20 diesel driving 3x300 hp Schottel azimuthing units, one at the bow and 2 at the stern allowing a high degree of maneuverability. A sophisticated dynamic positioning system provides automatic piloting and position control while servicing aids. The vessel is responsible for 50 navaids in the River Tees, Tees Bay and Hartlepool Bay as well as obstruction clearance and light salvage duties. Wilton is not an offshore vessel.

Antonides, L.J., **"The Buoy Tender 'BREEVEERTIEN',"** IALA Bulletin No. 65, 1976/1

The buoy tender "BREEVEERTIEN" built in 1973, is a new type of vessel compared to those previously used by the Dutch Lighthouse Service. Its larger size makes it possible to carry six to eight 10 m^3 buoys. Its increased power gave a trial speed of 14.25 knots while the use of two thrusters and the change from a derrick to a crane increase the number of weather working days. There is also increased flexibility in power distribution.

The paper summarizes the main features of the ship, her general layout, stability, behavior at sea and maneuverability. The necessary stability has been obtained, despite the low freeboard (1.30 m) required for easy buoy handling, and the bow and stern thrusters contribute to the maneuverability of the ship. The reasons for selecting an electric revolving crane are also described in detail as well as the ergonomic studies which underlie the layout of the bridge and the wings together with the positioning of the various controls of the propeller and thrusters, and the working deck.

Behavior at sea was also important in relation to the number of days that could be worked due to weather. "BREEVEERTIEN," with very effective means of station keeping, can work in winds up to force 6 with a wave height of 2.3 m compared with force 3-4 with wave height of 1.1 m for older ships. The ship could operate 67% of the time instead of 32% due to weather.

"Baltica, Built for Heavy Navaids Servicing and Icebreaking," Ship & Boat International, May, 1982, p. 35. BSRA Abstract #58,100.

"BALTICA," a navigation-aids tender designed jointly by her owners - the National Administration of Shipping & Navigation, Sweden - and her Swedish builders AB Asiverken, is primarily intended for handling heavy navigation buoys and to service fixed navigational aids. She is also intended to assist in various other works, and will be available for ice breaking in ports and coastal channels and for pollution control. She has the forward working-deck traditionally favored by the Administration although a layout similar to that of an anchor-handling supply ship was

also considered. The article, which gives reasons for retaining the forward working-deck arrangement, describes the ship and, in particular, her operational equipment, and includes general-arrangement and engine room drawings and an equipment list.

Main particulars of the vessel include: length, o.a./b.p. 180 ft (54-9/50 m) moulded breadth 39.4 ft (12 m); moulded depth (main deck 29.5 ft (9 m); mean draft 12.1 ft (3-7 m); displacement 1238 tons; two Hedemora V16A/12 main engines, 1295 kW each at 1200 rpm, geared to a single c.p. propeller running at 300 rpm; 300-hp thruster at both bow and stern; five 275-kVA generator sets; service speed 15 knots; complement 12, with accommodation for 12 extra; built (but not classed) to DnV, 1A1, Ice 1A, EO

Bollmann, Fr. W., **"Buoy Tender GUSTAV MEYER,"** Eighth International Conference on Lighthouses and Other Aids to Navigation, IALA-1970, Paper 3.1.1.

The buoy tender "GUSTAV MEYER" described in this paper is the prototype of a series of four newbuildings which were put into service by the German Waterways and Navigation Board during the years 1966 to 1968. The vessel was designed to service aids in the rivers and protected waterways.

The paper discloses to what extent the design features of the "GUSTAV MEYER" were influenced by the experience gained from operating earlier tenders and which aspects gave rise to depart from the standard arrangement of the machinery, crew's quarters, storage space and working rooms required aboard a buoy tender. Besides a brief description of the special construction of the buoy crane is given.

"Canadian Coast Guard Ship 'Sir Jame Douglas'", IALA Bulletin 1987/2.

This brief article describes the Canadian Coast Guard vessel 'Sir James Douglas" and her duties on the West Canadian Coast. The vessel was built in 1956, 150 feet loa, 30 foot beam and a draft of a 10 feet 4 inches. Sir James Douglas is classed as a Type 1000 (Medium Navaids Tender/Ice Strengthened) and is primarily responsible for the light stations and buoys in the waters around Vancouver Island, the West Canadian Coast and the Fraser River.

Edge, Capt P.M., and Mr. J.K. Rankin, **"Lighthouse Tender Design,"** Eleventh Conference of the International Association of Lighthouse Authorities, IALA-1985, Paper 9.2.1

The development of a successful design of buoyage and Lighthouse Tender, requires careful assessment of the work and duties the vessel will be required to fulfill and recognition of the high demands placed upon the vessel, its equipment and on those personnel required to ensure that all work is safely and efficiently carried out, while at sea, under widely varying conditions. The principal areas of investigation followed in evolving the most recent Trinity House Tender Vessel design, are put forward in this paper.

The latest vessel for the Trinity House is "THV MERMAID." Vessel particular: LOA - 80.4 m, Beam moulded - 14.5 m, Draft - 4.0 m, speed 12 kts, complement - 24, power - diesel electric 2x 860 kW @ 220 rpm. This vessel has 10 vertical stowage buoy pockets on the working deck which is served by a 20-ton derrick crane and a helideck aft.

"Flash - The Yearbook of the Trinity House Service, 1987," Trinity House Yearbook

This is the yearbook for the Trinity House Lightservice which is the General Lighthouse Authority for England, Wales, The Channel Islands and Gibralter and is responsible for providing Lightouses, Light Vessels Buoys and Beacons.

Included in this yearbook is a 2-page spread with particulars on the newest buoy tender "THV MERMAID" recently completed by Hyundai Heavy Industries Co. Ltd. in Korea. Additionally there is a listing of the Trinity House Fleet including district tenders (4), workboats (6), cutters (1), launches (26), etc.

Kinami, A., **"Buoy Tender in Japan"**, Tenth Conference of the International Association of Lighthouse Authorities, IALA-1980, paper 4.1.1

In order to install and maintain the buoys placed in Japanese waters, the Maritime Safety Agency possesses four buoy tenders. One of these buoy tenders, of the catamaran type and called "MYOJO", was already introduced in the IALA Bulletin No. 37 published in July, 1968. Replacement by new vessels of three other old buoy tenders has been taking place since 1979. This paper describes the technical features and main function of the buoy tender "HOKUTO", which was the first of these built.

Knight, LCDR D.J., **Buoyage & Salvage Vessel "Vigilant"**, Tenth Conference of the International Association of Lighthouse Authorities, IALA-1980, Paper 4.1.7.

The Buoyage & Salvage vessel "Vigilant" described in this paper was commissioned in July 1978 and replaced two older steam-powered vessels.

The Mersey Docks & Harbour Company is responsible for buoyage, wreck raising, hydrographic surveying and conservancy in general for the Port of Liverpool.

"Vigilant" as this paper reveals is able to carry out, in addition to buoyage duties, first aid salvage, fire-fighting and hydrographic surveying.

"Operation Order, CCGS JACKMAN, Evaluation Trials of the Offshore Supply Type Vessel for Non-SAR Coast Guard Operations", Canadian Coast Guard Document, August 1980

The vessel "JACKMAN" was acquired by the Canadian Coast Guard in July 1980 as a primary SAR resource for permanent deployment in the Newfoundland Region. The vessel is a 200-foot,

2000 HP offshore supply vessel (OSV) procured from the private sector and converted for Coast Guard use. Subsequently the CCG decided to conduct an operational evaluation for non-SAR program tasks associated with the Type 1000 Fleet Unit. Experiments were to be conducted using a deck-mounted mobile crane, and the vessel's own towing winch and stern roller, handling buoys over the ship's side aft, and the anchors over the stern.

This document is an operation order and provides background information and general guidelines on the test procedure and logistic operations. The primary emphasis was on testing the suitability of an OSV for buoytending operations. In particular, the maneuverability of the vessel in coastal sea state conditions and fast-water conditions (4-5 kts) were to be assessed. This document provides a general test outline and objectives and does not contain any test results or description of the vessel or vessel systems.

A second document attached provides some detail on vessel description and a very abbreviated assessment of the test results. Overall impression was that it could meet or exceed the majority of Type 1000 performance requirements. Recommendations included adapting the positive features of an OSV-type vessel to existing vessels and develop a modified Type 1050 Fleet Unit for including in the financial plan.

Ording, CDR S, Manninen, CAPT J., **"Servicing Craft and Shore-Based Depots"**, Tenth Conference of the International Association of Lighthouse Authorities, IALA-1980, Paper Gen. 4.

This brief paper presents some thoughts on buoy tender design trade-offs. Examples are given from the current international fleet.

"'PATRICIA': ELEGANCE AND EFFICIENCY IN THE NEW DIESEL ELECTRIC FLAGSHIP FOR TRINITY HOUSE," The Motor Ship, July 1982

A purpose-designed vessel was recently built for Trinity House to enable the service to meet its schedule of buoy tending, lighthouse/ship replenishment and platform for facility inspections, as well as occasional duty as royal escort. The vessel is 86.3 m. loa, 13.8 m in breadth, diesel electric powered with a total of 4000 bhp. She has a forward well deck arrangement which contains 10 storage wells for vertical storage of buoys. Weights are handled by a 20-ton jib crane stepped forward. A helideck aft supports replenishment by air duties. Quality of construction as well as outright elegance were designed into the vessel to provide a suitable platform for facility inspections, royal escort duty and an expected 40-year lifetime. Cost (about 1981) was 9 million pounds Sterling.

"'RELUME': A BUOY TENDER VESSEL FOR ARABIAN GULF SERVICE," The Motor Ship, September 1979

The "RELUME" is a buoy tender vessel built in Scotland by Ailsa Shipbuilding Co. Ltd for the Middle East Navigation Aids Service (MENAS) and delivered in May 1979. The vessel particulars are: loa - 75.94 m, breadth, molded - 12.24 m, draft - 3.75 m, deadweight - 761 tons, propulsion - 2x Allen 6PBCS12DX, output - 2x815 bhp @ 750 rpm, complement - 55. The vessel carries a 20-ton electro-hydraulic crane stepped fwd of the fwd well deck area. She has stowage space for 8 buoys on deck and 4 in the holds. Particular consideration is given to the design of a central fresh water cooling system to handle machinery waste heat in tropical conditions.

Smid, H., and J. Siebeneicher, **"Multi-Functional Vessels Designed for Oil Recovery and Also Used for Buoy-Tending and Ice-Breaking,"** Eleventh Conference of the International Association of Lighthouse Authorities, IALA-1985, Paper 9.2.2.

In July 1984, the oil recovery vessel "MELLUM" (principal characteristics: overall length 2345' (71.50 m), overall breadth 49.5' (15.10 m), draft 17.2' (5.25 m), propulsion 4x1655 kw, speed 16 knots) was commissioned in the Federal German Republic. It is mainly used as a buoy-tender and, due to its construction and propulsive efficiency, it can also serve for icebreaking. This vessel is part of a large program for oil pollution control. By using this vessel for navigational aids servicing, it has been possible to fulfill the conditions for the use of such costly oil recovery vessels for multiple functions. This is much more economical and provides a greater operational range for these vessels.

This design was developed following successful testing of the offshore supply vessel "OSTERTOR" which was modified for buoy tending and pollution control tasks and recommissioned as the "SCHARHORN" in 1982.

Srivathsan, B.S. and Arjunani, I.G., **"A NEW LIGHTHOUSE TENDER FOR INDIA, IALA-Paper 9.2.3**

For the construction, installation and maintenance of Navigational Aids in Andaman & Nicobar Group of Islands the main Lighthouse Tender M.V. Sagardeep was being diverted from main land which proved to be uneconomical and resulted in slow progress of works. Hence, a new Lighthouse Tender for these islands has been built and commissioned into service. This paper describes the duties and functions of the vessel including its technical features and capabilities.

M.V. Pradeep vessel particulars: loa 160.7' (49.0 m), beam moulded 31.2' (9.5 m), service draft 9.2' (2.8 m), gross tonnage 650 tons, speed 12 kts, power 2x GRW MAN R8V 490 BHP each @ 1500 rpm, crew 30.

"Technical Specification for Type 1050 Navigation Aids Vessel", Canadian Coast Guard, Fleet Systems, 2 Vols., February 1983.

This document contains the complete written specifications used in procurement of CCG's Type 1050 navaids vessel. Exhaustive detail of systems is presented.

"The Samuel Risley, first in a new design class of buoy tenders," The Work Boat, February 1986.

CCGS has experimented with handling navaids in the St. Lawrence using a modified offshore supply vessel (OSV). A mobile crane was mounted on the aft deck for handling buoys over the side and anchors over the vessel's own stern roller. Based on the success of these trials, a new design buoy tender was commissioned to be built based on the OSV design. Designated the 1050 class, the principal missions were inland and protected coastal waterway buoy tending, and light icebreaking. A large, specially built motion-compensated crane (Lebher - 20 ton) was installed on the aft deck for buoy work. The main propulsion of the vessel is provided by four Wartsila diesels combined in pairs to drive two cpps in Kort nozzles. Total shp = 8,400. The ship is highly maneuverable having a jet pump type bow thruster 750 hp) and a 400 hp CPP-type stern thruster. Both are electric-driven as is the main crane. Maximum speed of the vessel is 12.3 kts on two engines and 14.3 on four. A second (and last) vessel of the 1050 class was launched recently (January 1987) and named the "EARL GREY."

Waas, H., **"Buoy Tender "WALTER KORTE,"** *Sixth* International Technical Conference on Lighthouses and Other Aids to Navigation, IALA-1960

In 1957 the German Maritime Signals Board commissioned the new buoy tender "WALTER KORTE." Principal characteristics: LOA 180' (54.8 m), beam 29.5' (9.0 m), draft 11.5' (3.5 m), speed 14 kts, range 3500 nm, power 4x 6 cycle Maybach diesels, 1800 total HP. The vessel was designed with a forward well deck and 12t jib crane stepped forward. Vessel maneuverability was enhanced by using a 4-blade CPP for main propulsion along with a 200 HP active rudder and 250 HP bow thruster. The vessel can sidle without rotation using only the active rudder ($\pm$ 90 deg.) and the bow thruster. There is 1786 ft^2 (166 m^2) for buoy storage on the buoy deck.

OFFSHORE SUPPLY/SUPPORT/WORK VESSELS

TECHNICAL AND OVERVIEW ARTICLES

Arendt, John W., **"A Specialty Item (The anchor-handling tug on the marine pipeline)"**, Fourth International Tug Conference, New Orleans, LA, 1975, pp 91-95.

Comments on the development of the anchor-handling tug, which should not be confused with the anchor-handling supply boat. Pipeline lay barges need to set their anchors very frequently, and can justify a vessel specialized for just this task, as oppossed to the more generalized anchor-handling supply vessels. Very high power and maneuverability characterize the anchor handling tug.

Bowling, L., Kaplan, J., and Wilczynski, V., **"Offshore Supply Vessel to Buoy Tender Conversion Design"**, Report CG-D-6-86, NTIS Accession #AD-A168 901, March 1986.

A typical OSV was evaluated to determine of the ship could be converted into a buoy tender in this study by 3 students in the MIT Naval Constructor's program. Keeping the hull form and propulsion machinery the same, the internal arrangement of the design was altered to meet the design requirements of the buoy tender. This preliminary analysis which includes weight and volume allocations, stability floodable length, auxiliary machinery and propulsion calculations, shows that an OSV can be converted into a useful buoy tender. However, there are limitations in the areas of ice operations, towing ability, freeboard, volume margin and most critically in subdivision. An any one-compartment standard of subdivision is not achieved in the engine room, however, the wing tanks outboard offer a measure of protection from penetration to that compartment.

Burrows, I., **"Clyde 252, A new Class of Economy Ofshore Supply Ships"**, North East Coast Institute of Shipbuilders and Engineers, Paper no. 1456, December 1983, pp 19-23.

Details the design and construction of the most innovative supply vessel produced in the last 10 years. It employs many firsts and unusual features in an integrated design which provided "a supply ship of about the same capacity of our first vessels, but would be relatively cheap to build, have improved maneuverability, be fuel efficient, and easily controllled without the complexity of a computer". The single-screw, rotatable thruster, single engine, bulbous bow, V-section stern, design seems to have succeeded in all these respects. A landmark design.

Cornitus, T., **"Mid Yar Report, Support Fleet Tackles Current Challenges"**, Offshore, May 1982, pp 154-5.

Short article noting developments in the offshore fleet such as the expansion in the number of vessels and the trend toward multi-purpose vessels.

Covington, James O., **"State of the Offshore: Service vessel construction booms; tug/supply hot, crewboats cooling"**, The Work Boat, March 1982, pp 50-5, 135-6.

Review of 1981 offshore workboat construction and forecast for the next year. The last truly solvent year in the industry, although not the high point in the construction boom.

Daidola, J.C., Graham, D.A., Bister, J. & Hultberg, S.D., **"Space Shuttle Booster Retrieval Platform for the United States Air Force"**, SNAME Spring Meeting/STAR Symposium, Honolulu, Hawaii, April 1982, pp 23-49.

Traces the design from feasibility to contract design. The 200 ft monohull is propelled by three rotatable thrusters driven by a SCR diesel electric prime mover system, was based on OSV designs, and was chosen over SWATH, catamaran and barge concepts. Seakeeping, maneuvering, stability, propulsion, systems redundancy, maintainability, retrieval operation, structure and hull protection are discussed. The Booster retrieval operation resembles in some ways typical SRA tasks, and thus it is interesting to see how it was approached by the designers.

Daniel, J.J.S., **"Stand-By Rescue Ships -- Their Roles and the Factors Involved in Performing Them"**, 14th Annual Offshore Technology Conference, paper #OTC 4374, 1982, pp 33-39.

From a study which led to regulations Stand-by Rescue Ships in the U.K. Examines the need for such vessels and the details of design, pick-up boats, medical capabilities, communications and personnel. Shows another example of vessels designed for performing over-the-side operations at sea.

"Dayton's Guide to Offshore Support Vessels", Oilfield Publications Limited, Homend House, P.O. Box 11, Ledbury, Herefordshire HR8 1BN, England, 1987.

Provides information on the whole range of North Sea support vessels, including crane barges, geophysical ships, standby/rescue vessels, as well as supply/anchor handling boats. Slightly more comprehensive than Fleet Data Services' **"Offshore Service Vessels"**, but still oriented towards the charterer rather than the designer.

Grant, R., Kurzweil, A., Lord, R., Ryan, J., & Wood, L., **"Hull Design of the ARS 50 Salvage Ship"**, Chesapeake Section SNAME, October 28, 1981.

Covers the design of the ARS-50 class of salvage ships with regard to genral arrangements, human support, mass properties, stability and hydrodynamics. The impact of modern systems and requirements for mixed-sex crews, habitibility standards, waste treatment, etc., along with the requirements of the mission are discussed. It is interesting to note that the vessel was desgined and built using the commercial construction standards of the American Bureau of Shipping (ABS), and that this may be the last auxiliary type that will be designed 'in house' as the present trend is to farm out the total design to a single design agent.

Guarino, Salvadore J., **"Practical Aspects of Towing Vessel Design"**, Fourth International Tug Conference, New Orleans, LA, 1975, pp 241-250.
Reminds designers that attention to detail can help make an efficient ship. Provides numerous examples of details of arrangements, hull form, structure, etc., and makes comparisons between US and foreign practice.

"Guidelines for Supply Vessel Design", The Naval Architect, July 1983, pp 189-191.
Det Norske Veritas offers some advice for those involved in the design and construction of multi-function supply vessels with particular empahasis on fire fighting, oil spill recovery, dry cement, and liquid mud sytems, which are often fitted as afterthoughts, causing arrangement problems at a late stage of vessel construction.

Hatch, G.N., & Broome, D.R. **"Resistance, Powering and Propulsion of Small Workboats"**, Workboats, K.D. Troup Editor, Heyden Publishers, London, 1982, pp 30-47.
A useful design guide for this type of vessel.

"Mid-year forecast: Industry experts express opinions, ideas at offshore outlook conference", The Work Boat, July 1982, pp 39-42.
At the beginning of the downturn, builders, operators, drillers and contractor's painted an optimistic picture of market conditions that did not pan out.

Milwee, W.L., **"Considerations in the Naval Architecture of Salvage Ships"**, Naval Engineers Journal, October 1978, pp 19-28.
Develops a rough preliminary design of a U.S. Navy Salvage Ship to show how specialized missions influence design. Towing, weight handling, pulling and diver support all impact the vessel.

Milwee, W.L., **"Design Considerations in the Design Architecture of Salvage Ships"**, Naval Engineers Journal, March 1984, pp 59-68.
Further illustrates the impact on ship design of the specialized service of Salvage. The first part of the paper concentrates on the characteristics of the rescue tug, and how it differs from the general ocean tug, while the second part looks at the pulling ship.

Molland, Bruce, **"Comparison of Towing Capabilities and Characteristics: Supply Vessels Versus Tugs"**, Fourth International Tug Conference, New Orleans, LA, 1975, pp 143-145.
Looks at the differences between the two classes of vessels and considers their capabilities. While the TSV will continue to penetrate markets formerly reserved for pure tugs, the superior towing power, maneuverability, and alvage capabilities of the ocean tug will keep it around for some time.

"Moving Mountains of Ice", The Work Boat, October, 1986, pp 13-15.

Details the us of workboats to tow icebergs away from drilling rigs off Labrador.

"Ocean Industry's 1980 Marine Transportation Survey", Ocean Industry, February 1980.
Provides details on the world-wide workboat fleet of the time.

"Offshore Service Vessels, A Guide to the American Fleet", Fleet Data Services, P.O. Box 2576, Nacogdoches, TX 75963-2576, 1986.
Provides information on the active American OSV fleet, primarily for charterers, fleets and suppliers. A little short on detailed design information. Covers all self-propelled OSV's over 60ft LOA except for pure tugs.

Patton, L.M., **"The Offshore Supply Vessel"**, Marine Technology, Vol. 20, No. 3, July 1983, pp 252-256.
A fine overview paper which was relied upon heavily in writing the narrative review. Discusses the development of the offshore supply vessel. Laws, regualtion and inspections of the vessel as applied by the Coast Guard are outlined. Manning, use of the vessels, and basic vessel design are also considered. Should be read by anyone wishing to understand the design and use of OSV's.

Raj, A., & White, C.N., **"Trends in Offshore Towing and Supply Vessel Design"**, 11th Annual Offshore Technology Conference, paper #OTC 3388, 1979, pp 281-293.
An essential reference, it extends earlier work by Mok and Hill, and provides the principal design parameters of 196 towing and supply vessels built since the inception of the industry. Trends in the characteristics are examined, and tables and plots are presented as an aid in planning future vessels.

"State of the Offshore: Major U.S. builders gearing up with 'International Class' designs", The Work Boat, March 1983, pp 47-51.
Reviews vessel deigns proposed by builders for hostile, specifically Artic operations. The oil glut impacted Artic oil exploration even more than less hostile areas, and few of these big, complex, expensive vessels were built.

Storch, R.L., et al, **"Natural Environment Stability Tests of an Industrial Vessel Hull Form"**, 14th Annual Offshore Technology Conference, paper #OTC 4433, 1982, pp 647-664.
See seakeeping section for abstract.

Stouffer, Rick, **"American offshore industry retrenching for a rebound"**, The Work Boat, July 1983, pp 22-3, 61-3.
The OSV industry finally realizes it's in deep trouble, yet still predicts an upturn which as of this writing (1987) has not materialized. Opinions are from speakers at the Eighth Annual Marine/Offshore Industry Outlook Conference at Texas A&M.

Vorenkamp, R., **"The tug/supply vessel - A new concept"**, Fourth International Tug Conference, New Orleans, LA, 1975, pp 109-114.

The various duties unertaken by supply ships have given rise to the tug/supply ship and this paper looks at these duties. While it could be argued that the dual role imposes restrictions on her use, it must also be remembered the her increased flexibility of operations can show remarkable cost savings.

"1986 International Workboat Show", The Work Boat, March 1986, pp 20-22, 36-39, 42.

The industry looks to increase innovation, efficiency and quality, while suffering through a sever shakeout. The impact of Federal loan guarantees and P&I clubs is examined along with the potential for doing work for the government. No one predicts a major upturn in the near future.

SHIP REPORTS

The marine equivalent of birth announcements or new product press releases, Ship Reports provide the basic characteristics of the new vessel, a brief description, and discussion of any special features. Abstracts are not provided for the folowing reports due to the brief nature of the articles themselves, unless the vessel is particularly novel or noteworthy. If the boat's name is not mentioned in the title, it will be noted at the end if the citation, and is always in 'single quotes'.

"A Boat to Watch...'Hamilton Tide'", The Work Boat, March 1982, pp 87, 91, 93.

"A Brazilian First from Halter", The Work Boat, Sept. 1978 pp 43, ('Oxala').

"A pioneering icebreaker/tug for Artic development", The Motor Ship, March 1980, pp 26-29, ('Canamar Krigoriak').

"A natural-born leader 'Beacon Fleet 601'", The Work Boat, March 1982.

"A shipyard and four vessels later...", The Work Boat, ('Cane River').

"Affairs of State: Is the fleet complete", The Work Boat, September 1983, pp 37-39, 67, ('State Power').

"Alaska 500: A true icebreaker/supply boat", The Work Boat, August 1983, pp 49-51.

"Arctic offshore needs spur innovation", Marine Engineering/Log, April 1985, pp 66-7, 93.

"Back-to-back Deliveries", The Work Boat, ('Lamnalco Mallard', 'Lamnalco Teal', and 'Gulf Fleet 48')

"Big Boat Big Job", The Work Boat, February/March 1987, pp 26-8, 51 ('Damon Chouest')

"Big surprise 'under the hood'", The Work Boat, August 1981, pp 81, 104-5, ('PBR/330')
The surprise is the use in a supply vessel of a MTU high speed diesel more commonly seen in crewboats. Done for commonality with the owner's fleet of crewboats.

"'Bishop Rock'", The Work Boat, September 1983 pp 41-3.

"Black Gold's latest is sleek & speedy 'White Fox'", The Work Boat, June 1981, pp 94-5.

"Bound for Brazilian Oilfields, 'PBR/480'", The Work Boat, Feb. 1983, pp 55, 57, 79.

"Bruce Offshore takes four", The Work Boat, pp 47-8, ('Shirley Bruce')

"Builder calls 'Victoria Callais' "Cadillac" of supply boats", The Work Boat, April 1981, pp 71,73,109.

"Burton sets the Pace", The Work Boat, September 1982, pp 55,58 (Pacesetter 200 class).

"'Cameron Seahorse'", The Work Boat, May 1981, pp 44-5.

"'Cape Service': a boat to soothe the savage sea", The Work Boat, September 1982, pp 65-66, 102.

"'Capt. George' Quality is the key", The Work Boat, December 1978, pp 81, 114.

"China Delivering Anchor Handling/Supply Ship Series to Sentinel of Singapore", The Motor Ship, May 1984, pp 36-7, ('SSS Shanghai').

"Chouest takes two: 'Dino', 'Gary' join fleet", The Work Boat, June 1983, pp 81,83,119.

"Cost effective dive support ships for North Sea service", Ocean Industry, August 1983, pp 92-3.

"Data Sheet, 'Salvageman', Oceangoing tug", Ship and Boat International, September 1980, BSRA Abstract #54,682, pp 23-4.

"Designer seeks economic edge with new MSV", Ocean Industry, July 1984, pp 96.

"Diesel electric 'Kodiak 1' is largest US built tug/supply vessel", The Motor Ship, August 1983.
The many articles on this vessel and her sister ships reflect the innovation she represented. The scarcity of good

offshore electricians has prevented a wider acceptance of this concept, but there have been other ships built with very similar configurations of power plants, and acceptance of the advantages of this system is growing.

"Dome's second prototype icebreaker", Shipbuilding and Marine Engineering International, Nov. 1981, pp 510.

"Delivery to USSR of two echo sweeping vessels", Shipbuilding and Marine Engineering International, 1986.

"Distinctive Boats", ME/Log, January 1987, pp 18-28, ('Damon Choest', 'Seaway Pelican', 'British Argyll' 'Gullbas').

"Distinctive Offshore Boats and Mobile Rigs", Marine Engineering/Log, January 1984 pp 57-75, ('Nicor Clipper', 'Alstertor', 'Imkenturm', 'Kalvik', 'Pemex 652', 'Sil Tide', 'Kodiak 1', 'Frank Candies')

"Distinctive Offshore Boats and MODUs", Marine Engineering/Log, January 1986, pp 25-36, ('Normand Jarl', 'Kenda', 'H.O.S. Geomar Explorer', 'Gulf Service', 'Wm. A. McGaw', 'Laney Chouest', 'Otto Candies')

"Distinctive Work Boats of 1981", Marine Engineering/Log, January 1982, pp 63-80, ('Flinders Tide', 'Kotozaki', 'Safaniya Five', 'Seabex One')

"Equipped with Aquamaster propulsion", Navigator 86, pp 37-9, (m/s Solvbas)

"First diesel-electric supply vessel", Marine Engineering/Log, April 1979, pp 83-4, ('Acadian Mariner').

"First for Goole", Shipbuilding and Marine Engineering International, 1986, ('Stirling Esk')

"First of Gulf's Artic Class 4 supply ships", Small Ships, BSRA Abstract #61,204, pp 18.

"'Flinders Tide': a sophisticated supply vessel for Bass Strait Service", The Motor Ship, March 1981, p 33.

"'Golden Condor'", The Work Boat, 1982, p 62.

"'H.O.S. Bold Venture' For Hornbeck, From Rysco", The Work Boat, May 1982, pp 67,84.

"'Geo Tide'", The Work Boat, pp71,73,121.

"GRP catamaran gives Norwegian edge in offshore surveying and support", The Motor Ship, pp 30-1, ('Blom Surveyor').

"Halliburton 220, Acid for the Persian Gulf", The Work Boat, December 1978, pp 77,116.

"Halter completes diesel-electric series", The Motor Ship, November 1981, p 52, ('Acadian Commander').

"Halter delivers tug/supply 'Summer Sun'", The Work Boat.

"Halter sores 4-Point play", The Work Boat, March 1983, pp 81, 121-2, ('Point Bravo, Chaleur, Liberty, & Normandy')

"Halter's awesome 'Acadian Commander'", The Work Boat, January 1982.

"Halter's 'Kodiak' debuts, first of two for Penrod", The Work Boat, July 1983, pp 38.
One of the few "severe service" work boats from U.S. yards to actually hit the water.

"Halter's 1000th", The Work Boat, August 1982, pp 74-5, 118 ('Doc Tide').
Represents the highest development of the "stock" supply boat. Hull finer fore and aft to reduce resistance and improve seakeeping, raised bow, two speed gearbox, Kort nozzles.

"Hauling 'pigs' for Aramco", The Work Boat, June 1982, pp 97, 154-5, ('Safaniya Five')

"'Hawke Seal'", The Work Boat, January 1983, pp 153,155,261-2.

"Hong Kong built 'Salvageman' is world's largest anchor handling tug", The Motor Ship, March 1981, pp 23-7.

"Icebreakers and supply vessels", Navigator 86, p 23 (Valmet proposals).

"'IKALUK'/'MISCAROO' Icebreaking anchor handling/supply ships for the Canadian Artic", The Motor Ship, September 1983, pp 27-30.

"Inland and Offshore", Marine Engineering/Log, March 1979, pp 66 ('Ogum', 'State Victory', 'State Hawk' and 'State Pelican')

"'Inmar Duke', First of a $10 Million Four-Boat Package", The Work Boat, October 1978, pp 67, 94-5.

"'Interceptor': Offshore Service adds another proud name", The Work Boat, March 1981, pp 57, 106-7

"'Insignia' THE MARK OF RYSCO", The Work Boat, November 1981, pp 63-66.

"Japanese deliver Arctic workhorse 'Ikaluk'", The Work Boat, pp 57-8.

"**K Marine No. 1**", The Work Boat, pp 59-60.

"**'Kalvik', 'Terry Fox' in Service**", Harbour and Shipping, November 1983, pp 26-34, BSRA Abstract #63,496.

"**LATE builds a diving support vessel**", Navigator 86, pp 18-20 (Finnish built for USSR).

"**LEEVAC to build world class vessel**", The Work Boat, February 1983, (ME 500 Warld Class).
Proposal linking LEEVAC with Maritime Engineering A/S of Oslo Norway. Still only a proposal, but notable in it's attempt to combine European and Gulf practices. Depth is larger than usual, allowing much higher freeboard aft, and facilitating compliance with IMO damage stability code. Also optimized for bollard pull over free-running speed.

"**Leevac's 'Champion': A winner in every way**", The Work Boat, January 1983 pp 143, 145, 258.

"**'Lori Dawn VII' arrives**", The Work Boat, November 1981, pp 56-7
This utility boat is an echo of the smaller, simpler boats of the 60's. No underdeck bulk tanks, for example. Resembles a shrimp boat, and was built at a fish boat yard.

Marier, John B. "**What's Ahead in Shallow Water Seismic Vessel Design**", Ocean Industry, June 1983, ('Digicon Definition')

"**Marine Fabricators: launching a new era**", The Work Boat, pp 73,75 ('Pontus', 'Sallee')

"**'Midnight Alaskan' In search of oil**", The Work Boat, March 1982.

"**Moss Point helps build it 'The Golden Fleet'**", The Work Boat, December 1981, pp 94-5, 181-2.

"**Multi-pupose standby vessel for severe environments**", Ocean Industry, August 1981, p 82, ('Vigilant' class)

"**Multi-pupose Tugboat 'ULTRAMAR X'**", Shiffbau, June 1984, BSRA Abstract #63,499, pp 21-2.

"**m.t. 'EL HAFID'**", Holland Shipbuilding, April 1982, BSRA Abstract #57,924, pp 36-7.

"**m.t. 'RETRIEVER'**", Holland Shipbuilding, April 1982, BSRA Abstract #57,923, pp 29-31.

"**m.v. 'GELDERLAND'**", Holland Shipbuilding, June 1982, BSRA Abstract #59,960, pp 36-7.

"**New workboat construction**", Ocean Industry, February 1978, pp 68-73, ('Seaforth Highlander', 'Seaforth Jarl', 'Alice Briley',

'Gulf Fleet 22', '23', 'Edda Sprite', 'Sun Tide', 'Moon Tide', 'State Pride', 'Frigg', 'Mercia Shore', 'Smit Salvor', 'Sybil Freeman', 'Juanita Patrick')

"'Nicor Clipper'", The Work Boat, August 1983, pp 61,63,85.
An example of the scrambling for niches that accompanied the downturn in the OSV market. While under constuction, this 214 ft supply boat was "jumboized" with a 40 ft midbody plug, and equipped with a stern ramp to form a tug/supply/RO/RO container ship.

Pike, Dag, **"Smit International takes delivery of 'Smit Lloyd 72'"**, The Work Boat, p 67.

Pike, Dag, **"Unique Propulsion for European Supply Vessel"**, The Work Boat, July 1984, pp 48, 60-1.
Boats use a 2400 hp engine on the port side driving an open wheel and a 1600 hp engine on the stbd side with a ducted propeller.

"'Robert LeMeur' a supply ship for the Arctic", The Motor Ship, January 1983, pp 36-9.

"Sailing for Singapore", The Work Boat, September 1981, pp 60-1, ('Osam Eagle')

"'Sea Shuttle' Sailing Down to Trinidad", The Work Boat, July 1982.

"'Seaforth Emperor'/'Seaforth Viscount': contrasting propulsion plants for offshore pair", The Motor Ship, January 1983, pp 27-32.
The larger 'Emperor', designed for servicing multi-platform installations, chose a diesel-electric "power station" approach to provide flexible economy over a wide range of propulsion and discharging loadings, while the 'Viscount', a smaller, less sophisticated vessel for supplying MODU's, sought low capital and running costs with two direct drive diesels turning CP wheels.

"'Seagair': an Ulstein designed offshore safety/supply vessel for BP", The Motor Ship, November 1982, pp 32-6.

"'Seabex One': A New Breed of Surface and Subsea Service Vessel", The Motor Ship, Oct. 1981, pp 55.

"Seagoing Fire Horses are Workhorses, To", The Work Boat, January 1981, pp 131-3, 208-10, ('Point Au Fer', 'Point T')

"'Sentinel' - third generation standby rescue vessel", Noroil, April 1982, BSRA Abstract #57,926, pp 60, 63.

"'Sentinel': a third generation standby rescue vessel series", The Motor Ship, June 1983, ('Sentinel Cathinka').

"Service Machine finds subsea gem in DSV 225", The Work Boat, September 1983, pp 45, 47, 65.
This shipyard declined to enter the race for "Hostile Class" vessels, and felt the market was better for a dedicated DSV.

"Shallow-Draft Vessels", Marine Engineering/Log, January 1980, pp 44-54, ('Acadian Mariner', 'Clipper Paradise Island', 'Hatteras Seahorse', 'Charleston', 'State Venture')

"Shallow-Draft Vessels", Marine Engineering/Log, January 1981, pp 49-63, ('UTC Liberty', 'UTC Freedom', 'Gulf Fleet #40', 'Point T', 'Point Au Fer')

"Special Report: Ulstein Group. The UT700 Series of designs covers almost all offshore support needs", Ship and Boat International, July/August 1983, pp 42-45.
Gives the basic specifications of the nine vessel designs in the Ulstein series.

"Special Report: Ulstein Group. Purpose-built support vessels illustrate UT707 potential", Ship and Boat International, July/August 1983, pp 47, 49, ('Seagair', 'Samudra Suraksha')

"Special Ships", Supplement to The Motor Ship, February 1984, ('Deimos', 'Kalvik', 'Terry Fox').

"Special Ships Profile, 'Flinders Tide', Supply Vessel", Special Ships, BSRA Abstract #55,025, p. 6

"Special Supplement, Support and Maintenance vessel 'Stena Constructor'", Ship and Boat International, January/February 1980, BSRA Abstract #54,683.
First of the highly sophisticated offshore service vessels, designed to compete with very expensive semi-submersibles. Features a full diving spread, dynamic positioning, diesel-electric "power station" propulsion and ship service generators, extensive shops and craneage, etc. The British Navy chartered 2 of these vessels during the Falklnads campaign, and retains one as a Forward Repair Ship serving as a submarine and frigate tender.

"Spoon bow for Dome's icebreaking supply ship", The Motor Ship, October 1981.

"'Stad Troll': a pipe-carrying offshore supply vessel from Ulstein", The Motor Ship, October 1979.

"'Star Polaris' more punch from the UT704 design", The Motor Ship, June 1984, pp 22-26.

"State Boat Sizzles", The Work Boat, September 1982, pp 60-1, ('State Spirit').

"'Stena Constructor' leads new generation of offshore support vessels", The Motor Ship, February 1980, pp 31.

"'Stena Seawell' First of the Stena monohull maintenance and well service vessels from Sunderland", Shipping World & Shipbuilder, July/August 1986, pp 345-7.

"'Stena Seawell'", ME/LOG, September 1986, pp 37-41.

"'Stirling Imp' pioneers new class of economy offshore supply ships", The Motor Ship, July 1982.

"Supply boat for Dutch offshore rigs", Small Ships, January/February 1987, p 9, ('Shelf Express')
Uses 2 shaft generators for ship's service, with only one seperate emergency/harbour diesel generator. The 2 thrusters and the 2 propellers are all controllable pitch, and the ship can be positioned using just one joystick.

"Supply ship contract for Australian yard", The Motor Ship, November 1981.

"Supply ship for the far north", NSN No. 16, 1982, p 63.

"'Swan Ocean': sophisticated diving support vessel from Wartsila", The Motor Ship, pp 79-83.

"The 'Aleutian Command', a package deal", The Work Boat, November 1978, pp 79, 112-3.
One of the first Gulf of Mexico boats to use direct dive diesels and Controllable/Reversible Pitch Propellers.

"The Tide Rolls On", The Work Boat, July 1982, pp 55, 57, 83, ('Arcemont Tide', 'Clair Tide').

"They build 'em, they run 'em", The Work Boat, September 1981, pp 67. 91-2, ('Nellie H').

"They Really Are Big, Good & Ready", The Work Boat, pp 89-91, ('Bay Service')

"'Trafalgar Service': She's built to conquer", The Work Boat, 1983, pp 46-7.

"Transportation Resources' fourth is an Armor-Plated Lady", The Work Boat, January 1981, ('Pearl River').

"Tugs sail away to Bombay", The Work Boat, February 1981, pp 45, 59, ('Gulf Fleet No. 44').

"Two Boats Made to Meet Arctic Rigors", The Work Boat, March 1983, pp 77,79,120-1, ('Artci Nutsukpok, Nanook')

"Ulstein Delivers two UT 716 Vessesls", The Work Boat, ('Gullbas', 'Troms Skarven')

"Ulstein Firsts in U.K. and Australia", The Motor Ship, Nov. 1981, ('Atlas Dampier')

"Ulstein's New Offshore Stars Play Anchor Handling and Supply Roles", The Motor Ship, April 1986, pp 27-30 ('Star Sirius', 'Star Spica')

"US Yard Designs Shallow Draught A-H Tug/Supply Ship for Arctic", The Motor Ship, p 66.

"'Wimpey Seahorse'", Shipping World and Shipbuilder, May 1982, pp 273-4.

"Zapata and Bird-Johnson Collaborate to Meet Hostile Offshore Demands", Marine Engineering/Log, ('Freedom, Liberty, Heritage, Pioneer, Dominion, Sovereign, Statesman, and Ambassador Service')

"2 Cats Uncaged, 'Boson Tiger' and 'Boson Panther' are on the prowl", The Work Boat, June 1981, pp 90-1.

"2 Master Boats", The Work Boat, January 1982, pp 171, 173, 272. ('Patricia M.', 'BBL I')

"12th Annual Distinctive Shallow Draft Vessel Awards", Marine Engineering/Log, Jan 1983 ('Doc Tide', 'Cape Service', 'Geo Tide', 'Livita', 'Maersk Rover', 'Seaforth Monarch', 'Stirling Imp')

HULL FORMS FOR SEAKEEPING

GENERAL REFERENCES

Bhattacharya, R., "Dynamics of Marine Vehicles", Wiley-Interscience, New York, 1978.

Has become the standard reference for seakeeping problems. Develops the theory for all major phenomena concerning the interaction of ships and rough seas, presenting the state-of-the-art at the time, and with many example calculations. Highly recommended, but not for the casual reader.

Comstock, J.P. (editor), "Principles of Naval Architecture", SNAME, New York, 1967.

Naval architecture text with a slightly dated section covering the most important aspects of seakkeping and the effects of design parameters on performance.

Gilmer, Thomas C., "Modern Ship Design", U.S. Naval Institute Press, Annapolis, Maryland, 1972.

Basic Naval Architecture text with a brief discussion of ship motions useful to those un-familiar with the subject.

Lewis, Edward V., **"The Status of Naval Seakeeping Research"**, U.S. Naval Academy, Divison of Engineering and Weapons, Annapolis, Maryland, Report # EW-16-79, NTIS #ADA089-595, 1979.

An essential reference. Has been relied on very heavily for the narrative sections on Seakeeping. Surveys the development of seakeeping research since the 1975 Workshop on Seakeeping in the Ship Design Process. Recommendations are made for the most urgently needed research to accelerate the application of seakeeping knowledge to improved ship design. For the reader with at least a basic knowledge of the field.

Saunders, H.E., **"Hydrodynamics in Ship Design, Volume III"**, SNAME, New York, 1965.

Now somewhat dated, but presents a vast amount of anecdotal information regarding the behavior of ships in a seaway as well as the theory as of the early 1960's. Covers every conceivable aspect of seakeeping. Also has many historical references.

Tupper and Read, **"Basic Ship Theory, Volume 2"**, The Royal Institute of Naval Architects, London, England, 1979.

Basic Naval Architecture text which has a good section on seakeeping, developing the basic theory, discussing the method of seakeeping test and analysis, and noting the effect of design parameters on seakeeping performance.

PREDICTION, EVALUATION AND OPTIMIZATION

Bales, N.K. & Cummins,W.E., **"The Influence of Hull Form on Seakeeping"**, Transactions, SNAME, New York, 1970.

Seakeeping can be rationally included in the ship design process. The prerequisite is determination of trends in seakeeping variable with changes in hull geometry at an early stage in the design process. This paper outlines a "standard series" approach to the trend determination problem. It involves construction of an extensive database and interpolation over a subset for each specific problem. Series 60 hulls were used, and the motions of the vessels in Pierson-Moskowitz seas were computed using the method of Korvin-Kroukovsky with coefficients as determined by Grim's method. This paper concerns itself mostly with the method, and presents some correlation studies, the actual database is huge, although a portion of the information can be found in Bhattacharya.

Bales, N.K., **"Procedures for Computing the Freeboard Requirements of Displacement Monohulls"**, DTNSRDC/SPD-0811-05, NTIS Accession #AD-A065 828, January, 1979.

Presents methodologies for empirical assessment of the nonkinematic components of ship-to-wave relative motion, change of level, and bow wave profile. Applies primarily to ships proceeding in head seas, whereas critical WLB freeboard requirements are probably at zero speed, which will not require these refinements.

Bales, N.K., "**Seakeeping Characteristics of a United States Coast Guard Buoy Tender**", DTNSRDC/SPD-549-03, NTIS Accession #AD-A015 333, September, 1975.

Documents model tests run on a model of the 157 ft WLM. Two sets of tests were performed, the first head seas run in irregular waves to examine bottom and bow flare slamming as well as motions, and the second to explore drift and yaw divergence at zero speed. Slamming severity was less than expected, and transit operations will be limited more by deck wetness than slamming in head seas. The drift tests clearly show that head seas are preferable for minimizing drift and yaw divergence. Beam seas runs indicated that the model is experiencing harmonic rolling (I.E. at twice the wave encounter frequency). Linear superposition produces reasonably accurate results in predicting buoy tender vertical-plane responses in moderate head seas.

Bales, N.K., "**Validity of Analytical Predictions of Deck Wetness For an Offshore Supply Vessel in Following Waves**", DTNSRDC/SPD-726-01, NTIS Accession #AD-A032 339, September 1986.

Shows that analytical predictions of relative motions can be considered conservative under certain conditions, I.E. equal freeboard for both experimental and analytical calculations. A secondary conclusion is that for the vessel and conditions tested, dynamic swell-up and incident wave distortion decrease relative motion, the reverse of the findings from head seas trials. The largest problem with deck wetness on OSV's is likely to be amidship.

Bales, S.L., Cummins, W.E., & Comstock, E.N., "**Potential Impact of Twenty Year Hindcast Wind and Wave Climatology on Ship Design**", Marine Technology, Vol. 19, No. 2, April 1982, pp 111-139.

This paper highlights some features of the Navy's climatology. Briefly, models have been developed which step through 20 years of barometric pressure data, developing the wind patterns which develop from pressure gradients, and the waves which are driven by the wind. This climatology provides global wave and wind parameter statistics, identifies the occurrence and persistence of some heavy weather conditions, and aids the development of spectral shape and directionality models. Effects of these features are summarized in terms of predicted performance of several naval combatants. Some of the conclusions of interest include:

Wave heights from the hindcast correlate strongly with estimates derived from measurements, although the hindcast has a random error of about 1.4m over the entire range of wave heights. For values less than 1m, the hindcasts tend to underestimate the significant wave height. No statistical bias with respect to the "measured" wave heights was observed.

Evidence that the Bretschneider family of spectra do not predict pitching motions very well, particularly for small combatants.

The overall statistics of ship performance agree reasonably well with data from measurements at Station India, although individual comparisons at specific times may differ.

Bales, S.L., & Foley, E.W., **"Development of a Heavy Weather Operator Guidance Catalog for FF-1052 Class Ships"**, DTNSRDC/SPD-0773-02, NTIS Accession #AD-A075-223, Feb. 1979.

This report presents a condensed version of the Catalog of Heavy Weather Operator Guidance (HWOG) Developed for the FF-1052 class. The catalog provides the ship operator with hard copy, quanitative predictions as to how the ship responds in a seaway and some guidance for avoiding excessive ship motions or related events, such as slamming and wetness, that may cause damage to the ship. The HWOG Catalog consists of graphs which indicate the ship heading and speed combinations, for a variety of sea conditions, that may cause excessive motions or related events, and hence damage to the ship, or loss of mission effectiveness, readiness, or crew safety. The criteria used for identifying ship damage potential were developed by examining CASREPTS. While this report presents a rational and logical method of providing operators with guidance, the method looks rather cumbersome. The wave height and period must be estimated, and there is a graph for each relevant height/period combination, making for a thick document. With the small bridge crews of Coast Guard (and merchant) vessels, it is unlikely sufficient manpower would be available to use and interpret the available data. Automation, perhaps some Artificial Intelligence, and simplified graphical display of this information may make it of more practical use.

Bales, S.L., **"Designing Ships to the Natural Environment"**, Naval Engineers Journal, March 1983, pp 31-40.

Outlines the state-of-the-art for environmental modeling for seakeeping oriented design procedures with the US Navy. Details the revised Sea State numerical definitions, and offers a new standard for Sea State occurrence.

Bau, F.C., **"Rough Seas Capabilities and Ship Size: A Parametric Investigation Into the Small Warship Area"**, High Speed Surface Craft Conference, Brighton, England, 1983, pp 127-138

Extension of seakeeping evaluation techniques into smaller displacement vessels. Since for a given sea state, the smaller the vessel, the greater the motions, improvements in seakeeping are relatively more important to small vessels. Head seas limit speeds are developed using acceleration, slamming and deck wetness criteria, and considerable improvement is seen by adopting "optimum" hull forms in the higher sea states. Active stabilization is evaluated, and found to be quite effective. Finally, using long term statistical data on sea states world-wide, limit speeds for all headings, and some weighting and averaging, an overall effectiveness index is developed. Results indicate there is little to chose from between a 600 and 800 tonne vessel, while a 400 tonne vessel has reduced effectiveness. An important paper, one of the few on vessels less than frigate size.

Brown, D.K., **"The Value of Reducing Ship Motions"**, Naval Engineers Journal, March, 1985, pp-41-46.

This short article uses the now-familar techniques of seakeeping assessment and assigns a cash return on investment for improving seakeeping. His conclusions are important enough to quote "1)The cost of lost effectiveness is very high...the equivalent of 10-15 days/yr are lost by a conventional frigate at a cost approaching 100,000 pounds sterling/day. 2)More data is urgently needed. 3)On any interpretation of existing data it is clear that the is a considerable return on investing in longer ships. 4)Weapons systems should be selected for operational performance in bad weather--and tried in realistic conditions."

Chilo, B., & Santos, R.T.C., **"Seakeeping Assessment and Criteria of Naval Combatant Swath Vehicles"**, High Speed Surface Craft Conference, Brighton, England, 1983, pp 62-72.

An approximate method is developed to predict SWATH ship motions at an early design stage by using cylinders to represent the underwater hulls and rectangles to represent he struts. Calculation of the necessary hydrodynamic properties of these shapes is trivial, and this reduces the labor and computer time needed for a typical prediction of 20 frequencies by a factor of 10. This reduction more than justifies the reduced accuracy of the method at the earliest phases of the vehicle selection process. The evaluation of seakeeping performance is carried out in much the same manner as presented by Bales, Olson, and others.

Chilo, B., & Sartori, G., **"Seakeeping Merit Rating Criteria Applied to Ship Design"**, International Shipbuilding Progress, Vol. 26, No. 304, April 1980, pp 299-313.

This paper illustrates a method to express a merit rating characteristic of a ship, indicating the percentage of it's life that it will be fully operational. Similar to work done by Bales, Olson and others.

Comstock, E.N., Bales, S., & Keane, R., **"Seakeeping in Ship Operations"**, SNAME Spring Meeting/Star Symposium, Coronado, California, June 1980, pp 187-202.

Discusses the ways in which the Navy is working towards providing guidance to ship operators on the seakeeping performance of their vessels. Types of Seakeeping Operational Data (SOD) includes Optimal Ship Routing, to minimize transit time or fuel consumption, Tactical Operations Ship Routing, to minimize ship motions in order to conduct operations, Heavy Weather Ship Routing, to avoid ship damage, and Survival Ship Routing, to avoid broaching, capsizing or major structural failure. In order to develop SOD, the technologies of the Sea Environment, Ship Response, and Mission/Response Criteria need to be advanced and this paper describes efforts in these areas.

Comstock, E.N., Bales, S., & Gentile, D.M., **"Seakeeping Performance Comparison of Air Capable Ships"** Naval Engineers Journal, April, 1982, pp 101-117.

Presents the evaluation of a number of air-capable Navy combatant designs. Uses a relatively simple evaluation method, and does not advance the state-of-the-art, but serves as a good example of the utility of the technique and is a good source of criteria for operations. Notes once again the sensitivity of the results to the chosen environment and criteria.

Hearn, G., and Donati, E., **"Sea Keeping Theories -- Applying Some Choice"**, Transactions, North East Coast Institution of Engineers and Shipbuilders, Volume 96, page 53-72, 1980.

Various 2-D and 3-D methods are applied to a merchant ship and a warship. The variation of hydrodynamic reactive coefficients, of added mass and damping, and of the motions and structural response are compared for each method of analysis. The results indicate that results differ little for the various strip theory (2-D) methods, so long as the possible mathematical instabilities of the close fit methods are avoided. These difficulties, which also affect the 3-D singularity distribution method, are discussed in detail, along with methods for identifying their onset. The 3-D method produces significant differences in phase from the various 2-D methods, and requires far more labor and computer time for analysis, making it unsuitable for routine design use.

Hogben, N., & Lumb, F.E., **"Ocean Wave Statistics"**, Her Majesty's Stationery Office, London, 1967.

For years, the standard reference. Contains statistics on the directionality, period, and wave height for various locations both on an annual and a seasonal basis. Primarily derived from visual observations.

Hogben, N., Dacunha, N., & Olliver, G., **"Global Wave Statistics"**, Unwin Brothers for British Marine Technology, Old Woking, Surrey, 1986.

Updates and supercedes Hogben and Lumb. The primary difference is the use of an analysis technique using wind observations to verify and improve the visual wave observations.

Kehoe, J.W., **"Destroyer Seakeeping: Ours and Theirs"**, Proceedings, U.S. Naval Institute, Vol 99, No 11/849, November 1973, pp 26-37.

One of the first papers to note the poor seakeeping performance of U.S. destroyers and frigates relative to foreign, especially Russian, combatants.

Kennell, C.G., White, B.L., & Comstock, E.N., **"Innovative Naval Designs for North Atlantic Operations"**, SNAME Transactions, Vol. 93, 1985, pp. 261-281.

Summarizes the design and seakeeping evaluation of a SWATH and two monohulls to carry a frigate payload in the North Atlantic. The 'Payload' monohull uses the Navy's state-of-the-art in ship design to arrive at a minimum size vessel which will carry the specified payload: the SWATH was developed using the same philosophy. The 'Seakeeping' monohull was un-constrained in

size, and designed to have equivalent seakeeping performance to the SWATH. Seakeeping assessments were developed in three formats; region and seasonal summaries, geographical contours of annual operability, and annual operability versus wave height distributions for the Northern North Atlantic (taking into account the effects of heading and modal period at a given wave height). The predictions were compared with data for an existing frigate and destroyer, and the analysis of this data clearly demonstrates the improved capability of innovative hull forms in Northern latitudes. The methodology used in this paper represents the furthest current development of NAVSEC's seakeeping evaluation procedures.

Mandel, P., **"Seagoing Box Scores and Seakeeping Criteria for Monohull, SWATH, Planing, Hydrofoil, Surface Effect Ships, and Air Cushion Vehicles"**, DTNSRDC Report SDD-79/1, NTIS Accession #AD-074 522, March 1979.

Discusses three seagoing box scores, the first is that of Olson, which is useful for calculating the operational worth of vehicles performing ocean surveillance functions. The second score is related to the time required to transit a fixed distance in rough seas, and relates to the ordinary transportation functions of a vessel. The third score, developed by Comstock and others, is useful for measuring the seagoing merit of vehicles performing any function, but does not directly relate to operational effectiveness. These box scores directly depend on seakeeping criteria, and prescribed values of 18 such criteria are presented and discussed.

McCreight, K.K., & Stahl, R.G., **"Recent Advances in the Seakeeping Assessment of Ships"**, Naval Engineers Journal, May, 1985 pp 224-233.

Another application of the seakeeping assessment techniques developed by Jones, Olson, et al. Refinements include use of the wave height/modal-period data predicted by the Spectral Ocean Wave Model and a different procedure for calculating Limiting Significant Wave Height (LSWH). The sensitivity of the operability indices to changes in the limiting criteria is also addressed.

Meyers, W.G., & Baitis, A.E., **"SMP84: Improvements to Capability and Prediction Accuracy of the Standard Ship Motion Program SMP81"**, DTNSRDC Report SPD-0936-04, September 1985.

Documents the latest version of the Navy's standard program for predicting the motions of monohulls.

Olson, S.R., **"An Evaluation of the Seakeeping Qualities of Naval Combatants"**, Naval Engineers Journal, Feb. 1978, pp 23-40

Perhaps the best introduction to the evaluation of seakeeping qualities when selecting among alternative Naval platforms. Discusses the general approach from which estimates of ship motions are derived, followed by a presentation of twelve seakeeping criteria that may be used to evaluate vessel performance. A method for obtaining meaningful seakeeping

assessments using these criteria is introduced, and illustrated by comparing the seakeeping qualities of three monohulls and a SWATH. Highly recommended.

Olson, S.R., **"A Methodology for Quantifying the Operational Effects of Ship Seakeeping Characteristics"**, Center for Naval Analyses Report #CRC-333, NTIS Accession #AD-A045 443, February 1977.

A fuller exposition of Olson's work. Includes program listing and user's documentation.

Paulling, J.R., & Wood, P.D., **"Computation of Relative Motion Effects in Offshore Supply Operations"**, Eighth Annual Offshore Technology Conference, paper #OTC 2634, 1976

Using currently available computer programs for computing the motions of ships and stable platforms, it is now possible to make good predictions of vessel absolute and relative motion in both regular and random waves. It remains only to combine these computations for typical supply boats and semi-submersibles to determine the relative motion between, say the platform crane boom and the after deck of the supply boat. The same method might be used to compute motions between a buoy tender (and it's crane boom) and a buoy.

Schmitke, R.T., **"Prediction of Ship Roll, Sway and Yaw Motions in Oblique Waves"**, DREA Report 77/4, Canadian Department of National Defence, NTIS Accession # AD-A051 965, September, 1977.

Schmitke's work greatly improved the prediction of ship lateral motions by modeling of dynamic lift on skegs, rudders, bilge keels, etc. Fairly extensive comparisons of predicted and measured roll response are made, with good comparison at all headings considered. Active fin stabilizers are not included in this particular work.

Storch, R.L., et al, **"Natural Environment Stability Tests of an Industrial Vessel Hull Form"**, 14th Annual Offshore Technology Conference, paper #OTC 4433, 1982, pp 647-664.

In order to study the dynamics of industrial hull forms used in OSV's, fishing vessels and tugs, characterized by single or double chine hull forms, a high fwd deckhouse, shallow transom sterns, and long, low, working decks aft, a capability for "natural environment" model testing has been developed at the University of Washington. Building on the work of Paulling in using free-running models to investigate capsizing, test instrumentation was developed including a Mobile Wave Measuring platform and a suite of instruments for controlling and measuring the motion response of free-running, radio controlled models. Similar work is conducted by a subsidiary of British Hovercraft in the Solent near the Isle of Wight. Results are presented from tests of an eight foot model representing an Alaskan King Crab fishing boat, several of which have been lost with all hands in accidents possibly related to stability problems.

Walden, D.A., & Grundman, P., **"Seakeeping Optimization"**, DTNSRDC/SPD-1144-01, NTIS Accession #AD-A159 805, May 1985.

This paper outlines a procedure to improve the seakeeping performance of a hull constrained by a fixed displacement, a constant speed, and a motion criteria (in this case, a rather simplistic one, significant motions at five wave periods). Hull form parameters were varied over a wide range to find the optimum hull using both direct and random search techniques. The results presented for a 4300 tonne frigate have little application to WLB's but the method could easily be applied to Buoy Tender hulls, and extended to include other criteria, such as resistance.

Walden, D.A., & Grundman, P., **"Methods for Designing Hull Forms With Reduced Motions and Dry Decks"**, Naval Engineers Journal, May 1985, pp 214-223.

A different approach for seakeeping optimization is outlined in this paper. The performance and design parameters of a number of existing frigate and destroyer hulls were regressed to predict the relative seakeeping performance of a given hull. Calculations of relative rank have been made to determine dependence on ship speed and modal period. Measures of merit are discussed that include maximum allowed values rather than just the absolute goal of reducing motions. In a similar effort, the method developed by Bales for determining required freeboard is applied to a large number of hulls. The results are used to show the influence of both ship size and seakeeping performance on required performance. Using these results, a simple method of predicting required freeboard is developed, and compared favorably with direct calculation and other methods.

Walden, D.A., & Kopp, P.J., **"Hull Form Parameters for Improved Seakeeping and Reduced Resistance"**, DTNSRDC/SPD-1168-01, NTIS Accession # AD-A162 882, August 1985.

An extension of Walden and Grundmann(1985), in which resistance is also factored into the cost function (using the regression equations of Holtrop) which is minimized in the optimization process. The pure seakeeping hull forms have broader waterplanes, particularly in the stern, than the resistance optimum hulls and the combination hulls fall somewhere in between. With different limits on various parameters, this method could be used to seek the optimum buoy tender hull.

MOTION STABILIZATION

Baitis, E., Applebee, T., & Meyers, W., **"U.S. Coast Guard 270 ft Medium Endurance Cutter Fin Stabilizer Performance"**, DTNSRDC/SPD-1120-02, NTIS Accession #AD-A163 056, October 1985.

An instructive report on what can go wrong with fin stabilizer installations. As noted in Foley, the 270 ft WMEC was designed with the fins forward of the bilge keels, an arrangement later shown to degrade the performance of the fins. This, along with several deficiencies in the fin control system aboard the USCGC BEAR, led to roll reductions well below prediction. The

problems and their fixes are discussed in some detail. Should be read by all designers working on fin stabilizer installations.

Baitis, E., Woolaver, D., & Beck, T. **"Rudder Roll Stabilization for Coast Guard Cutters and Frigates"**, Naval Engineers Journal, May 1983, pp 267-282.

This paper describes the first operational use of a Rudder Roll Stabilization System (RRS). The components of the RRs are described along with the design goals and methodology. The excellent performance of the system is documented, and the potential benefits of the installed system and a system with upgraded capabilities are demonstrated using ship speed polars. The economics of various RRS alternatives are discussed and compared to active fin stabilizers. An improved RRS with high rudder rates can provide stabilization near that achievable with active fins with a far lower impact on ship cost, weight, and volume.

Bales, S., Tucker, J., & Cox, G., **"A Roll, Fin and Fin Controller Prediction Computer Program"**, DTNSRDC-80/014, NTIS Accession #AD-A085 468, June, 1980.

This program is based on the work of Cox and Lloyd and predicts stabilized and un-stabilized ship roll motion, bilge keel and anti-roll fin sizing effects and the influence of fin controller characteristics by use of a one degree-of-freedom roll motion equation. Non-linearity, and long and short crested seas are accounted for.

Barr, R.A., Ankudinov, V., & Webster, W.C., **"Development of Technical Practices for Roll Stabilization Tanks During Later Ship Design Phases"**, Naval Ship Engineering Center, NAVSEC Report 6136-75-12, NTIS Accession # AD-A017 669, April 1975.

Methods appropriate to the selection and detail design of roll stabilization tanks (active, passive and controlled passive) are developed for use in the Contract Design phase of the ship design process. The role of model testing and methods for validating predicted tank performance are discussed. Drafts of Technical Practice Sheets for roll stabilization systems are included as appendices. Doubt is cast upon one-degree-of-freedom models particularly in oblique and irregular seas, while the roll-table simulation and three-degree-of-freedom methods appear to work equally well. (This otherwise useful reference was supplied on a very poor microfiche from NTIS, and cannot be recommended for use in that format. RRY)

Boyd, C.J., Malone, W.L., & Vickery, J.M., **"Simulation as a Design Aid For Ride Control Systems"**, Proceedings, Fourth Ship Control Symposium, 1975.

Describes the use of a motion simulator in the development of design criteria for use with Surface Effect Ride Control Systems. A similar approach using human subjects performing tasks in a simulated motions environment could be used to develop criteria for other motions on any type of vessel as well as for SES'. Criteria development is perhaps the least well developed part of seakeeping assessment.

Carley, J.B., **"Feasibility Study of Steering and Stabilising by Rudder"**, Proceedings, Fourth Ship Control Symposium, 1975.

Discusses the limits of Rudder Roll Stabilization for frigates due to stability and adverse coupling problems. At encounter frequencies around 0.02 hz, both roll and yaw motions are amplified by the combined steering-stabilization system. This is likely to seriously effect the ship, particularly in conditions of potential broaching. The limited success of this application of rudder steering-stabilization systems is related to the high maneuverability of frigates resulting from their neutral steering characteristic. This gives rise to high yaw rates and significant rudder to roll coupling at the lower frequency range. This problem should be examined for buoy tenders if use of RRS is contemplated.

Cowley, W.E. and Lambert, T.H., **"Sea Trials on A Roll Stabiliser Using the Ship's Rudder"**, Proceedings, Fourth Ship Control Symposium, 1975.

Details the theory of such stabilizers, as well as the sea trials, calm water trials and trans-Atlantic tests of a prototype system installed on 15000 tonne container ship also fitted with passive stabiliser tanks. Contrary to model experiments, the full scale tests showed unsatisfactory performance of the RRS and the passive tanks combined, in spite of good results with each system alone (up to 70% reduction for RRS over the unstabilized ship, greater than that achieved for the tanks). This may be related to the yaw damping effect of the tanks, or to sloshing at large amplitudes making the tanks *non*-linear. To be successful, a RRS depends on the capacity of the rudder to excite significant angles of roll. For new designs, the advantages of using a slightly larger and faster rudder instead of passive tanks or active fins should be considered.

Cox, G.G., & Lloyd, A.R., **"Hydrodynamic Design Basis for Navy Ship Roll Motion Stabilization"**, SNAME Transactions, Vol. 85, 1977, pp. 51-93.

The best introduction to roll stabilization and an exposition of how it is practiced in the US Navy. Covers the state of the art, criteria, evaluation, types of devices, etc. Covers bilge keels, active fins, tanks (active and passive), and briefly mentions other methods. Detailed descriptions of necessary design and performance evaluation tools for predicting unstabilized roll motion, bilge keel and antiroll fin sizing, and fin controller characteristics are provided in appendices. Essential reference.

Donahue, J., McMahon, E., & Nelson, L., **"FFG 7 Class Fin Stabilizer System"**, Naval Engineers Journal, May 1984, pp 62-68.

Discusses the fin stabilizer system developed for this class. Valuable for it's discussion of the systems development, including land-based testing and sea trials.

Fairlie-Clarke, A.C., **"Anti-Roll Devices: Active and Passive"**, Marine Engineers Review, June 1980, pp 20-22.

A brief review of the various systems, their advantages and disadvantages, with particular emphasis on the fin stabilizers produced by the author's employer, which incorporate micro-processors and inertial sensors to increase reliability and effectiveness.

Field, S.B., & Martin, J.P., **"Comparative Effects of U-Tube and Free Surface Type Passive Roll Stabilisation Systems"**, Transactions RINA, Vol 118, 1976, pp 73-92.

Presents the results of a series of model tests performed on a oscillator table using scale models of free-surface and U-tube type passive roll stabilizing tanks. Shows the effects of modifying tank geometry and vertical location. Presents a simplified mathematical expression for estimation of ship response in regular beam seas, and compares the results for a stabilized and un-stabilized ship for both types of stabilizer. The author's conclusion that free-surface tanks are superior should be noted with the caveat that their employer holds several patents on this type of stabilizer.

Escalona, J.R., **"The Anti-Roll Stabilization of Ships"**, Master's Thesis, Naval Postgraduate School, NTIS Accession #AD 738 869, June 1971.

Covers the theory and equations of motion of tank stabilizers, gyroscopic stabilizers, and active fin stabilizers. Studys the use of fluidics to control an active tank system. Fairly good general review for the types of systems covered.

Foley, Edward. W., & Jones, Harry, **"Roll Stabilization Investigation for the Strike Cruiser (CSGN)"**, DTNSRDC/SPD-724-02, NTIS Accession #AD-A031 350, September 1976.

Uses standard US Navy evaluation techniques to provide roll motion predictions for two candidate hull forms (conventional and large waterplane) unstabilized and with a proposed bilge keel. Sizing computations for fins and bilge keels were made for the conventional hull and various stabilized configurations.

Foley, Edward. W., & Jones, Harry, **"Preliminary Roll Stabilizer Predictions for a U.S. Coast Guard Medium Endurance Cutter (WMEC)"**, DTNSRDC/SPD-674-07, NTIS Accession #AD-A035 741, November 1976.

Provides roll motion predictions the 270 ft WMEC. The predictions are used to assess the roll stabilization obtained with various sizes of bilge keels and active fin stabilizers. The predictions indicate that a reasonable roll response can be obtained with 104 ft^2 bilge keels located aft of 25 ft^2 active fin stabilizers. It should be noted that the later work of Lloyd showed that this arrangement degrades the performance of the fins.

Fuller, N., Koelbel, J., & Hankley, D., **"Ship Stabilization By Paravanes"**, Proceedings, High Speed Surface Craft Conference, 1980.

A slight extension of the authors 1979 paper. Has more pictures.

Giannotti and Buck Associates, **"Results of a Survey of Offshore Supply Vessel Builders and Operators Concerning the use of Passive Anti-Roll Tanks and Recommendations for the T-AGOS"**, NAVSEC Report # 6136-77-19, NTIS accession #AD-A071 889, May 1977.

A report that essentially concludes that anti-roll tanks are un-necessary on single and double chine offshore supply vessels. On vessels with molded hulls (I.E. European practice), bilge keels and passive tanks are felt to greatly improve the rolling characteristics of offshore supply vessels.

Halden, Horst, **"Combined Stabilisation/Anti-heeling Systems and Their Influence on Ro-Ro Vessels and Ferry Designs"**, RO/RO 83 Conference, BSRA Abstract # 58,559, pp 97-117.

Describes a system which can function either to counteract the static heel produced by un-symmetric loading of RO/RO cargo or to reduce dynamic roll of the ship as a U-tube stabilizer under active control. Discusses the impact on ship design of fitting such a system and the economic benefits produced by faster loading, reduced cargo damage, and reduced fuel requirements.

Jones, H., & Cox, G.G., **"Roll Stabilization Investigation for the Guided Missile Frigate (FFG-7)"**, DTNSRDC/SPD-495-18, NTIS Accession #AD-A028 973, July 1976.

Provides roll motion predictions and the results of the roll decay experiments for the FFG-7 design hull form. Uses a modified single degree of freedom linear roll model which recognizes nonlinear damping (See Cox and Lloyd(1977)). Stabilization is investigated for the ship fitted with various sizes and arrangements of bilge keels, including segments forward and aft of the anti-roll fins, and keels forward of the fins.

Jones, H., **"Antiroll Tank Evaluation for the United States Coast Guard 300 ft Icebreaker (WAGB)"**, DTNSRDC/SPD-0983-07, NTIS #AD-A102 638, June 1981.

Icebreakers are ideal installations for antiroll tanks since they are lightly damped in roll and cannot fit bilge keels or active fins. Using the Navy's procedures as outlined in Cox and Lloyd(1975), a passive tank was designed for the WAGB which achieved roll reductions of up to 70%.

Koelbel, J., Fuller, N., & Hankley, D., **"Paravane Roll Stabilization"**, SNAME STAR Symposium, April 1979, pp 261-299.

A landmark paper on this cheap and effective method of low speed ship stabilization. Enough information is presented to design such a system. In the discussion there is a reference to a proposed design for such a system to be installed on the Coast Guard's 157 ft WLM's. The methodology presented in this paper indicated that such a system would out-perform bilge keels by a substantial margin, while costing 20% less.

Lewison, G.R.G., **"Optimum Design of Passive Roll Stabiliser Tanks"**, Transaction RINA, Vol 117, 1976, pp 31-45.
Uses an analog computer simulation to investigate the parameters affecting roll stabilizer performance. Also validates the results using a oscillator table model. Presents charts for design purposes.

Lloyd, A., **"Roll Stabiliser Fins: A Design Procedure"**, Transactions RINA, 1975, pp 223-254.
Develops a method of predicting the effectiveness of active fins which considers the losses due to bilge keel interference, the immersion of the fins in the hull boundary layer, and the effects of coupling between roll, sway and yaw motions. Model tests and full scale trials show reasonable agreement with the procedure. It is recommended that multiple fin arrangements and configurations with bilge keels mounted aft the stabilizers be avoided, and to avoid the degradation in effectiveness at low frequencies caused by lateral motions, stabilizers should be as near to horizontal and as far forward as possible. Forms the basis for the present US Navy Design Procedure for active fins.

Lloyd, A., **"Roll Stabilization By Rudder"**, Proceedings, Fourth Ship Control Symposium, 1975.
A companion paper to Carley(1975). The rudder will be expected to amplify the rolling motions at high and low frequencies (assuming the control system is not configured to prevent this effect) and this makes it ineffective in following seas at high speeds. It is concluded that the rudder stabilizer will not be as effective as a good fin stabilizer, but is probably preferable to a passive tank.

McCallum, D. **"Passive Anti-Roll Tanks - Design Considerations"**, Association of Scientists and Engineers, 13th Annual Technical Symposium, 1976, NTIS Accession #AD-A022 312.
An excellent review of this type of stabilizer. Critically reviews the advantages of tank stabilizers, the various types of tank stabilizers, the economics of their installation and the existing methods of designing and optimizing the system. Recommended, not highly technical.

Miller, E.R., Slager, J.J., & Webster, W.W., **"Phase I Report on the Development of a Technical Practice for Roll Stabilization System Selection"**, Naval Ship Engineering Center Technical Report 7401.06-1, NTIS Accession Number AD-A017-655, October 1974
Oriented towards preliminary design, this report discusses the main types of roll stabilizers and outlines the procedures for developing performance specifications for roll motions, selection of stabilizer type, preliminary estimates of stabilizer size and estimates of performance suitable for the early stages of the ship design process.

Nelson, L., & McCallum, D., **"Fins of the Future -- FFG 7"**, Naval Engineers Journal, October 1978.

This paper addresses the justification, design philosophy, system description and technical evaluation of the FFG 7 fin stabilization system. Interesting details include discussion of fin sizing and planform, operating modes to minimize cavitation induced noise, and extensive measures, based on experience with earlier fin installations, to increase reliability and maintainability of the fin stabilization system.

"New Motion Suppression System Will Open up New Areas for Tenders" Ocean Industry, Vol 16, August 1981, pp 62-65

A motion suppression system using tanks at the sides of the vessel open to the sea at the bottom, connected with ducts and pressurized with air. This is not an active system, the fans don't run continuously. The system was developed by SeaTek of Goleta California, and the first application, an anti-roll and anti-pitch system on a drilling tender barge, is detailed.

"Reducing the Wave Induced Motions of Offshore Vessels", Marine Engineer's Review, April 1986.

Another system using open-bottom tanks, this one without any interconnection between the tanks. The tanks may be open to the atmosphere through valves to provide an orifice for damping, they may be closed, or they may be pressurized. Developed at University College London and licensed to BP Ocean Technologies.

"Roll Damping for Naval Vessels", ME/LOG, May 1987, pp 51-2.

Describes a micro-processor based rudder roll stabilizer developed by Sweden's SSPA research institute. The Roll-Nix system reduced roll motions 30% in 2m beam seas when fitted to a 35m fast attack craft.

Thorsen, T.L., & Dalzell, J.F., **"Summary Report: Design and Development of U-Tube Stabilizer Tanks for the United States Coast Guard Dual Draft Icebreaker"**, Stevens Institute of Technology report SIT-DL-81-9-2225, NTIS Accession #AD-A103 370, August 1981.

A fine example of the results achievable with roll stabilizing tanks if the space and weight they require is allocated early in the design process. The tanks finally selected are nearly optimum. Although both U-tube and free-surface tanks were model tested, results of which appear here, this report covers primarily the U-tube design. The reasons for selecting this arrangement are not clear from reading the report, but the noise of free-surface tanks as they approach saturation, and possibly poorer arrangement of the ship's volume are this editor's (RRY) speculation.

Zdybek, T., **"The Use of Bench Test Results For Calculating Roll Response of the Tank Stabilized Ship"**, International Shipbuilding Progress, Vol. 27, #308, April 1980, pp 96-105.

The paper presents a method whereby the results of bench tests of a passive tank may be used to calculate the stabilised ship roll response to beam seas. It is shown that slightly modified equations for the roll motions of a ship equipped with a

U-Tube roll stabilizer represent the behavior of a ship with any type of stabilizer tank, with reasonable accuracy. The equations contain three unknown tank parameters which can be determined from the results of bench tests.

SEAKEEPING HULL FORMS - GENERAL

Baitis, E., Meyers, W., Woolaver, D.A., & Lee, C.M., **"A Seakeeping Comparison Between Three Monohulls, Two Swaths, and a Column-Stabilized Catamaran for the Same Mission"**, DTNSRDC/SPD-622-01, NTIS Accession #AD-A023 606, July 1975.

A comparison of six different ships designed as Navy workboats (Torpedo Weapon Retrievers) for Hawaiian operations. Based on the seakeeping characteristics of the various designs only, with no consideration of cost, etc., the SWATH designs provide the most promising performance.

Eames, Michael C., **"Prospects for Advanced Types of Surface Warships"**, High Speed Surface Craft Conference, pp 19-30, 1983.

This paper from the Canadian Defence Establishment Atlantic examines the operational need for advances in ship-platform technology and how they might best be exploited, with the emphasis on the value of speed. Advanced forms of conventional ships are examined, along with new types such as SWATH, hydrofoil and SES, in order to find the most promising types from the viewpoint of on of the smaller navies. A matrix of functional class versus platform type defines the promising regimes of size, speed and operational capability for each vehicle type.

SEAKEEPING HULL FORMS - DISPLACEMENT MONOHULLS

Beukelman, W., & Huijser, A., **"Variation of Parameters Determining Seakeeping"**, International Shipbuilding Progress, 1975, pp 171-186

Using a strip-theory program to calculate the seakeeping responses in head seas of a systematic variation of hull forms based on the "Todd-60" series. Concludes that increased size and speed, and V'd forebody section shapes have the greatest influence on performance. Increasing block coefficient also improves performance. Concludes that radius of gyration is of little importance, in contrast with work done at the U.S. Naval Academy on frigate hulls. Perhaps the full merchant hulls behave differently than the fine combatants.

Blok, J., & Beukelman, W., **"The High Speed Displacement Ship Systematic Series Hull Forms - Seakeeping Characteristics"**, SNAME Transactions, Vol. 92, 1984, pp 125-150.

Describes a series of test used to select a parent hull form to be used in a systematic series of model experiments aimed at providing seakeeping and resistance data for use in design. The hull form chosen attempts to balance favorable seakeeping and resistance characteristics. The report also contains some interesting comparisons of theoretical predictions with model test data, indicating fair correlation, little to chose from

between Close Fit and Ordinary Strip Method Predictions, and poor results using equations of motion which include speed dependent damping terms. The hull forms developed in this report unfortunately have little application to buoy tenders.

Chilo, B., **"Methodology and Results of Full-Scale Seakeeping Tests Performed by Using a Fully On-Board Instrumentation Set"**, International Shipbuilding Progress, Vol 30, Sept 1983, p 200.
Uses an ultrasonic sensor mounted on the bow of the ship instead of a wave buoy to measure the incident wave. Similar techniques have been developed by DTNSRDC.

Gerritsma, J., Beukelman, W., & Glansdorp, C., **"The Effect of Beam on the Hydrodynamic Characteristics of Ships"**, Proceedings, Tenth Symposium on Naval Hydrodynamics, 1974.
Examines the limits of the slenderness restriction on the appliciability of Strip Theory by comparing analytical predictions with model test results. The somewhat surprising conclusion is that even for Length to Beam ratios as low as 4, calculated responses in head seas show good agreement with measured model experiments. Since buoy tenders tend towards low Length to Beam ratios, this is an important finding.

Giannotti and Buck Associates, **"Predictions of Motions for the T-AGOS Hard Chine Hull"**, NAVSEC Report # 6136-77-19, NTIS accession #AD-A071 889, May 1977.
A study made using MIT-5D to analytically predict the motions of a candidate T-AGOS hull. Bilge keels were used in an attempt to match the experimental results in roll for this hard chine hull, with little success. The experimental roll RAO's were substituted for analytical values in the short and long term predictions of ship and point motions.

Keane, R., & Sandberg, W., **"Naval Architecture for Combatants, A Technology Survey"**, Naval Engineers Journal, September, 1984, pp 47-64.
A review of existing and emerging ship hydrodynamics technologies which are expanding hull design options, and their associated ship performance characteristics. Covers seakeeping effectiveness indices and Bales Seakeeping Rank Estimator.

Lin, W., Day, W., Hough,J., Keane, R., Walden, D., & Young, I., **"An Advanced Methodology for Preliminary Hull Form Development"**, Naval Engineers Journal, July 1984, pp 147-161.
A procedure for hull form development that starts out with a design optimized for seakeeping, then modifies it to improve resistance, powering, maneuvering and other characteristics without compromising seakeeping performance. This is essentially the opposite of the traditional approach to hull form generation.

Ochi, M.K., & Motter, L.E., **"Performance of High Speed Naval Vessels Part 1: Effect of Locations of Center of Buoyancy and Floatation on Seaworthiness Characteristics"**, DTNSRDC report #C-3169, NTIS Accession #AD-A950 133, July 1969, de-classified January 1980.

Of limited value to buoy tenders, shows that location of LCB and LCF is un-important if they are co-located, LCF aft of LCB significantly improves vertical plane motions in head seas, particularly at high speeds, although deck wetness is degraded.

Schmitke, R.T., **"The Influence of Displacement, Hull Form, Appendages, Metacentric Height and Stabilization on Frigate Rolling in Irregular Seas"**, SNAME Spring Meeting/STAR Symposium, June 4-6, 1980, pp 203-217.

The factors with primary influence on Frigate rolling are studied parametrically, with predictions made for an operationally meaningful range of speed and sea conditions. The key result of the study is the overwhelming benefit of active stabilization. By comparison, all other parameters studied have an insignificant effect on rolling. Rudder roll stabilization, particularly if the dynamics of the rudder system are upgraded, compares favorably with an active fin system. Other results include the following:

--Rolling considerations give slight preference to hull forms with high C_W and low C_B. The overall influence is slight.

--At service speed, passive fins provide a much more effective means of reducing roll than increased bilge keel area.

--Moderate GM values of roughly 8% of beam are favored, while roll at the worst heading increases substantially at low values of GM.

--Variations in displacement and radius of gyration have little effect on rolling.

SEAKEEPING HULL FORMS - DISPLACEMENT MULTIHULLS

Hadler, J.B. et al, **"Ocean Catamaran Seakeeping Design, Based on Experiences of USNS HAYES"**, Transactions SNAME, Volume 82, 1974, pp 126-161.

Describes the experience of taking one of the least successful naval craft of the last 40 years and making it a useable sea boat. When first tried at sea, the HAYES was afflicted with severe cross structure slamming and a sickening, corkscrew motion in which it seemed to move in all axes at the same time. Model testing and analytical analysis lead to the fitting of a hydrofoil in between the two hulls which greatly improved the motions of the vessel. Contains model and full scale results for a range of systematic variations on the hull form used for this ship and two ASR's built during the same time frame. Contains much valuable information and advice for the designer of similar vessels.

Robson, B.L., **"Development of the Royal Australian Navy GRP Minehunter Design"**, Royal Institution of Naval Architects, 1982, pp 124-142.

Discusses the development of the RAN's small (31m, 170 tonnes) catamaran minehunter. Uses sandwich skin GRP

construction in the manner of Swedish monohull MCM vessels. Has many features to minimize underwater signature and maximize hull shock resistance. Hull form somewhat resembles that of the HAYES, but higher Length to Beam Ratio. Fitted with anti-pitching foil (to no one's surprise).

Woolaver, D.A., **"Report on the USS Ortolan (ASR-22) Forward Foil Seakeeping Trials"**, DTNSRDC/SPD-122-20, NTIS Accession #AD-A021 582, November 1975.

The Ortolan, along with other catamaran auxiliary ships constructed in the same time period, suffered from severe slamming of the cross-structure, which created structural problems and produced large rigid-body motions. Modifications to the cross-structure to increase under-deck clearance, and the addition of a pitch-dampening foil greatly improved the seakeeping behavior of the vessel, while reducing the structural loads due to slamming.

SEAKEEPING HULL FORMS - SMALL WATERPLANE AREA TWIN HULLS (SWATH)

Allen, R.G., & Holcomb, R.S., **"The Application of Small SWATH Ships to Coastal and Offshore Patrol Missions"**, RINA Symposium on Small Fast Warships and Security Vessels, 1982, pp 41-58.

The paper is an overview of a study conducted to examine the potential of small SWATH ships for coastal and offshore patrol missions. Resistance, powering and seakeeping characteristics of 125 to 1270 metric tonne(Mg) SWATH ships were investigated together with analysis of all major weight groups. Conclusions are:

1) The maximum speed selected has a large effect on the design
2) Speeds of 20-25 kts can be easily accommodated with diesel engines. CODAG systems may be required if higher speeds are desired.
3) If speeds above 20 kts are required in conjunction with acceptable range, aluminum structures will be required. Composite and/or hybrid steel/aluminum structures appear to have few advantages.
4) Seakeeping is excellent and provides a substantial improvement over conventional ships.
5) Helicopter operations are possible on SWATH ships as small as 250 Mg, but full hangering, maintenance, etc., will require SWATH ships of 500 to 750 Mg displacement.
6) Outfit and Machinery weights for SWATH ships tend to be somewhat higher than for monohulls of the same displacement.

Barnes, W.C., **"SWATH: Advanced Technology or Mythology"**, Proceeding, U.S. Naval Institute, September 1986, pp 119-121.

Points out what the author feels are the severe penalties paid by the SWATH concept in return for it's excellent seakeeping. The problems cited are excessive power, draft, and hull area, poor arrangements, stability, maneuverability and survivability. These (potential) problems are sketched out to encourage a more realistic, objective engineering exposition of the concepts advantages and drawbacks.

Caldeira-Saraiva, F.L.A., & Clarke, D., **"Application of Multivariable Control Techniques to the Active Motion Control of SWATH Craft"**, RINA International Conference on SWATH Ships and Advanced Multi-Hulled Vessels, 17-19 April, 1985.

Application of a multivariable controller seems to offer vast improvements in motion response over un-stabilized SWATH's and those using active fins controlled by simple feedback. The evaluation of SWATH ships without considering active control is misleading, and does not adequately represent the true performance of SWATH ships. However, it appears that the benefits of simple feedback control appear to under-predicted in this paper, perhaps exaggerating the benefits of more complex control.

Chalmers, H., **"SWATH Hull Form for an ARS Salvage Ship"**, NOSC TD-274, NTIS #AD-A078 038, September 1979.

An attempt to "sell" the SWATH concept for the ARS mission as an alternative to the ARS-46 design (conventional monohull), which it is contended provides no increase in capability over the hulls it is to replace except increased horsepower. The SWATH concept offers high sea state operation, low motion stress, full helo operations, and some unique underwater and salvage operations capabilities un-achievable with conventional ARS designs. Conversely, the ARS mission, with it's modest speed requirements, provides an excellent opportunity to establish the design and construction techniques for moderate sized SWATHs. It should be noted that the new ARS ships are being built to the conventional design.

Chryssostomidis, C., and Patrilkalakis, N.M., **"Seakeeping Calculations for SWATH Ships Using a New Modified Version of CAT-5"**, Report # MITSG 86-71TN, May 1986.

The seakeeping program CAT-5 previously developed for catamarans has been modified to predict the motions of SWATHS. The modifications are described, the program listing is given, and the results of the modified program for catamaran and SWATH ships are presented along with comparisons with published experimental and other results. Runs on a DEC VAX under VM, does not model active control, and appears to be fairly compact.

Coe, T.J., **"Side By Side Buoy-Tender Evaluation, Seakeeping and Maneuvering Comparisons of the USCGC MALLOW (WLB-396) and the SSP KAIMILINO (Semi-Submerged Stable Platform)"**, U.S. Coast Guard Research and Development Report No. CG-D-34-84, NTIS Accession #AD-A153 613, February 1984.

A companion report to Strickland, 1985. Covers the seakeeping and maneuvering portions of this series of side-by-side tests. Motions of the KAIMALINO were up to 20 times less than for the MALLOW, and maneuverability was as good or better.

Cressy, C.P., and Meinhold, M.J., **"SWATHGEN Computer Aided Design Program User's Manual"**, DoT Report # CG-D-8-85, NTIS Accession #AD-A154 859, February 1985.

SWATHGEN is a program which produces faired hull forms, performs resistance calculations and optimizes the hull form by shaping the lower hulls to minimize wave resistance. See also Salveson et al (1985).

Curphey, R.M., & Lee, C.M., **"Theoretical Predictions of Dynamic Wave Loads on Small-Waterplane-Area, Twin-Hull Ships"**, DTNSRDC-77-0061, NTIS #AD-A042 563, July 1977.

A mathematical model developed to predict the bending moment, sideload, and vertical shear force acting on the cross structure and strut of twin-hull ships in beam waves. The program has shown good agreement with experimental data. The prominent feature of sideload and bending moment responses for SWATH ships is a sharp peak resulting from wave diffraction at an excitation wavelength roughly three to four times the overall beam of the ship. Horizontal forces are about an order of magnitude greater than vertically acting forces in regular beam seas at zero speed, the situation examined in the report.

Drummond, S.E., **"Hydrographic Applications of SWATH Ships and Swath Survey Systems"**, IEEE Oceans '82, pp 387-391.

Points out the pressing need for up-to-date hydrographic data, and discusses ways in which Small Waterplane Area Twin Hull Vessels and Multi-beam survey systems can alleviate some of the problems of present survey techniques and equipment. Particular reference to the Suave Lino.

Drummond, S.E., **"SWATH Ship -- Calming Seas for Operating Efficiency"**, Sea Technology, August 1983, pp 33-34.

Short ship report on the Suave Lino.

Fein, J., **"Low Speed Seakeeping Trials of the SSP Kaimalino"**, DTNSRDC/SPD-0650-04, NTIS Accession #AD-A062 644, March 1978.

Presents full scale seakeeping trial results from tests conducted in sea state 5 at various headings at 5 kts. Control surfaces were fixed for these tests.

Fein, J., **"Control Response Trials of the Stable Semi-Submerged Platform (SSP KAIMALINO)"**, DTNSRDC SPD 650-02, April 1976

Contains the results of full scale control response trials. This is the SSP in it's original configuration (193 ton displacement). The response in pitch and roll due to canards and flaps in calm water is documented. The yaw rate response due to rudder is also investigated.

Fein, J., **"Turning Trials on SSP KAIMALINO During February 1978"**, DTNSRDC TM 15-78-91, June 1978, For Official Use Only.

Duplicates some of the tests report in Fein, 1976, in the new configuration (217.5 tons displacement) and explores the effectiveness of various turning strategies, such as differential thrust and inducing inboard heel during a turn, both of which reduce the turning diameter.

Fein, J., & Lamb, G.R. **"The Developing Technology for SWATH Ship Dynamics"**, Proceedings of the 14th Annual Offshore Technology Conference, Houston, Texas, 1982, pp 631-645.

This paper is itself a summary of the state-of-the-art as it existed in 1982, and should be read by any interested investigator. Only a few of the perhaps less obvious points presented in the paper can be noted here.

--Larger SWATH vessels will be proportionally less trim and heel sensitive than small SWATH's, since their waterplane area can be larger without degrading seakeeping performance. Once the natural period of the vessel gets long enough with respect to ocean waves, there is little added benefit to making it longer, and big SWATH's that are Geosims of little SWATH's will have a longer period than they need, so they can trade off waterplane are if need be.

--The approximate seakeeping methods of Dalzell and Lee are producing cheaper predictions of seakeeping without numerical instabilities exhibited by close fit techniques.

--The extant model test data covers only a small region of the SWATH domain.

--Correllation between theory and experiment has hardly eliminated the need for model testing in SWATH design.

--SWATH's for low speed steadiness need low waterplane areas and GM's, for higher speed those parameters can be relaxed. The number of struts, by itself, has little effect on motions.

--SWATH ships can be made to turn at least as well as conventional ships of the same displacement. Since SWATH's tend to be short, looking at turning circled in ship lengths is rather misleading.

The report concludes that the technology exists to design a SWATH ship that will exhibit outstanding operational performance with low technical risk.

Fontneau, P.B., **"SWATH Design Model for Coast Guard Applications"**, Master's Thesis, Department of Ocean Engineering, Massachusetts Institute of Technology, May 1976.

A synthesis model for patrol cutters based on an earlier model by Goodwin for monohulls, and the available SWATH data of the time. Overpredicts structural weight and generator required capacity, but could be used as the basis of a new effort using the far wider database now available.

Gupta, S.K., & Schmidt, T.W. **"Developments in SWATH Technology"**, Naval Engineers Journal. May 1986, pp 171-188.

Another survey paper, introducing canted struts for improved motions, and combined with stabilizer steering, better control, longitudinal framing for cost and weight reduction, and discussing the general advantages of SWATH's, producibility, cost and weight prediction and proposed designs for Coast Guard Cutters, patrol, crew, hydrographic, oceanographic, and ocean surveillance vessels. The canted strut and stabilizer steering concepts look very promising and deserve serious consideration.

Hightower, J.D., Parnell, L.A., Strickland, A.T., & Wanhuis, P.L., **"SWATH Technology Development at the Naval Ocean Systems Center"**, RINA International Conference on SWATH Ships and Advanced Multi-Hulled Vessels, 17-19 April, 1985.

Traces the effort at NOSC to develop the SWATH concept. Their emphasis has been been primarily on units capable of operations with fast-moving surface warfare groups, but they have also developed the SSP 'Kaimalino' which is used for low-speed support of underwater systems development, and has also been tested for application as a buoy tender. One of the key contentions of this paper is that SWATH's need not cost more than conventional ships, and on a mission-equivalency basis are probably far less expensive.

Holcomb, R.S., & Allen, R.G., **"Investigation of the Characteristics of Small SWATH Ships Configured for United States Coast Guard Missions"**, Department of Transportation Report CG-D-15-84, DTNSRDC/SDD-83-3, June 1983.

Develops four SWATH concepts configured for Coast Guard WPB/WMEC missions and uses these as a foundation for examining the principal characteristics and performance of small SWATH ships. The displacements were chosen to bracket existing cutters and remained fixed during the study. For each of the concepts, the parameters of interest were Gross Geometry: Area and Volume Characteristics: Weight Group Distribution: Speed, Endurance and Range Trade-offs. See the abstract of Allen and Holcomb (1982) for some of the conclusions of this important study.

Jones, M.P., **"Test and Evaluation of the Ocean Systems Research 64' SWATH Demonstration Craft"**, NAVSEADET Norfolk Report No. 6660-95, October 1982.

Details tests for speed/power/fuel consumption, seakeeping, maneuvering, hull stress and strain, and towing run on the SUAVE LINO, after early problems with payload capacity and trim were corrected by the addition of buoyancy blisters. The vessel reached 18.6 kts at light displacement and 17.0 kts when heavy. Seakeeping trials in rather mild conditions produced pitch, roll and accelerations much lower than expected for comparable monohulls. Directional stability was excellent, although due to poor rudder design, turning diameters were large.

Kennel, C.G., & Anderson, T.A., **"Small Waterplane Area Twin Hull (SWATH) Combatant Ship Parametric Study"**, DTNSRDC Report #6114-048-78, NTIS accession #AD-A061 565, September 1978.

Posits the anticipated size and speed of SWATH escort ships. Includes studies of several exotic propulsion systems and very high installed horsepowers. The method is useful even if the results of this particular study are somewhat irrelevant to buoy tenders. The conclusion that "Smaller ships and higher speeds are possible by using all aluminum structure, reducing crew size, or changing mission elements such as range and endurance speed" is universally applicable.

Kallio, J.A., and Ricci, J.J., **"Seaworthiness Characteristics of a Small Waterplane-Area Twin-Hull Ship (SWATH IV), Part I"**, DTNSRDC SPD-620-01, March 1975.

Kallio, J.A., and Ricci, J.J., **"Seaworthiness Characteristics of a Small Waterplane-Area Twin-Hull Ship (SWATH IV), Part II"**, DTNSRDC SPD-620-02, NTIS Accession # AD-A024 724, March 1975.

A useful series of tests including a substantial part of the matrix defined by four speeds, four headings and three drafts for the basic hull as well as for the hull with various appendages. No active controls. Deeper drafts reduced cross-structure clearance, increasing motion response due to more prevalent wave impacts.

Kennel, C.G., **"SWATH Ship Design Trends"**, RINA International Conference on SWATH Ships and Advanced Multi-Hulled Vessels, 17-19 April, 1985.

Displays trends in design parameters predicted during the last 14 years of SWATH design. Since most of the designs examined have not been built, the results should be applied cautiously. Also, many of the relationships show their greatest change as displacement increases above 10,000 tons displacement, well above buoy tender size. It would be helpful if the same relationships could be developed limiting the displacement to about 2000 tons. The comparisons between SWATH and monohull practice are very illuminating.

King, James, **"Small Waterplane Are Twin Hull (SWATH) Ship Structural Weight Parametrics Using the Structural Synthesis Design Program"**, DTNSRDC/SDD-78/1, NTIS Accession # AD-A051 682, September 1977.

Excellent overview on the effects of various structural modifications on SWATH Structural weight fraction. 10-20% reductions in the weight of the primary structure can be achieved relative to the baseline of the then-current SWATH Synthesis Program estimates. The parameters studied included: transverse frame spacing, materials, intermediate lateral support, and the use of longitudinal girders.

Koops, A., & Nethercote, W.C.E., **"SWATH Model Resistance Experiments"**, RINA International Conference on SWATH Ships and Advanced Multi-Hulled Vessels, 17-19 April, 1985.

A small series test of SWATH configurations. Single strut models with long and short struts, and simple and contoured lower hulls were tested with systematic variations in breadth and draft to produce 20 variants. Comparisons are made between the experimental results and predictions based on the theory of Chapman. The character to the resistance curves were well-predicted by the theory, although the absolute values of resistance are underpredicted at high speeds and over-predicted at hump speed. Variations in resistance due to breadth and draft variations are well predicted by theory, and it is concluded that the existing theory is a good comparitive tool for the ship types shown.

Lang, T., Becker, N., Kaysen, D., & Price, K. "**Raytheon/SSCO Oceanographic SWATH Ship Design**", IEEE Oceans '82, pp 711-722.

This paper describes a concept for an Oceanographic Ship combining SWATH with state-of-the-art Oceanographic Instrumentation to provide a stable platform for comfortable and detailed at-sea research.

Lang, T., & Sloggett, J.E., "**SWATH Developments and Performance Comparisons With Other Craft**", RINA International Conference on SWATH Ships and Advanced Multi-Hulled Vessels, 17-19 April, 1985.

Presents a useful database of performance for SWATH's and conventional vessels and some simple performance assessments for calm and rough water. Gives ranges of speed and sea states, as well as design applications where the SWATH concept offers clear advantages over conventional ships.

Lee, C.M., & Martin, M. "**Determination of Stabilizing Fins for SWATH Ships**", Proceedings, Fourth Ship Control Symposium, The Hague, Netherlands, 1975.

A theoretical approach for determining the size of stabilizing fins for SWATH ships is described. Determination of fin size is made on the basis of retaining vertical plane stability for high speeds as well as augmenting the heave and pith damping for motion in waves. The lack of waterplane area in a SWATH ships can result in pitch instability due to the "Munk Moment" on the submerged hull which provides a destabilizing pitch moment roughly proportional to the square of the speed. Inception speed for instability is well predicted by the theory, and it is seen that there is an optimum size for stabilizer fins. Fitting fins larger than optimum may result in unstable heave modes. Fore and aft fins provide improved stability and motion damping characteristics over aft fins alone. Note that this report considers only fixed fins. Active fins are <u>not</u> strictly necessary to prevent pitch instability, but it seems logical that if fins are fitted, they may as well be active.

Lee, C.M., & Curphey, R.M., "**Prediction of Motion, Stability, and Wave Load of Small Waterplane Area Twin Hull (SWATH) Ships**", Transactions, SNAME, Vol. 85, 1977, pp 94-130.

The programs still in use by DTNSRDC for SWATH analysis owe much to the theory developed by Lee in this paper.

Lin, A.C.M., Crook, L.B., & Murray, L.O., "**Prediction of Resistance and Propulsion Characteristics for a Small Waterplane Area Twin Hull (SWATH) Form Represented by Model 5287**", DTNSRDC/SPD-78/396-08, NTIS Accession #AD-A056 581, December 1972 (reissued April 1978)

An experimental evaluation on the cambered-hull effect on resistance and propulsion of a SWATH. This experimental evaluation was divided into six sections to investigate the affects of variation in draft, propeller diameter, correlation allowance, one propeller driving - one windmilling, change of camber from inboard to outboard, and in experimental techniques

using free to trim and heave, free to heave, and captive modes. The effects of draft on resistance and propulsion are sizeable in the low speed range, but are not significant above a speed length ratio of 1.0. The propeller diameter doesn't affect hull efficiency as much as varying speed does. The propulsion coefficients are not significantly changed by correlation allowance. Hull camber inward was superior for both resistance and propulsion. The powering characteristics were dependent on interference, sinkage and time effects, thus the technique for conducting the experiments is of prime importance.

Lipp, David, **"Design Criteria and Considerations for a Hawaiian Stable Semi-Submerged Fishing Vessel (SSFV)"**, Sea Grant Cooperative Report UNIHI-SEAGRANT-CR-79-02, NTIS Accession #PB300 676, University of Hawaii, Honululu, Hawaii, December 1978.

Due to the rough seas around Hawaii, it is estimated that only 50% of a typical fishing vessels time on site is actually spent in operation. A SWATH fishing vessel promises much greater operational utility. This report develops the requirements, and sketches the preliminary design of such a vessel.

Luedeke, G., Montague, J., Posnasky, H., & Lewis, Q., **"The RMI SD-60 SWATH Demonstration Project"**, RINA International Conference on SWATH Ships and Advanced Multi-Hulled Vessels, 17-19 April, 1985.

A very detailed description of a small SWATH demonstration craft. This vessel has been extensively tested by the Coast Guard R&D Center and by DTNSRDC.

Mabuchi,T., Kunitake, Y., & Nakamura, H., **"A Status Report on Design and Operational Experiences with the Semi-Submerged Catamaran (SSC) Vessels"**, RINA International Conference on SWATH Ships and Advanced Multi-Hulled Vessels, 17-19 April, 1985.

Summarizes the development and operations of the largest fleet of operational SWATH's. Discusses trade-offs in construction materials, propulsion, and descibes the operational experience with the 'Seagull', a fast ferry, and the 'Kotzaki', a hydrographic survey vessel. The very high operability and effectiveness of SWATH ships is borne out in actual practice.

McCreight, Kathryn K., **"The Effect of Longitudinal Center of Flotation and Longitudinal Metacentric Height on Responses of Low Speed SWATH Configurations"**, DTNSRDC/SPD-1047-01, NTIS Accession #AD-A159 069, March 1985.

An analytical study examining the effect of varying the longitudinal metacentric height and longitudinal center of flotation on the motion responses of a series of 2550 tonne SWATH ships, all with twin struts and contoured lower hulls. The predictions show that increasing GM_l generally results in decreased responses to irregular seas. Locating LCF aft of the LCB in head seas reduces responses for all motions studied for low speeds, and in following seas reduced relative and absolute vertical motions at the bow for all speed.

McCreight, Kathryn K., Hering, J., Waters, R.T., **"Seakeeping and Maneuvering Assessment of SWATH AGOR 23 Configurations"**, DTNSRDC/SPD-1198-01, NTIS Accession #AD-A173 481, July 1986.

Various designs for the AGOR 23 oceanographic vessel were tested to see if designs which were within cost constraints could also meet the Operational Requirements for seakeeping and stationkeeping.

McCreight, Kathryn K., and Zarnick, Ernest E., **"Seakeeping Assessment of SWATH Oceanographic Research Vessel (AGX) Designs"**, DTNSRDC/SPD-1195-01, NTIS Accession #AD-B106 438, June 1986.

This work preceeded the previous reference. The NAVSEA baseline design was evaluated with and without active fins and was found to have excessive motions at zero speed. A modified design with larger displacement was then evaluated, and found to have better motions at zero speed, but problems with roll at the transit speed. The expected cost of this larger vessel drove the next study (see previous) to examine designs within cost constraints. Distribution of this report is limited to U.S. Government agencies and their contractors.

McGregor, R.C. **"An Illustration of Some SWATH Vessel Characteristics"**, High Speed Surface Craft Conference, 1983.

Presents a summary of research work conducted since 1978 at Glasgow University. Some interesting phenomena were observed during tests of a 3-column SWATH, and the results of general investigations into SWATH resistance and seakeeping are presented.

"'MESA 80': Mitsui's semi-submersible catamaran as a fast ferry", The Motor Ship, July, 1980, pp 95-97.

Ship report on the first commercial application of Mitsui's SWATH research program.

Mulligan, R.D., & Edkins, J.N., **"ASSET/SWATH - A Computer-Based Model for SWATH Ships"**, RINA International Conference on SWATH Ships and Advanced Multi-Hulled Vessels, 17-19 April, 1985.

ASSET/SWATH is a ship synthesis computer program that was developed by the U.S. Navy. It is the latest addition to the family of ship synthesis modules know as ASSET (Advanced Surface Ship Evaluation Tool) and is used to perform early-stage SWATH designs and to assess the whole-ship impact of applied technologies. The majority of computational modules employ analytical, rather than empirical, algorithms. An important design tool, but may be more suitable for Naval Combatants than for Coast Guard Buoy Tenders.

Murphy, D.W., & Morinaga, W.S., **"Advanced Ship System Concepts for Hydrographic Surveying"**, NOSC Technical Report 577, NTIS Accession #AD-A092 374, September 1980.

An Excellent paper integrating the SWATH concept into a larger system. The present hydrographic survey capability is limited by numbers of assets, old and unreliable equipment and high personnel turnover. An improved capability can be achieved

by 1) Utilizing state-of-the-art equipment for navigation, data collection and processing, 2) Utilizing much smaller SWATH survey ships which would provide the same or improved operational capabilities as present units with lower acquisition and operating costs, 3) Use remote sensing for very shallow water surveying, 4) use more reliable launches for shallow water and near-shore operations 5) Utilize larger self-sustaining Survey Launches or single hull semi-submersible drones operating in conjunction with the mother craft for survey of un-obstructed waters.

Nethercote, W.C., **"SWATM2 - A Computer Program For the Prediction of SWATH Ship Motions in Regular and Irregular Waves"**, DREA Technical Memorandum 85/217, NTIS Accession #AD-A168 307, September 1985.

Describes a five-degree-of-freedom SWATH motions program based on the theoretical model of Lee, and earlier programs developed at DTNSRDC. Uses strip theory, includes viscous flow and the contributions of the control surfaces. Agreement is good for vertical motions, rather less so for lateral motions. Long- and short-crested irregular seaways can be specified.

Nethercote, W.C., **"SWSPA - A Computer Package For Seakeeping Performance Assessment of SWATH Ships"**, DREA Technical Memorandum 86/210, NTIS Accession #AD-A168 307, April 1986.

A package based on SWATM2 which automates the assessment of seakeeping performance. Computes the ship motions for the entire range of sea conditions for a user-specified ocean area in the North Atlantic, applies seakeeping criteria, averages the performance parameters over all headings to obtain mean values for each sea condition and obtains averages for all sea conditions by weighting each individual sea condition by it's probability of occurrence.

Numata, Edward, **"Predicting Hydrodynamic Behavior of Small Waterplane Area Twin Hull Ships"**, Marine Technology, Vol. 18, No. 1, Jan. 1981, pp 69-75.

Describes the analytical and experimental techniques then available for use in the design process. Presents simple relationships for use in predicting resistance and seakeeping behavior in the early stages of design.

Reed, Arthur, **"Documentation of SWATH Ship Resistance and Propulsion Prediction Programs (CLOSEFIT and SYNTHESIS): Maintenance Manual"**, DTNSRDC/SPD-0927-02, NTIS Accession #AD-A099 533, April 1981

Documents two related computer programs for determining the wave resistance and propulsive performance of Small Waterplane Area Twin Hull (SWATH) Ships. CLOSEFIT uses an integration technique based on the actual offsets to generate the coefficients of the Chebychev series used for representing the geometry of the hull and struts used in the thin-ship analysis, where SYNTHESIS uses an approximation based on the moments of the strut waterplane and body. SYNTHESIS thus saves 10 to 40 times

the computation needed to determine wave resistance, albeit doing so less accurately. SYNTHESIS also calculates SHP using wake data from propulsion experiments and Troost propeller data. This document is primarily for those who seek to modify and maintain the programs and need a thorough understanding of how it works; the User's Manual explains input and output in sufficient detail for most users.

"RINA International Conference on SWATH Ships and Advanced Multi-Hulled Vessels", The Royal Institute of Naval Architects, 17-19 April, 1985.

A landmark conference. Research. design, development and operation of SWATH ships was discussed in nearly 30 papers by authors from all the major shipbuilding countries. Pertinent articles are referenced by author.

Salveson, N., von Kerczek, C.H., Scragg, C.A., Cressy, C.P., and Meinhold, M.J., **"Hydro-Numeric Design of SWATH Ships"**, SNAME Transactions, Vol. 93, 1985, pp. 325-346.

Describes the development of a program which enables the designer of a SWATH to include advanced hydrodynamic performance predictions in the early stages of the design process. The first module of the program generates mathematically faired SWATH hull forms (including the lowerhull/strut intersection), performs hydrostatic calculations and generates geometry descriptions needed for the hydrodynamic computations. The second module computes the total calm water resistance using a modification of the method of Chapman, and the third module seeks to optimize the hull form by contouring the lower hulls to minimize wave resistance. See also Cressy and Meinhold(1985).

Seren, D.B., Miller, N.S. & Ferguson, A.M., **"Some Motion and Resistance Aspects of SWATH-Ship Design"** RINA International Conference on SWATH Ships and Advanced Multi-Hulled Vessels, 17-19 April, 1985.

Presents an overview of the technical progress in the field of tandem-strut SWATH hydrodynamics at the University of Glasgow. Frequency and time-domain seakeeping programs are being developed and comparative model tests have been run to gather resistance and wake survey data and to examine the effects of beam and draft variations. Motions control design considerations are addressed based on experiments carried out in head and following seas, and it seems that aft, fixed stabilizer fins may not be sufficient for pitch stability in following waves.

Smith, S.N. **"Parasitic Motions and Capsize Safety of a SWATH-type Ship"**, 15th Annual Offshore Technology Conference, Houston, Texas, May 1983, pp 351-358.

Presents experimental results of an investigation into the 'parasitic' motions (rolling in head seas, sub-harmonic rolling in beam seas) of Glasgow University's 3 column SWATH. While the motions never led to a capsize, they shed some light on the peculiarities of this type of vessel, and the influences of heave and roll natural frequencies, and above water shape on their motions.

Smith, S.N. **"An Investigation Into the Hydrodynamics of Small SWATH Ships"**, High Speed Surface Craft Conference, 1981, pp 153-164.

This paper gives a brief review of the design for a small SWATH vessel for life-science and engineering research developed at the University of Glasgow, and describes motion responses experiments run in head seas while stationary and at forward speed.

Smith, S.N. **"Design and Hydrodynamic Performance of a Small Semi-Submersible (SWATH) Research Vessel"**, RINA Transactions, 1982, pp 69-91.

A fairly complete presentation of the preliminary design for a small (319t) SWATH Research Vessel. Design basis, requirements, equipment, group weights, preliminary scantling estimates, intact stability and a limited amount of cost data are presented, along with resistance results by theory and experiment, and motions experimental results. The 'jump' phenomena is explored.

Strickland, A.T., **"Side-By-Side Buoy-Tending Trials of the SWATH Ship SSP KAIMILINO and the USCG Cutter MALLOW (WLB-396)"**, Naval Ocean Systems Center Technical Report 963, August 1985. Distribution Limited.

Reports on a series of side-by-side trials with a SWATH and a conventional 180 ft WLB in the waters off Hawaii in order to develop comparable data on performance of ATON tasks under identical sea and weather conditions. The superior motions, maneuverability, ample deck area and lack of drift of the SSP KAIMILINO made it an attatracive platform for buoy tending, in spite of it's deep draft, high freeboard, weight sensitivity, heel sensitivity and lack of adaptation in layout and hardware to ATON operations. Companion report to Coe, 1983.

Turner, C.R., & McCreight, Kathryn K., **"Response Characteristics of a Systematic Series of 30,000 ton SWATH Configurations"**, DTNSRDC/SPD-1072-01, NTIS Accession #AD-A134 858, July 1983.

The response characteristics of a systematic series of seventy-nine SWATH configurations have been investigated analytically. Three values each of waterplane area, strut length, LCB and LCF are used to define the hullforms. RMS values of heave, pitch, relative bow motion and absolute stern motions are presented for a unit wave height and a range of modal periods for head and following seas at four speeds. Performance assessments are given and trends are indicated. Small (relative to ocean waves) SWATH's tend to be more sensitive to parametric variations than large SWATH's (such as these), but the method and the general trends of this study are very useful in assessing variations in SWATH design variables.

Woolaver, D.A., & Peters, J.B., **"Comparitive Ship Performance Trials for the U.S. Coast Guard Cutters MELLON and CAPE CORWIN and the U.S. Navy Small Waterplane Area Twin Hull Ship KAIMALINO"**, Coast Guard Research and Development Report CG-D-10-80, DTNSRDC-80/037, NTIS Accession #AD-A084 184, February 1980.

A WHEC, WPB and the SSP KAIMALINO were tested side-by-side on a series of courses of Hawaii, and an extensive set of motions and human factors measurements were made. Measurements were made for three 8-hour periods at different headings relative to the waves, and an additional 36-hour trial period involving only the CAPE CORWIN and the KAIMALINO was conducted. In the relatively mild sea conditions encountered, none of the vessels was limited by ship motions, but the KAIMALINO was the most stable of the three vessels, being superior to MELLON in roll and lateral acceleration and superior to CAPE CORWIN in roll, pitch, heave, vertical acceleration and lateral acceleration.

Zarnick, Ernest E., & Hong, Young S., **"Relative Bow Motion and Frequency of Slamming of SWATH Cross-Structure"**, DTNSRDC/SPD-1174-01, NTIS Accession #AD-A166 893, April 1986.

Studies have indicated that Relative Bow Motion and related slamming are nearly always the limiting performance parameter in SWATH seakeeping assessment. A study was made of methods for improving the means of estimating the number of wave impacts per unit time of SWATH cross-structures. Two avenues were explored: 1) Improvement of relative motion estimates by adding the components of ship-generated wave and diffracted wave to the incident wave in describing the free surface; and, 2) including a limiting impact angle in the criteria defining the occurrence of a slam. The refined modeling of the free surface does not improve the correlation of the computed relative motion results with experiment, and, as expected, the limiting angle criteria reduces the estimated frequency of slamming. Additional model tests are recommended to obtain a more definitive estimate of threshold velocity and limiting impact angle for estimating SWATH cross-structure slamming.

Zarnick, Ernest E., **"Vertical Plane and Roll Motion Stabilization of SWATH Ships"**, DTNSRDC/SPD-1199-01, NTIS Accession #AD-A172 114, September 1986.

A method to assess the effects of active fins on the vertical motions (platforming and contouring modes) and/or the roll motion of a SWATH in waves. Uses Linear Quadratic Theory for Optimal control and handles fin angle and saturation non-linearities by using limiting values, permitting frequency domain calculations to be computed that are more consistent with LQT and more cost effective than time-domain approaches. An important paper and method.

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