AD-A146 408 INTERNATIONAL SYMPOSIUM ON MINE WARFARE VESSELS AND SYSTEMS HELD AT LONDON ENGLAND ON 12-15 JUNE 1984(U) OFFICE OF NAVAL RESEARCH LONDON (ENGLAND) C MCKINNEY 1/1

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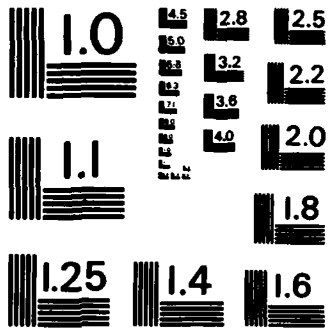

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OFFICE OF NAVAL RESEARCH

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INTERNATIONAL SYMPOSIUM ON MINE WARFARE VESSELS AND SYSTEMS

CHESTER McKINNEY

19 JUL 84

UNITED STATES OF AMERICA

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REPORT DOCUMENTATION PAGE

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1. REPORT NUMBER C-3-84	2. GOVT ACCESSION NO. AD-A146 408	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) International Symposium on Mine Warfare Vessels and Systems		5. TYPE OF REPORT & PERIOD COVERED Conference
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Chester McKinney		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS US Office of Naval Research Branch Office London Box 39 FPO NY 09510		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS		12. REPORT DATE 19 July 1984
		13. NUMBER OF PAGES 12
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Mine warfare
Mine countermeasures
Platforms
Propulsion equipment
Minehunting systems

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

The International Symposium on Mine Warfare Vessels and Systems was held in London from 12 through 15 June 1984. This report discusses presentations on platforms and propulsion equipment for mine countermeasures systems, and minehunting systems and components.

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CONTENTS

INTERNATIONAL SYMPOSIUM ON MINE WARFARE VESSELS AND SYSTEMS

1 OVERVIEW

The International Symposium on Mine Warfare Vessels and Systems was held in London from 12 to 15 June 1984. The meeting was sponsored by the Royal Institution of Naval Architects (RINA), and to my knowledge was the first unclassified conference on the subject ever to be held. The meeting was an excellent one in several respects, and the broad participation exceeded the expectations of the sponsors. In spite of the high registration fee (£390) there were about 260 participants from 20 countries, and the technical program included 28 papers from nine countries (see Table 1 and the appendix). The symposium was definitely international, but the papers and discussion were all in English. The flavor was clearly commercial, with 20 of the papers coming from industry (four others were coauthored by company delegates) and 74 percent of the registrants listing company affiliations.

A valuable feature of the arrangements was the distribution of preprints of 17 papers to registrants several weeks prior to the meeting. Copies of the other 11 papers were distributed at the start of the conference. (Only one of the scheduled papers was withdrawn.) The most lasting benefit of the symposium may well be the publication of a collection of good papers in a single unclassified proceedings. Although much of the material presented has appeared in prior publications and is known to the US mine warfare community, a significant block of new information was given. Having the information consolidated in one place and in English certainly is worthwhile.

The purpose of this report is to describe the technical presentations in brief detail for those who have an interest in mine warfare but were unable to attend the meeting. Those who desire more details can purchase a set of the proceedings from RINA, 10 Upper Belgrave Street, London SW1X 8BQ; telephone: 01-235-4622. The price and publication date had not been set at the end of the conference.

The technical sessions were lively and unhurried. In part this can be attributed to the excellent work of the session chairmen, who presided well but firmly, and who encouraged comments and questions, often asking questions themselves and calling on specific members in the audience for comments. A major reason for lively discussions was that most of the commercial and government competition in a given area were present and sought additional information. Also they were not shy about alluding to known weaknesses in a given piece of equipment or technique of a competitor. The discussion (20 minutes per paper) was as good as I have ever observed in a conference of this nature and size. The questions and comments, after editing and allowing authors to prepare more carefully considered responses, will be published as one volume of the proceedings and will be distributed to participants.

Table 1

Origins of Symposium Papers and Registrants

Country	Papers	Registrants
Australia	1	5
Belgium		3
Canada		2
China (PRC)	1	6
Finland	1	3
France		10
Germany (FRG)	3	26
Italy	3	15
Japan		2
Korea (South)		2
Netherlands	2	10
Norway		5
Spain		6
Sweden	2	18
UK	11	105
US	4	23
Yugoslavia		2

There were 29 commercial exhibits which attracted a great deal of interest. The exhibits were mostly in the form of photographs, posters, equipment brochures, a few scale models, and some video tapes. These exhibits complemented the technical sessions in that they included pieces of equipment which were not discussed in the technical papers. It was a good opportunity to have personal discussions with company representatives and to obtain information which could not be given in public papers.

The technical program was opened by Admiral Sir Anthony Griffin, president of RINA, and his remarks were followed by an excellent overview paper on mine warfare by Mr. R.J. Daniel, one of the organizers of the symposium. Daniel's paper contains little not well known to professionals in the field, but it is a good concise reference for the layman. The largest block of papers (12) dealt with mine countermeasures (MCM) platforms (ships and air-cushioned vehicles) and ship design. Another six were on propulsion systems (primary and auxiliary), engines, and ship control. Five dealt with minehunting and minesweeping systems or system components, and one was a fine paper on the fundamentals of degaussing. There were two papers on mine disposal vehicles, and other similar vehicles were covered in the exhibits. Several areas were notable for not being covered in the technical program. A few MCM platforms were not discussed (e.g., the US helicopters, the US MCM-1, the French BAMO, and others), and there were no specific papers on minelaying platforms. Minehunting sonar systems were hardly covered at all, and little was said about minesweeping (mechanical and influence) systems. Only one paper dealt with mines, and it was on a new exercise mine. The probable reason for not having papers on most of these topics relates to the security classification of technical details. However, it would have been useful if these topics could have been covered at the unclassified level, and there is a significant body of such information which is not classified. However, to include such topics might have made the symposium unduly long.

Titles and authors of papers are included in the appendix. In the following sections a very brief resume will be given of the papers, grouped by topic, not order of presentation. The numbers in parentheses refer to the paper numbers in the appendix.

2 PLATFORMS AND PROPULSION EQUIPMENT FOR MCM SYSTEMS

Most present MCM platforms are surface ships with conventional displacement hulls. However, the US uses some helicopters, and the US and UK are considering using hovercraft or air-cushion vehicles (ACV). MCM vessels (MCMVs) have very special requirements which make them quite different from conventional ships, both naval and civilian. Most MCMVs are at risk since they are intended to operate in mined areas or areas suspected of being mined. These vessels must be able to conduct mine clearance (sweeping or hunting) effectively; that is, they must carry the equipment and people needed to conduct the mission. Conventional minesweeping is done in two ways: (1) by towing wires, armed with explosive cutters, through the water to cut the tether lines of buoyant mines; or (2) by towing magnetic and acoustic signal generators through the water to simulate the signatures of real ships and (hopefully) cause influence mines (typically resting on the ocean bottom) to actuate. Minehunting is the procedure wherein a sonar (or other sensor) is used to search an area; detect, locate, and classify/identify individual mines; and then either avoid the area, remove the mines, or destroy them in place. In general, large numbers of MCMVs are needed. To minimize the risk, the various "signatures" of the MCMV (e.g., magnetic, acoustic, and pressure) should be made as small as feasible to reduce the probability of causing mines to explode when the MCMV is within lethal range of the explosions. This is achieved by using nonmagnetic construction materials where feasible, using countermagnetic devices, mounting reciprocating and rotary machines on vibration isolation pads, and locating magnetic and noisy components as far from the water line as possible. To minimize pressure signatures, one uses the smallest sizes of vessels which can perform the required missions, which generally serves also to minimize magnetic and acoustic signatures. Even with these design precautions and using the best known tactics, some mines may explode close to the MCMVs; and, to improve the probability of survival, these ships are designed to be especially resistant to damage from underwater explosions. Platforms are rated in terms of "shock factor" (SF), which is defined as the square root of the mass of explosive (in kilograms of TNT equivalent) divided by the distance (in meters) from the explosion to the ship, for which the ship can still operate or at least survive. Another requirement is high maneuverability since MCMVs usually must be able to navigate along a precise course (within a few meters), circle a suspect target while holding a precise standoff, and hover if necessary. Usually an MCMV must have excellent low-speed and medium-speed performance. Finally, MCMVs typically must operate (i.e., conduct MCM) in sea states 3 or 4 and survive in much rougher weather. All of these requirements and many more make the MCM platform a small but complex vessel. It is against this brief background that some of the papers will be described.

The UK has been the pioneer in using nonmagnetic glass reinforced plastic (GRP) for the hulls, decks, and superstructures of MCMVs. (The traditional material had been wood.) The HUNT class of dual-role (combination sweeper-hunter) MCMV is coming into the Royal Navy (RN) fleet, and it remains the largest GRP ship built to date. D.W. Chambers (no. 13) reviewed the UK experience in developing GRP construction techniques. He reviewed the extensive program to evaluate wood, laminated wood, single-skin GRP, and sandwich GRP for many characteristics, including resistance to shock, fire, etc. The testing program used 3×3 m panels, two-thirds scale sections of ships, and even a full-size TON class of minehunter (HMS WILTON) prior to starting the HUNT construction program. In brief, the UK decision was to use single-skin GRP, with conventional ribs and stringers, and lots of tie bolts. GRP is strong but flexible and usually requires some form of stiffening. The tie bolts were used to increase the shock factor. The HUNT is built like a traditional wooden MCM vessel, except it uses GRP. The RN has now had several years of intensive experience with several of the HUNTs, and they are well pleased in general. The experience with BRECON and LEDBURY in the Falklands conflict resulted in considerable confidence in this type of ship. Other unplanned "experiments" have occurred. BRECON was involved in a major collision with another ship and came through very well. A section of the bow had to be replaced, but the time for repair was only 8 weeks. LEDBURY had a serious fire in the main engine room which burned for 4 hours, but no damage was done to other compartments and only 5 weeks were needed for repair.

The two main criticisms of the HUNT design are the high costs (by European MCMV standards) and poor maneuverability in high winds. These points have prompted the UK to develop a smaller, single-purpose MCMV known as the Single Role Minehunter (SRMH). E.C. Pitts (no. 2) discussed the design of this new vessel, the first of which is to be ordered by the end of this year. The design and fabrication will be by Vosper Thornycroft Ltd. The cost of SRMH has been reduced (relative to HUNT) by building a smaller vessel, eliminating all sweeping gear, reducing the speed and endurance a bit, and relaxing the magnetic signature requirements (although NATO standards will be met). The SRMH will have a length of 52.2 m, a beam of 10.5 m, a draft of 2.2 m, and will displace 475 tonnes. The hull will be single-skin GRP with longitudinal stiffeners along the bottom (keel) and vertical ribs on the sides. The hull is flared rather strongly to achieve improved stability and provide more space midship and aft. Maneuverability, especially at slow speeds and for hovering, is improved by using two Voith-Schneider cycloidal (horizontal) propellers. This design allows placing the diesel engines high above the water, which decreases the magnetic signature in the water. Maneuverability under high wind conditions is improved by moving the bridge toward midships. A bow thruster is still included for use primarily when operating in rough weather. Few or no tie bolts will be employed in the SRMH.

The Tripartite ships were the next MCMVs to use GRP hulls. Forty of these vessels will be built (15 by France, 15 by The Netherlands, and 10 by Belgium), using a common design and equipment suite. France and The Netherlands have completed several ships. The Tripartite design is a single-skin hull with conventional ribs and stringers. W.P.J. Laros (Van der Giessen de Noord) presented an interesting paper (no. 5) describing the shipbuilding system used by his company in a specially built facility near Rotterdam. The system is unusual in that it is a production line type in which the vessels move successively through four work stations. Two of these are GRP stations and two are for fitting out. Time in each station is about 20 weeks, and 2.5 ships are built a year. Studies indicated that a saving of 20 percent in man-hours could be achieved by using the production-line system and that the facility cost of f. 45 million could be amortized easily in the construction of 15 ships. There is considerable automation in the GRP part. One half of the mild steel female mold is fixed in position while the other half is removable when the molded hull is to be moved (on air cushion) to the next station. The 365 employees are about equally divided between GRP, fitting out, quality assurance, engineering, and administration. All construction is under cover so that weather does not affect the schedule. Five ships have been commissioned, two are in trials, and four more are in various stages of construction.

Italy was the next country to select GRP for new MCMVs. Their ships were designed and are being built by Intermarine at Sarzana. The hull design is very different from those just described. It is a single-skin type with no stringers or ribs. The monocoque shell is much thicker than the more conventional hulls, and the thickness is variable over the hull, being thickest at the bottom and thinnest at the main deck level. Michael Trimming (Intermarine) presented an excellent paper (no. 17) on the design and features of the LERICI Class, four of which have been built for the Italian navy with six more on order. In addition, four have been bought by Malaysia and two by Nigeria. Also, Intermarine, jointly with a US company, is competing for the MSH contract. A main feature of the LERICI design is its high shock factor, stated to be about 1.3, which would likely place it well above those of the other new GRP vessels. The Italian navy has conducted 14 explosion shock tests with no damage to the hull. Trimming stated that shock loading can be about 40 times that of sea loading (slamming). With this type of hull the challenge is to protect equally well the people and equipment on board. The fuel, oil, and water are in filament-wound cylindrical tanks which are isolated from the hull. The diesel engine is mounted in a cradle, which also is isolated from the hull. This type of isolation increases the resistance to underwater shock waves. The bulkheads are load bearing, as is the one-piece main deck. The joint between deck and hull is fairly flexible. Electrical shielding is a problem in GRP ships, and the LERICI uses sprayed conducting coatings in some compartments. This technique seems to work well and is quick to apply. For fire protection a special fire-resistant barrier coating is used that can withstand a 800°C fire for 30 minutes, which should be adequate time to extinguish the fire by other means. The Intermarine facility employs considerable automation. A machine operated by one man can apply the fabric, and up to four machines can work on the hull at a time. A crew of six finishers work with each machine. Six cloths are applied wet-on-wet, which forms a 15-mm panel. Fifty days are required to make a hull. The length of the LERICI is 50 m, the beam is 9.5 m, and the draft is 2.2 m. The displacement is 550 tonnes. A complex degaussing system is employed which uses magnetometer control (as compared with simple systems which use ship's heading for control).

Two other countries, Sweden and Australia, have selected GRP hulls for their new MCMVs, but the type of GRP is quite different from those just described. Both countries will use a sandwich type of GRP panel in which a thin (up to 9 mm) GRP skin is used with a thick (60 mm) lightweight core of PVC. The merit of this construction is to have a stiff panel which is lightweight. The main concern is over the ability of the lightweight core to withstand high shock. Sweden has been working with sandwich GRP for more than 15 years and has collected a wealth of data on this type of material for MCMV hulls. J. Sjogrou (no. 3) summarized the Swedish work and described the construction of their new ship, LANDSORT. This new MCMV has a 47.5-m length, a 9.6 m beam, and a 2.3 m draft, with a displacement of 360 tonnes. The vessel is powered by four 268-kW diesels, which drive two Voith-Schneider cycloidal propellers. The maximum speed is 15 knots, and the endurance is 2000 miles at 12 knots. No rudders or thrusters are used. The hull includes no frames. The hull is constructed with a male mold on which the core is first fitted and then covered with the GRP external skin. The hull is then removed and the inner GRP skin is applied. The Swedes use a two-component polyurethane glue, a PVC-foam core, and for the skins, woven-roven inner section, bounded on both sides by a special GRP coating. The bulkheads are double stiffened and coated with a special intumescent paint to resist fire damage. The fire hazard of the PVC core is one of the major concerns about the sandwich type of hull, but it is claimed that the Swedish design is good for at least a 1-hour fire. Sweden claims that the GRP sandwich panel has a high shock factor, but no quantitative data were given. For minehunting, the LANDSORT is fitted with a Thomson-CSF TSM 2022 sonar and both remotely controlled submersibles and divers for mine neutralization. For minesweeping, it is fitted with mechanical sweep gear and magnetic and acoustic influence sweep gear. It is also intended to control multiple, remotely controlled, self-powered surface craft for magnetic and acoustic influence sweeping. The boats, designated SAM's, are similar in concept to the West German TROIKA boats. The LANDSORT, one of which is undergoing trials, is equipped with an Action Information Organization system, precise navigation equipment, and a degaussing system. The Swedes claim that the GRP sandwich ship is less expensive than other types which they considered. H.P. Loid (Sweden) presented a good paper (no. 6) on evaluation of various propulsion systems, with emphasis on the Voith-Schneider cycloidal system. The researchers developed a math model and also conducted tests on scale models and at full scale. They sought good maneuverability, no cavitation, and good seakeeping, and felt that the cycloidal propeller system met the requirements.

Several years ago Australia elected to use GRP sandwich hulls for its new GRP minehunting catamarans. B.L. Robson gave a status report on their work (no. 4). This MCMV is small, with a length of 31 m, a beam of 9 m, and a draft of 1.9 m. The beam of each hull is 3 m and the displacement is only 170 tonnes. The height of the main deck is 4.6 m above the water. The speed is modest (10 knots) and the crew is small (14). Orders have been placed for two boats, and a special facility has been constructed for the fabrication of the catamarans. Propulsion is by two Schottel right-angle drives, one in each hull, with the two diesel engines being on the main deck. The drive is hydraulic. The hull material is similar to the Swedish type but will be built in Australia, using Swedish core material. A lot of through-bolts will be used to anchor equipment. The minehunting suite, housed in a GRP container, consists of a Krupp Atlas (KAE) MWS 80 system. This system includes the DSQS-11H sonar, a Kelvin Hughes 1006 radar, a KAE depth sounder and Doppler log, and a Mini Ranger electronic navigation system. Mine neutralization will be done with the ECA PAP-104 submersible. For degaussing only equipment coils are used--no ship coils. The first boat is to be delivered in 1985.

O. Ostring (Finland) described an influence minesweeping system which uses their new KUHA class MCMV (no. 16). This is a small GRP vessel which is 24.3 m long by 6.7 m abeam and displaces 120 tons. The superstructure is of aluminum. Propulsion is by a hydraulically powered out-board type propeller (no other rudder) which is driven by a 450-kW diesel engine. The speed is 8 knots when towing the influence sweep gear and 10 knots otherwise. The complement is five officers and 10 ratings. The most intriguing part of his presentation was the description of the magnetic influence sweep gear. It is an electrode-type system (the return path being the seawater) which is popular in the US but not in Europe. The magnetic sweep cable is 500 m long and 300 m between electrodes. The total electric power is only 70 kW, which seems abnormally low. Most similar sweeps employ several times this power. In response to questions from the audience on this aspect, the only answer was that special electrodes were employed and that the electrode spacing was not large. The speaker claimed that the sweep effectiveness was about four to eight times that of a comparable closed-loop system. The electric power unit weighs about 650 kg, and the total system weight is only 2 tonnes. The reel diameter is only 60 cm, which indicates that the cable diameter is small. The generator output is rectified, and a microprocessor is used to generate the selected waveform. The full system includes a KIISKI class of minesweeper which is used as a "slave" boat. It is even smaller (15.8 m long by 4.1 m abeam), displacing 18 tonnes. The slave boat, manned by a crew of four, runs parallel to the KUHA but laterally offset by 100 to 125 m. It also tows a magnetic sweep but with a wave form of the opposite polarity. Syncronized clocks are employed, and the syncronism is stated to be good for several days. The acoustic-sweep gear is a noise maker. The KUHA employs a simple, gyro-controlled degaussing system for the ship and engine room. It was stated that the KUHA could be converted into a minehunter, but no details on the equipment suite were given.

By this time the reader may conclude that all of the new MCMVs use GRP hulls, but such is not the case. West Germany is planning to procure two new classes of MCM platforms, the first a convertible sweeper-minelayer (Type 343) and the second a minehunter (Type 332). After a detailed study which included multiple concept designs by several shipbuilders, extensive analyses and math modeling, and numerous tests on panels of different materials, The Germans elected to use nonmagnetic stainless steel. H. Schutz (West Germany's B.W.B.) summarized the results of their studies (no. 14). The material he presented was much the same as he has published in earlier articles. The Type 343 will be 51 m long and 9.2 m abeam, and will have a draft of 2.5 m. The displacement will be about 590 tonnes. The German decision may have been influenced by their favorable experience with the Type 206 stainless-steel submarines and because they had already developed the technology of stainless-steel ship fabrication. The Type 332 minehunter probably will use the same basic hull design as the 343.

After listening to all of the papers mentioned above, many in the audience were uncertain which of several types of hull material was the best for MCMVs. The requirements in each country are quite similar. Each country made detailed studies and conducted similar tests. The input data likely were similar. Yet the conclusions reached and decisions made were quite varied. By giving arbitrary weights to various factors, one can make a good case for stainless steel, GRP sandwich, GRP single skin with ribs and stringers, GRP monocoque, or even wood. In the final analysis the difference in costs and in hull weight are not great, regardless of the material used. One thing is clear: because several countries are building MCMVs of similar sizes but of different hull materials at about the same time, we will be able to observe an unplanned but major comparison experiment. If you love MCM this may be more exciting than the America's Cup races. May the best hull win.

However, conventional displacement hulls may have some competition in the form of air-cushion vehicles. For more than 20 years the UK has experimented with hovercraft and has tested them in the MCM role. The special merits of such craft are low magnetic, acoustic, and pressure signatures and high shock resistance to underwater explosions (because of the air cushion, which reflects a large part of the shock wave energy). They also are very maneuverable, can hover well, and generally have less motion (roll, pitch, and yaw) than conventional ships of the same weight. They can operate in very shallow water--even over the beach--and can operate over a wide range of speeds. During 1983 British Hovercraft, Plessey Marine, and the RN outfitted the BH7 MK2 hovercraft (60 tonnes) with standard RN minehunting gear (Type 193M sonar, MK20 plotting table, gyro, and Racal trisponder navigation equipment); they demonstrated that the system could minehunt as well as the present systems. A good question is why, after years of experimentation and study, has the hovercraft not found a place in the MCM fleet? The hovercraft does have some disadvantages, with the major one being high fuel consumption. Typically, the time on station is a matter of hours, not days. Also, there is a question of seaworthiness in rough weather--above sea state no. 4. And perhaps navies tend to be conservative and are reluctant to use new platforms. Although the proposed hovercraft was not selected in the SRMH competition, it may have a future in RN MCM. The UK's Ministry of Defence plans to develop and procure a high speed (10 to 20 knots) route-survey system, and the hovercraft is a prime candidate for the platform. If this comes about, the craft probably would tow a very high resolution side-scan sonar for bottom mapping of channels. Martin Stevens and John Martin (substituting for R. Wheeler) presented a good review of the work with the BH7 MK2 and described the proposed MK20, which is a stretched (by 5 m) MK2 with a new engine, increased fuel capacity, and a new type of skirt (no. 18). A well-known movie was shown of an old SRN3 hovercraft (on cushion) being scarcely affected by a close-by underwater mine explosion. The craft was only slightly damaged by the shock wave and seemed to slide off the side of the emerging water plume. It returned to port under its own power. The shock factor was not stated, but it must have been high.

The US Navy is considering two types of platforms for its planned new MSH and one is an air cushion vehicle which has rigid sides and flexible bow and stern flaps to contain the air cushion. J.B. Chaplin reviewed the US experience with such craft in both sweeping and hunting (no. 19). He described recent tests of a Bell Halter BH-110 MKII Surface Effect Ship (SES) against a series of underwater explosions. The closest shot was 200 feet from the starboard side of the SES. The craft was able to leave the test area at high speed with all systems operating. The results of these experiments are impressive, but sufficient data were not given to allow a calculation of the shock factor. One member of the audience stated that he thought the shock factor was low. The depth of the charge was not given, but for a distance of 60 m the charge weight would have to have been 3600 kg to give a shock factor of 1.0. It probably was lower. The MSH design will be of the Swedish type of sandwich GRP. The length will be about 58 m and the width about 12 m with a 2.3-m air cushion. With this type of craft the propellers are in the water.

Several papers dealt with ship control and propulsion. A.J. Carran (no. 11) discussed the problems of ship control when the ship must hover, circle contacts, and move laterally as well as forward. His talk covered various types of manual and automatic control. I believe that his company (Hawker Siddeley) is furnishing the control system for LANDSORT and perhaps the SRMH. He stressed the need for modular systems which have the capability to grow.

The conventional ship propulsion system uses an engine to drive a propeller through a gearbox and straight shaft, but often this is not the case for MCMVs. Mention has been made of two new ship designs which use the Voith-Schneider cycloidal propeller system. Several others use the Schottel system, which is a steerable right-angle drive and does not employ a separate rudder. O. Bussemaker (no. 22) described such systems which are used on the German TROIKA remotely controlled influence sweeping boats and will be used on the Australian catamaran. The latter will use two 125-kW units, one in each hull.

The advantages of this type of drive are good maneuverability at low speed and the ability to place the engine high in the ship. Minehunters frequently use an auxiliary propulsion system for slow-speed operation. A. Ortelli (Italy) described the Riva Calzoni system, which is used on the LERICI class and on other Italian minehunters (no. 21). A diesel engine drives a hydraulic pump, which in turn powers a propeller which can be trained through 360 degrees. These units are available in 120- and 180-hp sizes and are used for propulsion at speeds up to about 6 knots. For higher speeds the unit is retracted into the hull, and the main propulsion system is employed. In paper no. 7, C.M. Aker (US) discussed materials and design techniques for MCMV thrusters, especially in regard to minimizing noise generation, corrosion, and cavitation erosion.

If one uses nonmagnetic materials for the hull, decks, and superstructure of an MCMV, the engines usually make up the largest remaining magnetizable mass. In a conventional diesel engine about 95 percent of the weight is ferromagnetic. Partially magnetic engines are those in which this figure is reduced to 50 percent, and nonmagnetic ones are those with this reduced to less than 5 percent. One design philosophy is to use a conventional engine, for reasons of reliability and low costs, and then reduce the magnetic signature by using local permanent magnets and degaussing coils. C. Guenther (West Germany) described this approach and gave results for the popular MTU engines (no. 28). He stated that about 90 percent of the cancellation was done by suitably placed permanent magnets. R.V. Hughes described several of the Paxman diesels which are built largely with light alloy nonmagnetic materials (no. 29). The Napier Deltic is an example of an engine with a very low magnetic signature, but its cost is high. The Valenta engine is an example of an engine with about 50-percent magnetic mass. Three local degaussing coils are employed to reduce the signature.

Even with nonmagnetic hulls and engines, the magnetic signatures of most MCMVs are large enough to actuate sensitive mines at short range. Degaussing is the technique used to further minimize the remaining magnetic moment of the ship. M.E. Hemming (UK) gave an excellent tutorial paper on modern degaussing techniques and equipment (no. 24). In a typical system a set of coils, carrying currents, is arranged to cancel the permanent, induced, and eddy current fields along the three principle axes of the ship (longitudinal, athwartship, and vertical). The system needs to be dynamic in that the currents need to be adjusted to compensate for the geographical location, ship's heading, and ship's motion (roll, pitch, and yaw). For best results, a three-axis magnetometer, usually mounted on the mast, measures the earth's field and uses these data to determine current levels. A set of coils usually covers one or more compartments, while smaller coils may be placed around individual items of equipment. Analytical modeling of the magnetic signature of a ship seems to be well advanced.

3 MINEHUNTING SYSTEMS AND COMPONENTS

As noted earlier, the coverage of MCM systems was not nearly so broad or balanced as that for platforms and propulsions.

In minehunting, an important phase is the final step of disposing of a mine once it has been detected, located, and classified as a mine. Two papers (nos. 10 and 15) described wire guided, remotely controlled, small submersibles which approach very close to a mine and provide either TV or sonar images for positive identification. If the target is identified as a mine, an explosive charge is dropped adjacent to the mine (if the mine is lying on the ocean bottom), or an explosive cutter is attached to the mooring line (in the case of a buoyant mine). V. Gehrke (West Germany) described the PINGUIN B3 system, which will be used on the new German minehunter. The B3 vehicle is 3.5 m long, by 1.5 m wide, and 1.4 m high, and weighs 1350 kg. It carries two mine-destruction charges. The propulsion system includes conventional batteries, electric motors, and propellers. Duration between battery rechargings is about 60 minutes. Maximum operating depth is 100 m, and the tether cable is 600 m long. One of the most interesting parts of the presentation was a set of photographs of the sonar display showing high-resolution images of bottom targets. The sonar is a commercial unit made by UDI Group (Aberdeen). It is a single beam, mechanically scanning system with ranges up to about 20 m. It is a very inexpensive sonar. G. Bedeschi (Italy) described the MIN system which will be used on the Italian LERICI class ships. Perhaps the most unusual feature of the MIN is the propulsion system. It uses a pressurized oleopneumatic (oil and nitrogen) energy-storage arrangement which drives hydraulic motors for both main propulsion and thrusters. Maximum speed is 5 knots and the duration is 40 minutes at 3 knots. The time to recharge (pressurize) the oleopneumatic tanks is less than 15 minutes. The vehicle is designed to operate to depths of 200 m. It is 3.6 m long and 0.94 m in diameter, and weighs 1300 kg. At present MIN is undergoing evaluation by the Italian navy. The TV sensor is operational, and the sonar has been built but not yet installed.

M. Wolff (West Germany) described a small submersible minehunting system (not mine disposal), which uses the PINGUIN A1 vehicle (no. 15a). In this system the submersible carries a minehunting sonar, either of the ahead-scanning or side-scanning type, to search a channel and detect, locate, and classify mines for subsequent disposal by other means. Propulsion and sensor power, and control signals are transmitted down the tether cable, while sensor information and vehicle monitor signals are sent up the cable. In one configuration the A1 vehicle tows a small surface catamaran which contains a diesel-electric generator. Communication with the control ship is by radio link. In another version the tether cable goes directly from the A1 to the control ship. This minehunting system is in an early stage of development, and a decision on sonar sensors has not yet been made. Some tests have been made with a Klein side-scan sonar, and it is planned to install a modified version of the Krupp Atlas DSQS-11H sonar. The PINGUIN A1 submersible has dimensions of 3.7×1.0×2.0 m and weighs 2000 kg. The maximum depth is 200 m and maximum speed is 7 knots. Propulsion is by a single screw, and there are no provisions for hovering. The system concept is for a parent ship to control two or more submersibles.

W.H. Key (US) described a proposed minehunting system using commercial components, mostly those developed for offshore oil work (no. 9). He suggests the use of GRP craft of the 20-ton size, towed side-scan sonar, precise navigation equipment, and remotely operated vehicles. The role of such a system would be to conduct route surveys and to clear minefields in home waters. A commercial sub-bottom profiler is suggested for use in classifying bottom sediments but not for detection of buried mines. The concept proposed by Key is a craft-of-opportunity system.

Some minehunting sonars have transducers which can be operated in a position just beneath the hull or can be towed on the end of a flexible cable (variable depth soundhead or VDS). The soundhead is usually heavily weighed to minimize trail-back, and the shape of the body typically is spherical or cylindrical (for sonar design reasons). For ease of deployment and retrival and for hull-mounted operation, it is desirable to deploy the towed body through a well in the hull rather than over the stern or side. It is necessary to have good stability of the towed body at operational speeds. At speeds below about 5 knots, stability is not a serious problem but such is not the case for the higher speeds specified for some of the newer systems. The method of launching and recovery rules out the use of conventional rudder and elevator fins. In paper no. 25, T. Silvey (UK) discussed the work of Plessey Marine to develop a stable towed body of the type just described. Their program included analytical modeling, scale model tests, and full-scale tests at sea. The method they selected uses two vertical flat fins parallel to the cylindrical body but slightly offset. These fins are on the back side of the body and offset 45 degrees from the center line (direction of travel). Results indicate good stability in terms of yaw and swinging at speeds up to 11 knots. No pitch stability data were presented. A scale model of the system was on display.

Any modern minehunting system needs a means for integrating navigation, sonar, mine disposal, and ship control subsystems. In the UK this integration subsystem is designated Action Information Organization (AIO). A number of such systems have been developed in several countries, but they are all similar in concept and employ small computers. A typical system receives real-time inputs from navigation equipment, the minehunting sonar (range, bearing, and classification of targets), and the mine-disposal vehicle. The AIO plots (and displays) ship position and track and the locations of targets. The AIO also can include pre-planned ship tracks and historical target data (from earlier searches). Steering information is provided to the bridge or to an autopilot. Typically, data are displayed on a large CRT (for the operations officer) and are recorded on tape and perhaps on a hard-copy chart. I.S. Bogie (UK) described the Racal Minehunting Integrated Action Information and Navigation Systems (MAINS), which is similar in concept to the basic system just described (no. 12). MAINS is used on some of the UK MCMVs and by several other countries. G.T. Gerrero (UK) described a methodology for analyzing and designing an AIO for minehunting (no. 27). His company (CAP Scientific) together with Plessey Displays recently received the contract to design and build the AIO for the SRMH.

There was only one paper (no. 26) on mines, and it dealt with an exercise mine. C.R. Pegrum (UK) described the British Aerospace Versatile Exercise Mine System (VEMS), a recent and successful development of a mine-like device which can be used for evaluation and training for influence sweeping and hunting. It is a bottom-resting "mine" which can simulate a wide variety of magnetic, acoustic, and pressure mine mechanisms. Actuation data are recorded, and the distance from the VEMS to the ship is measured at the time of actuation. VEMS will be in production soon. The paper gave no details on the sensors or on the signal processing available.

As noted, most of the papers dealt with specific types of platforms and equipment. One exception was a paper by

Ma Jinhua (China), which gave a theoretical treatment of the bending movement for ships subjected to underwater explosions (no. 8).

APPENDIX: TITLES AND AUTHORS OF PAPERS

1. "Mine Warfare Vessels and Systems," by R.J. Daniel, British Shipbuilders, UK.

2. "Experience With the Design of MCM Vessels," by E.C. Pitts and A.L. Dorey, Ministry of Defence and Vosper Thornycroft (UK) Ltd.

3. "Swedish Development of MCMV-Hull Design and Production," by J. Sjogron, C.G. Celsing, K.A. Olsson, C.G. Levander, and S.E. Hellbratt, Naval Material Dept., R. Inst. of Techn. and Karlskrona Shipyard, Sweden.

4. "The RAN GRP Minehunter--A Status Report," by B.L. Robson, Dept. of Defence, Australia.

5. "Triparitite MCMV," by W.P.J. Laros, Van der Giessen de Noord, Netherlands.

6. "Hydrodynamic Investigations of a Mine Hunter Project," by C.G. Kallstrom and H.P. Loid, Swedish Maritime Research Center, SSPA, Sweden.

7. "Design Considerations for a Ship Manoeuvring System as Applied to Mine Warfare Operational Requirements," by C.M. Aker, Omnithruster Inc., US.

8. "Estimation of Dynamic Bending Moment for Ships Subjected to Underwater Non-contact Explosions," by Chinese Society of Naval Architecture and Marine Engineering, People's Republic of China.

9. "20 Meter Coastal Minehunter With Mine Sonar and Remote Control Vehicle Capabilities," by W.H. Key, Klein Associates Inc., US.

10. "Mine Identification and Neutralisaton System Developed by the SMIN Consortium," by A. Ortelli and C. Muia, Italy.

11. "Propulsion Control of Mine Countermeasures Vessels," by A.J. Carran, Hawker Siddeley Dynamics Engineering Ltd., UK.

12. "Minehunting Integrated Action Information and Navigation Systems," by I.S. Bogie, Racal-SMS Ltd., UK.

13. "Hull Construction of MCMVs in the United Kingdom," by D.W. Chalmers, Ministry of Defence, UK; R.J. Osborn and A. Bunny, Vosper Thornycroft (UK) Ltd.

14. "Aspects of Material Selection for MCMV Hulls," by H. Schutz, Federal Office for Military Technology and Procurement, Koblenz, West Germany.

15. and 15a. "The PINGUIN B3 and PINGUIN A1 Remotely Piloted Vehicles For Mine Identification and Disposal," by V. Gehrke, M.B.B.; and M. Wolff, Ministry of Defense, West Germany.

16. "The Development of Minesweeping Systems for Finnish Waters," by O. Ostring, Valmetin Laivateollisuus Oy, and P. Pylkkanen, Oy Fiskars Ab Elesco, Finland.

17. "Monocoque GRP Minehunters," by M. Trimming, Intermarine, Italy.

18. "The BH7 MK.20 Amphibious Hovercraft in the MCM Role," by R.L. Wheeler, British Hovercraft Corporation Ltd., UK.

19. "The Application of Air Cushion Technology to Mine Countermeasures in the United States of America," by J.B. Chaplin, Bell Aerospace Textron, US.

20. "Arapaho--Applications to Mine Warfare," by G.W. Fromknecht, ORI Inc., US.

21. "An Auxiliary Propulsion Unit for Minehunters," by A. Ortelli and S. Ghignone, Riva Calzoni SpA, Italy.

22. "Rudderpropellers for Propulsion and Manoeuvring Systems of Minehunting Vessels," by O. Bussemaker, Schottel-Nederland B.V., Netherlands.

23. Paper withdrawn.

24. "Degaussing for Mine Countermeasures," by M.E. Hemming, Marconi Radar Systems Ltd., UK.

25. "Hydrodynamics of Variable Depth Minehunting Sonar Towed Bodies," by T. Silvey, Plessey Electronic Systems Ltd., UK.

26. "The Versatile Exercise Mine System (VEMS)," by C.R. Pegrum, British Aerospace, UK.

27. "Function Analysis of Minehunting Weapon Systems," by G.T. Ferrero, CAP Scientific, UK.

28. "Diesel Engines for Mine Warfare Vessels," by R. Deutschle and C. Guenther, M.T.U., West Germany.

29. "Engines for Mine Counter Measures Vessels," by R.V. Hughes and M.F. Clover, Paxman Diesels Ltd., UK.