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19TH ANNUAL TECHNICAL SYMPOSIUM 1982

ASSOCIATION OF SCIENTISTS AND ENGINEERS OF THE NAVAL SEA SYSTEMS COMMAND
DEPARTMENT OF THE NAVY – WASHINGTON, D.C. 20360

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IN THE CONTRACT DESIGN EVALUATION OF A SALVAGE SHIP

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April, 1982

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ABSTRACT

This paper describes the use of a maneuvering simulation in the evaluation of a vessel's performance during the design stage. The specific case investigated is the new U. S. Navy Rescue Salvage Ship ARS-50. The objective of the simulation program was to verify the acceptability of the vessel's maneuvering performance in a wide range of missions. The Ship Maneuvering Simulator at Hydronautics, Incorporated was used; this simulator has relatively simple equipment and displays, coupled to very complete mathematical models.

Required ship missions were reviewed, and a group of representative scenarios was developed for evaluation purposes. These included open-water maneuvers, maneuvers around docks and piers, approach and station-keeping on a stranded vessel in shallow water, approach to a drifting vessel and towing of a disabled vessel.

The simulations were carried out by experienced Naval Officers with service on ARS-Class vessels and knowledge of the maneuvering and performance requirements of such vessels. The Officers evaluated the performance of the ARS-50 on its ability to carry out the required missions and its performance relative to existing vessels. The maneuvering performance of the ARS-50 was found to be acceptable and recommendations were made relative to some modification of the ship control system.

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ABSTRACT

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INTRODUCTION

The Naval Sea System Command, NAVSEA, has designed a new salvage vessel, the ARS-50 Class, to replace existing vessels that have been in service for many years. The missions of a salvage ship require good maneuvering performance at low speeds over a range of environmental conditions as well as the ability to tow large vessels. It is very difficult to define meaningful quantitative measures of maneuvering performances (such as tactical diameter, stopping distance, etc.) for these types of missions. During the ship design process, desired values of some parameters related to maneuvering performance were developed and used. These were based on experience with existing vessels of similar type (for example required Bollard thrust). Because of the importance of maneuvering performance in the salvage missions, it was considered desirable to obtain a further verification of the acceptability of the maneuvering performance of the ship as designed. The method chosen to do this was a series of real-time simulations of typical missions.

The Hull Form and Fluid Dynamics Branch of NAVSEA (SEA 3213) authorized HYDRONAUTICS, Incorporated to conduct an evaluation of the maneuvering performance of the Salvage Ship (ARS-50) using a program of real-time maneuvering simulations on the HYDRONAUTICS Ship Maneuvering Simulator. These simulations were carried out by Naval Officers with operational experience in similar types of ships. The objectives of this effort were to obtain an evaluation of the maneuvering performance of the ARS-50 relative to the missions to be performed, to develop a preliminary understanding of any unusual operating procedures required by the vessel's maneuvering characteristics, and to obtain guidance in formulating quantitative measures of maneuvering performance that could be used in future designs of similar vessels. A secondary objective was to develop a better understanding of how to use real-time maneuvering simulation in the design process.

This paper describes the evaluation procedures used, the ship simulator and designed ship characteristics, and presents typical results.

EVALUATION PROCEDURE

Because of the complex maneuvers a salvage vessel must perform, it is difficult to define meaningful quantitative measures of maneuvering performance against which a new design can be evaluated. It is, however, possible to define typical mission scenarios which the ship must be able to carry out (for example approach and hold station on a stranded vessel in a given wind and current). As a result, real time simulations using these typical mission scenarios provide a means of evaluating the maneuvering performance. This approach was adopted for the contract design phase evaluation of the maneuvering performance of the ARS-50.

The Ship Maneuvering Simulator at HYDRONAUTICS, Incorporated, which is described in the next section of this paper, was programmed to represent the ARS-50. Typical operations that the ship was expected to be able to perform were defined in the top-level requirements for the design. These were developed into a series of operational scenarios and programmed into the simulator. These scenarios are described in more detail in later sections of the paper.

In order to obtain as realistic an evaluation of the ARS-50 maneuvering performance as possible, four experienced Naval Officers carried out the simulations and evaluated the results. These Officers were all experienced with salvage ship operations.

At the start of the simulation program, these Officers were briefed on the objectives of the program, the evaluation procedures to be used and on the general characteristics of the ARS-50. A series of typical operational scenarios were available for use. The Officers selected the scenarios they wished to run and the environmetnal conditions (wind, current, waves) to be used. Before each simulation run a simulation plan was prepared which defined the initial and environmental conditions, and the type and objective of the maneuver to be performed. At the conclusion of each run, or series of runs, an evaluation form was completed; on this form the Officers were asked to provide an evaluation of the ARS-50's ability to perform the particular mission and to compare its performance with existing vessels.

The evaluation of the maneuvering performance of the design was then based on results from each scenario. Recommendations were prepared based on the evaluations.

SIMULATOR CHARACTERISTICS

The real time simulations were carried out on the Ship Maneuvering Simulator at HYDRONAUTICS, Incorporated. Figure 1 presents a view of the Bridge of the simulator. In addition to the steering stand, the operators had a ship-control display, a radar display and an out-of-the-window visual scene display for use in control of the simulation. Typical examples of these displays are presented in Figures 2, 3, and 4. The ship-control and radar displays were updated every 8 seconds during the simulation. The visual scene display, although presented on a single CRT monitor was equipped with a feature which allowed the viewing angle to be adjusted as desired. This allowed, for example, the position of a ship astern of the ARS to be viewed. The simulator bridge was not a mock-up of the actual ARS-50 bridge arrangement. The operators were provided with the same type of information that will be available on the ARS-50.

The simulation was run on a PDP 11-34 computer. The simulation programs allow the simulation of a vessel in all modes of motion including ahead and astern at low speed under various wind, current and wave environments. Because of the importance of maneuvering performance, extensive model tests were carried out to determine the hydrodynamic coefficients of the ARS-50 for use in the simulations. These tests included complete Large Amplitude Horizontal Planar Motion Mechanism (LAHPMM) tests with a large (16 ft) propelled model in both deep and shallow water. These tests were conducted in the HYDRONAUTICS Ship Model Basin, HSMB, and the results are reported in Reference 1 along with the resulting hydrodynamic coefficients, equations of motion and the results of simulations of definitive maneuvers.

In addition, a complete simulation of a second vessel operating in the same environment could be run simultaneously with the ARS-50 simulation. This allowed simulations of the ARS approaching a drifting vessel as well as simulations of the ARS towing the second vessel. In a towing simulation, the dynamics of the tow cable were simulated and the tow line tension was displayed to the operators.

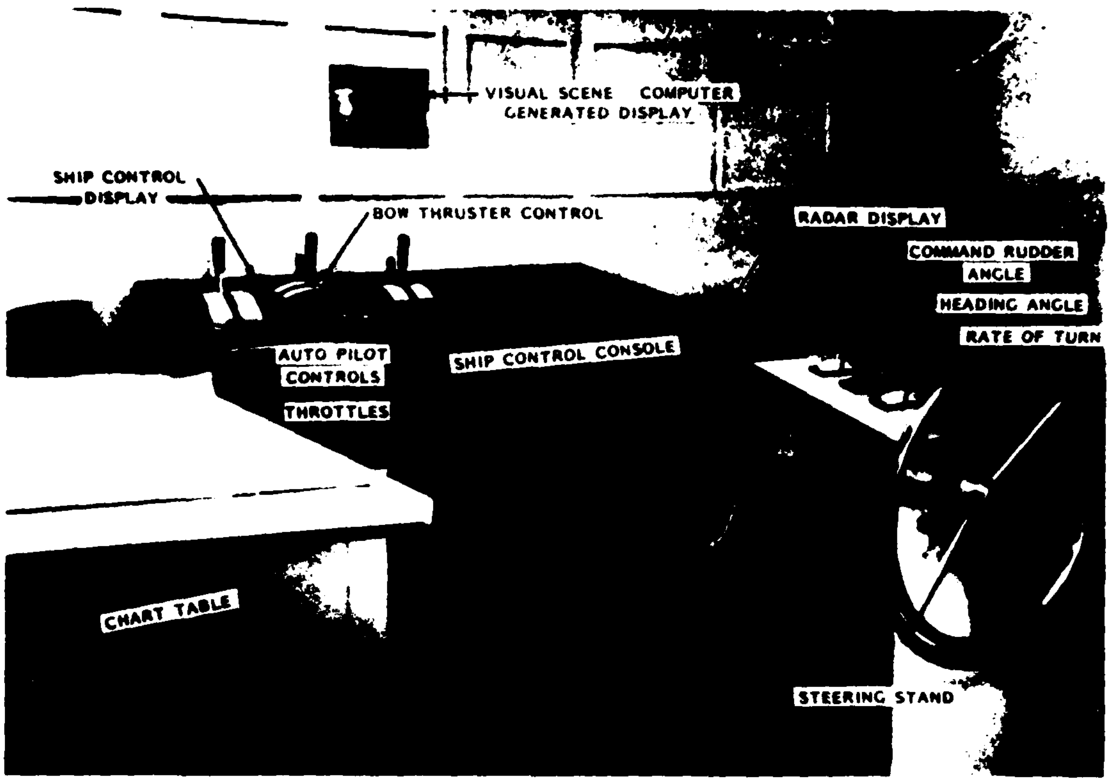

Figure 1. Bridge of Ship Maneuvering System

At the time, the simulation system did not have the capability of simulating the actual response of the diesel engine-CRP propeller system of the actual ARS-50. The response of the actual propulsion system was represented by an equivalent fixed pitch propeller system with response of 3.5 RPM/sec to a change in throttle position. In fact, the ARS propulsion system should be able to respond more quickly than this.

SHIP CHARACTERISTICS

The ARS-50 is a modern salvage ship designed to satisfy the various mission requirements of a naval salvage vessel. The basic characteristics of the ARS-50 design are presented in Table 1. An outboard Profile of the vessel is presented in Figure 5.

TABLE 1. CHARACTERISTICS OF ARS-50 DESIGN

Length LWL	239.7 ft	(73.021 M)
Length LBP	240.0 ft	(73.152 M)
Beam @ Ax (MLD)	51.00 ft	(15.545 M)
Draft @ Ax (MLD)	15.5 ft	(4.724)
Displacement	2864.0 LT	(2910.1 MT)
Trim		
1 CRP Propellers in Kort Nozzle Dia.	9.925 ft	(3.025 M)
Installed SHP	4200	
Bow Thruster HP	500	

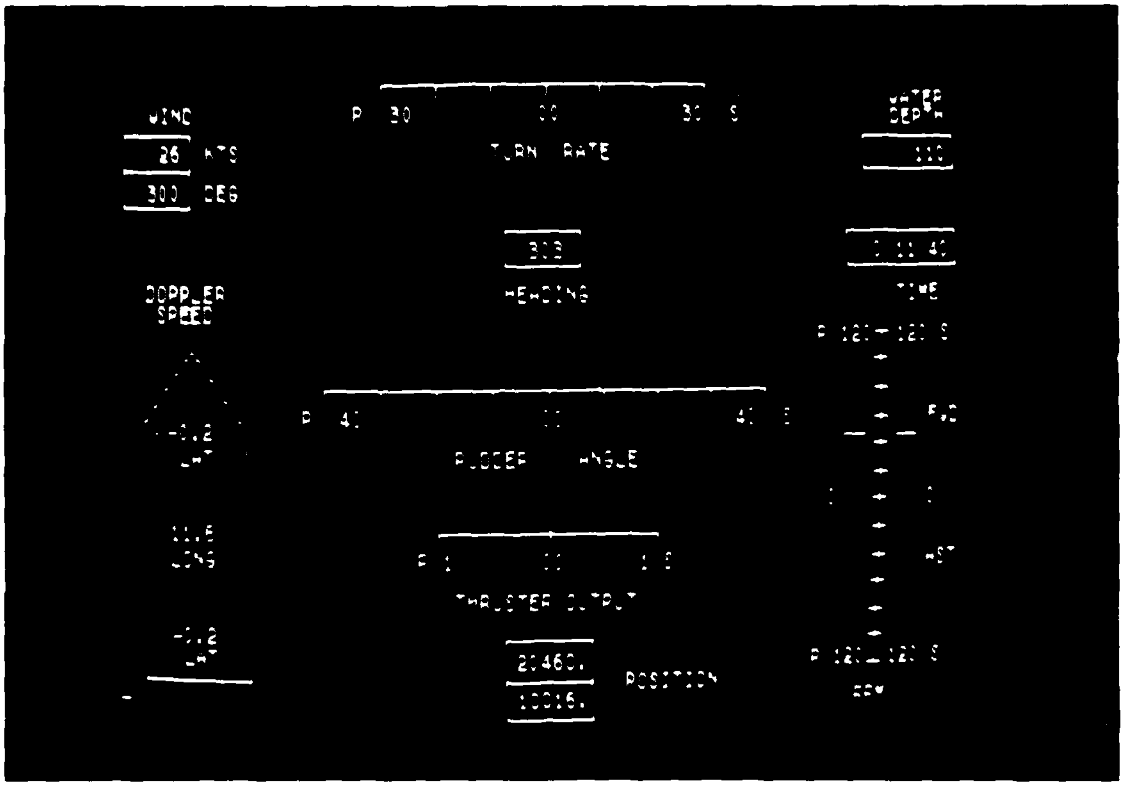

Figure 2. Computer Generated Ship Control Display

EVALUATION SCENARIOS

Based on the mission of the ARS-50 a series of five scenarios were selected to represent the types of operations which could be expected. These scenarios were: (1) Open Water, (2) Harbor with Piers, (3) Stranded Vessel in Shallow Water, (4) Drifting Vessel in Open Water and (5) Towing in Open Water. These scenarios are described in more detail as follows.

Open Water. In this scenario open water of unlimited extent was represented. Wind, waves and current could be applied from any direction and with the desired magnitude. This scenario was intended for initial runs to allow the officers to become familiar with the simulator and the basic handling qualities of the ARS-50.

Harbor with Piers. This scenario provided a harbor situation with piers. A chart of the scenario is provided in Figure 6. Current could be imposed parallel to the shoreline and wind could be imposed from any direction. This scenario was used to evaluate the ability to maneuver in confined waters and to approach and depart from piers. This scenario could be run with deep or shallow water.

Stranded Vessel. The ARS-50 will be required to approach and hold station on a vessel stranded in shallow water so that cables and equipment can be passed; this scenario represents such a situation. Shallow water with a depth of 1.2 times draft of the ARS-50 is used. The current velocity varies with position in the area of the stranded vessel. The velocity vectors are shown in Figure 7 which is the chart for this scenario.

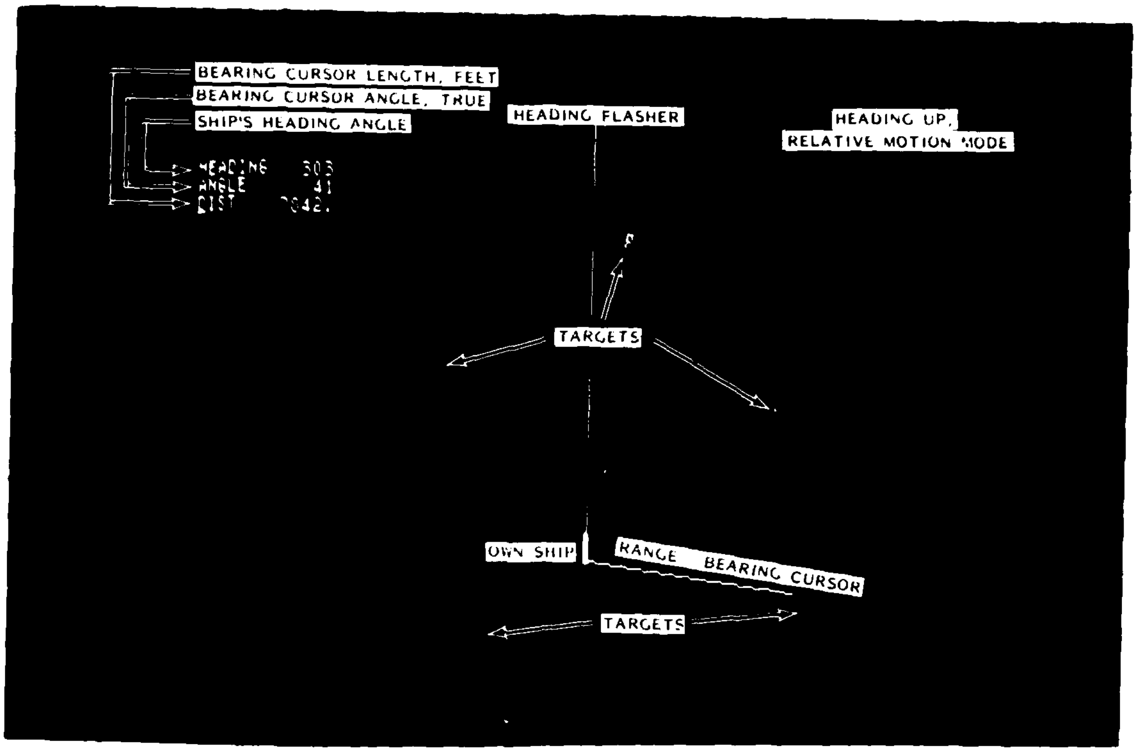

Figure 3. Computer Generated Radar Display

Drifting Vessel in Open Water. In this scenario a large vessel is allowed to drift under the influence of wind, waves and current and the ARS-50 is required to maneuver into a position to pass a tow wire. A vessel of the A0-177 Class was used as the drifting vessel. The magnitude of wind, waves and current could be varied as desired.

Towing in Open Water. This scenario is an extension of the above scenario in which the ARS-50 is connected to the drifting vessel with a 2¼ inch towing wire of specified length. The objective is to check the drift of the vessel and get it underway and under control. Both a vessel of the A0-177 Class and a typical 80,000 DWT tanker in full load condition were used as the towed vessels. The magnitude of wind, waves and currents could be varied as desired.

TYPICAL RESULTS

The performance of the ARS-50 in the evaluation scenarios was used to judge the acceptability of its maneuvering capabilities. Approximately 25 simulation runs were carried out over a four day period. Typical results from the evaluation scenarios were as follows.

Open Water. The operators who carried out the simulations used the time to carry out a 360 degree standing turn as a comparative measure of maneuverability for salvage vessels. This maneuver was carried out from zeor speed with full differential thrust, full rudder angle and full bow thruster power. When using the bow thruster, it was found that the ARS-50 could turn 360 degrees in the same time as the existing smaller vessels.

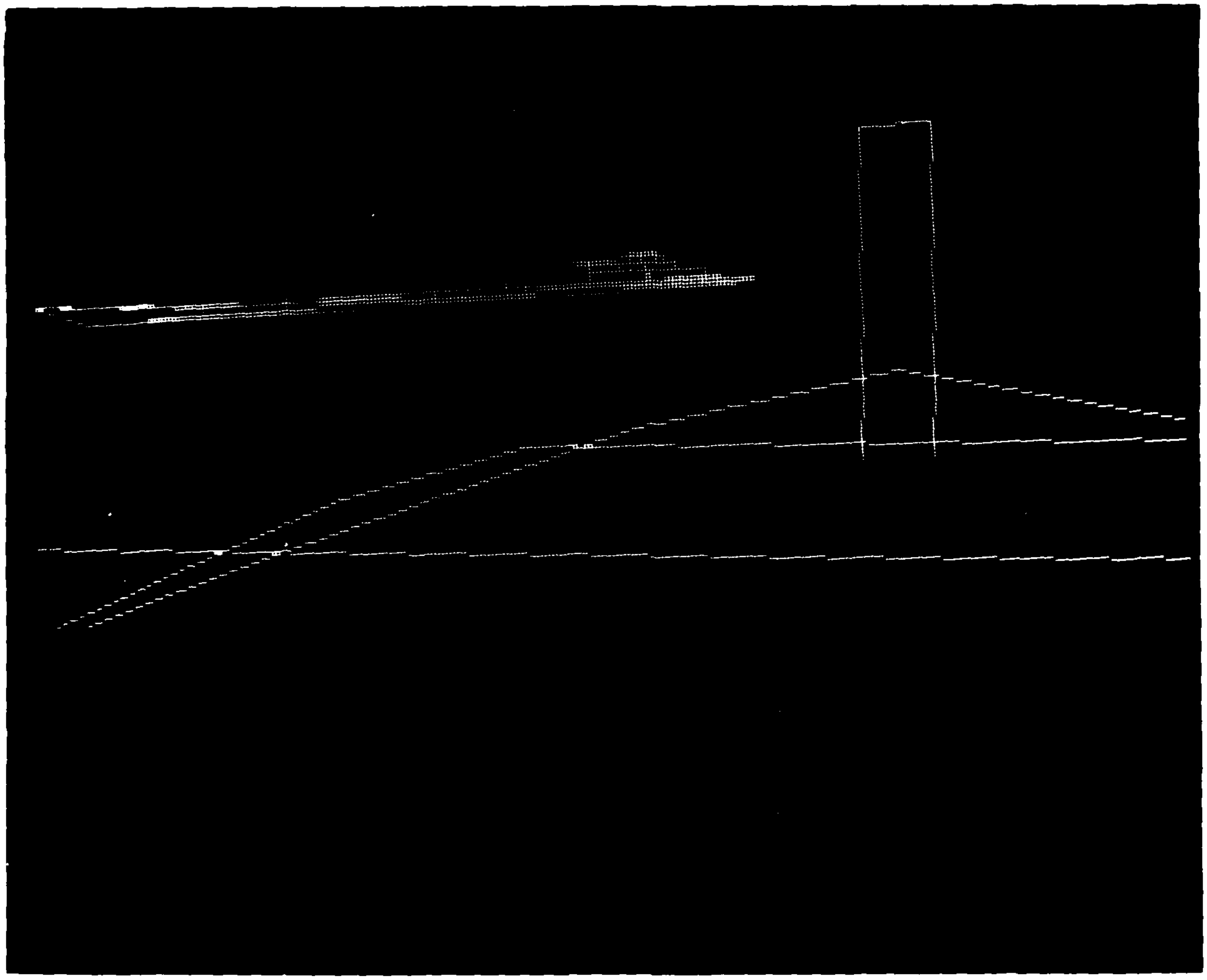

Figure 4. Computer Generated Visual Display

During both the open water maneuvers, and maneuvers in the other scenarios, the operators all noted that the ARS-50 seemed less responsive at a given Engine Order Bell setting than the existing ARS-38 Class. It was later determined that a given Engine Order Bell setting on the ARS-38 provided a significantly higher percentage of the available power than a similar setting on the ARS-50. As a result, the power at a given engine order bell setting will be increased on the ARS-50. Because of this change, and as a result of questions about the actual machinery response, additional real time simulation runs will be made. In these simulations the CRP propellers and machinery dynamics will be modeled in detail.

Harbor with Piers. Most maneuvers with this scenario were carried out in shallow water (depth equal to 1.2 times draft). In general the ARS-50 was able to successfully carry out the maneuvers attempted. It was, for example, possible to work the vessel up to the "T" pier against a 20 knot wind using the bow thruster, rudders and differential thrust. Figure 8 shows the tracks for this maneuver. It was not possible to work the vessel up the finger pier against a 2/3 knot current. It should be noted that in such shallow water the current forces are significantly larger than in slightly deeper waters and that this effect may cloud comparison with other vessels.

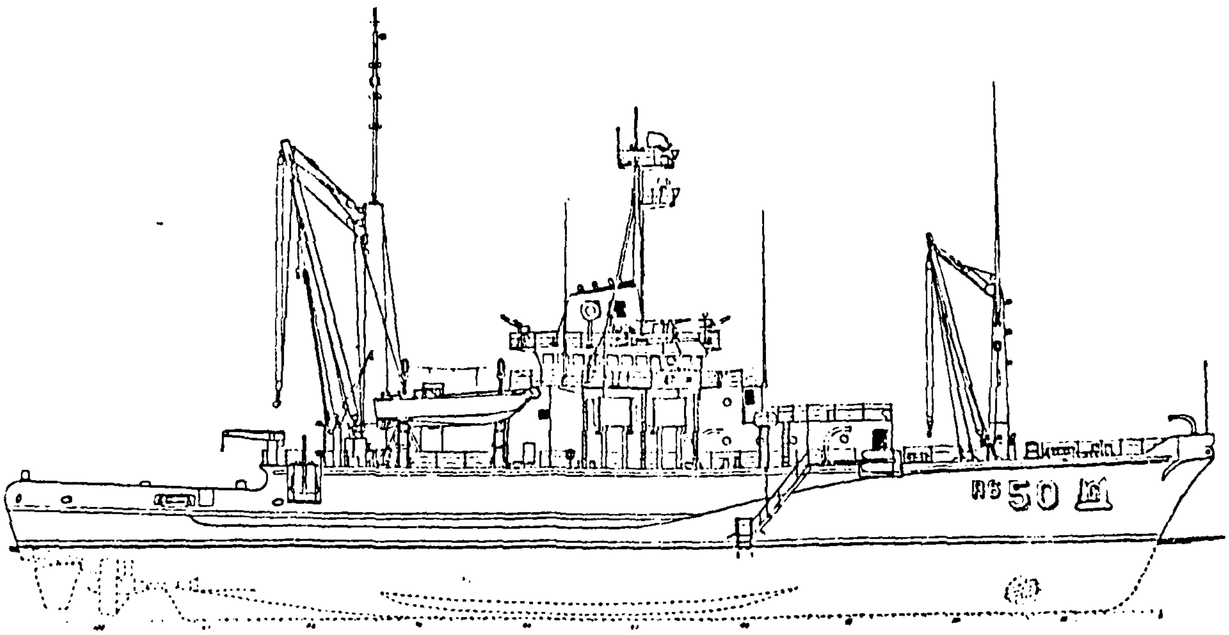

Figure 5. Outboard Profile of ARS-50

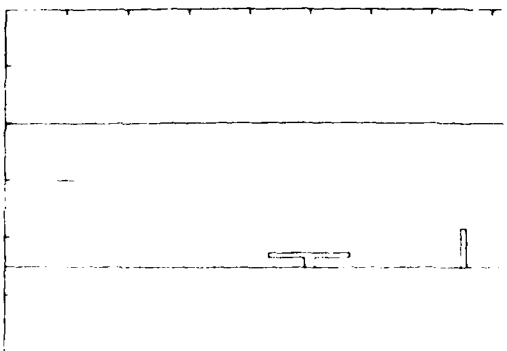

Figure 6. Harbor with Piers

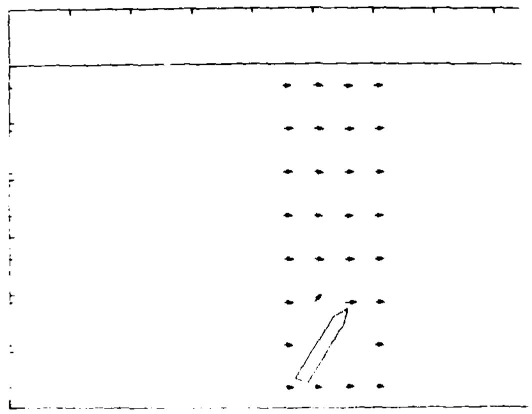

Figure 7. Velocity Vectors

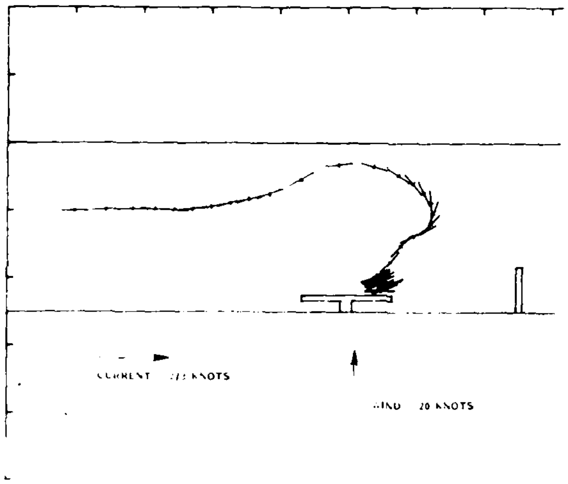

Figure 8. Track of ARS-50 During Approach to "T" Pier

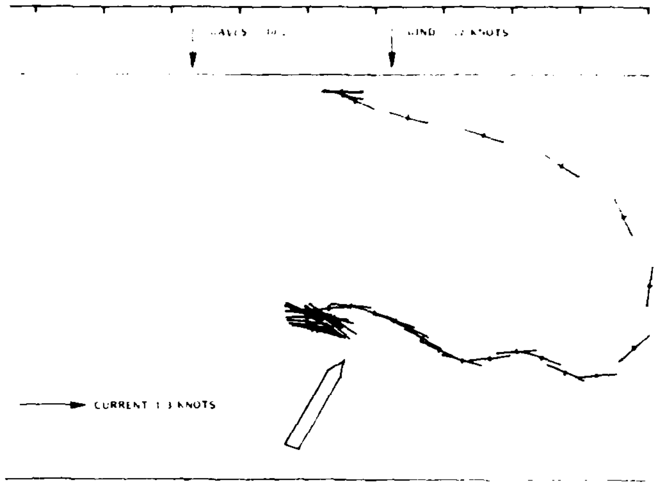

Figure 9. Track of ARS-50 During Approach to Stranded Vessel

Several backing and control maneuvers were carried out in deep water. The conclusion was that the performance was acceptable and as good as that of the ARS-38 when the bow thruster was used.

Stranded Vessel. In ths scenario, maneuvers were carried out to simulate the laying of beaching gear and holding position near the stranded vessel to allow the passing of the bullrope. In most cases the wind and waves were toward the beach and the current along the beach. The ARS-50 was able to complete the maneuvers attempted and the performance was considered adequate. A track plot from a typical maneuver is shown in Figure 9. Some of the evaluators rated the ARS-50 as better than the ARS-38 and the ATS in this scenario and some rated it as worse. The best feature of the ARS-50 was considered to be the bow thruster and its effect on the maneuvers that could be performed. It was also noted that current had a very significant effect on the ARS-50. This is to be expected in the shallow water condition being simulated.

Approach to Drifting Vessel and Towing. The scenarios requiring the approach to a drifting vessel and then getting the drifting vessel underway by towing were combined. In all cases the ARS-50 was able to approach and hold station on the drifting vessel. The ARS-50 was able to control the drifting vessel and get it turned and underway in the range of environmental conditions used. Both the AO-177 Class vessel (displacement 27,000 tons) and a loaded 80,000 DWT tanker were used as the drifting vessels. The towing speeds for these two vessels were determined for a range of environmental conditions. The results are shown in Figure 10. All of the evaluators felt that the ARS-50 should have more power to be better able to handle large vessels in the limiting environmental conditions.

CONCLUSIONS

It was felt by the design project personnel at NAVSEA that the technique of obtaining evaluations of the maneuvering performance of a proposed design from exerienced Naval Officers by means of real-time simulations worked well. Excellent cooperation was obtained from the Officers involved. In order to be of most value, the simulations should be carried out as early in the design cycle as possible so that feedback from the evaluation can be used in the design with minimum impact. This is now being done in a program of real-time simulations involving a mine countermeasure vessel.

With respect to the ARS-50 design, the following conclusions were developed as a result of the simulations.

- The overall maneuvering performance of the ARS-50 is considered to be acceptable. It was possible to carry out almost all of the maneuvers attempted. The ARS-50 is as agile as the existing ARS-38 Class as long as the bow thruster is used.

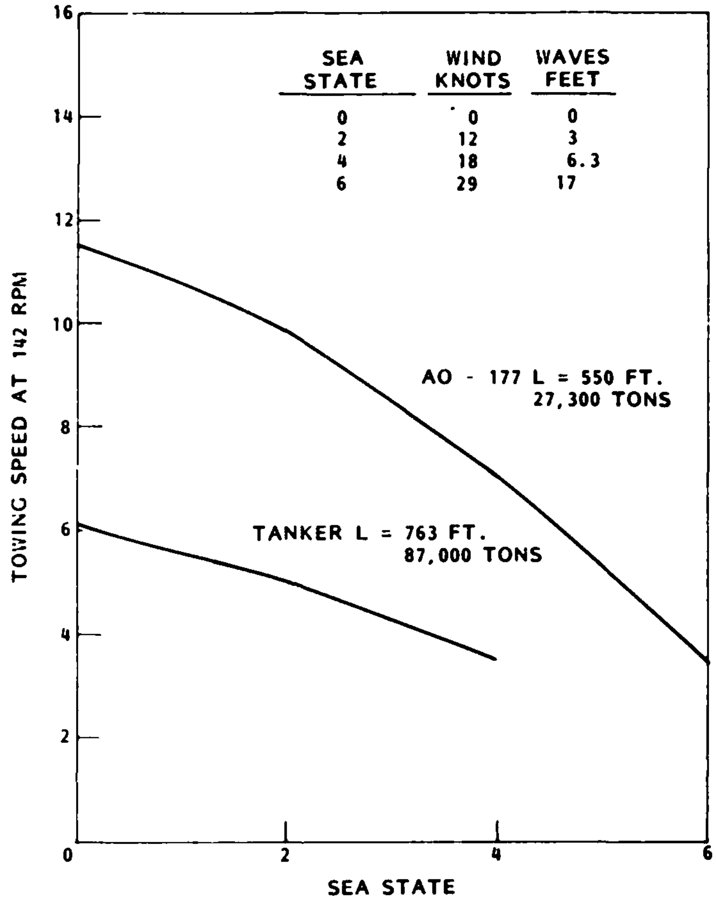

Figure 10. Steady Towing Speed vs. Environmental Conditions

- The bow thruster is very useful and is considered essential in making the maneuvering performance of the ARS-50 acceptable.

- The Engine Order Bell settings of the ARS-50 should be adjusted to provide more power at a given setting so that ship response will be more consistent with the existing ARS-38 Class. Additional simulations, using a detailed simulation of the CRP propeller system and diesel engine, will be carried out to confirm that the response is as expected.

- The ARS-50 was able to carry out the towing missions in the scenarios used. The evaluators felt that more power would be desirable to tow large vessels in limiting environmenal conditions. This was considered early in the design and the installed power was selected based on tradeoffs between ship size, ship cost, towing performance and free route speed.

With respect to the simulator system used, the following observations were made:

- The simulator was able to model all of the complex maneuvers required for the evaluation of a salvage vessel including the towing of a disabled vessel.

- The operators found the relatively simple displays used on the bridge mockup to be acceptable. The only problem was the relatively slow 8-second update of some of the ship control parameters such as engine RPM on the computer-generated CRT display. The simulator has since been modified to display these ship control parameters on conventional analog devices updated each time step in the simulation.

REFERENCES

1. Ankudinov, Lee, and Hatton, "Salvage Ship (ARS-50) Contract Design Deep and Shallow Water Maneuvering Model Tests and Simulations," NAVSEA Report 3213-80-17, September 1980.