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Evaluation of New Approaches to the Containment and Recovery of Oil in Fast Water

FINAL REPORT
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Prepared for:

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United States Coast Guard
Marine Safety and Environmental Protection (G-M)
Washington, DC 20593-0001

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16. Abstract (MAXIMUM 200 WORDS)

This report describes the efforts to identify and close performance gaps for containing and recovering oil spills in fast water areas. An initial assessment indicated that little was being done in fast water environments because the technology and training were limited. An evaluation and development program was initiated to identify and test potential equipment to be used in currents greater than one knot.

Tests were conducted at Ohmsett, the National Oil Spill Response Facility, and promising equipment was demonstrated in field tests on both coasts of the United States. As a result of the tests at Ohmsett, changes were made that improved the performance of several existing systems and prototype equipment was developed that appear to be useful in fast currents. It was determined that two pieces of equipment that were demonstrated in the field, the Boom Vane and Boom Deflectors, can enhance the oil recovery performance of booms in fast water conditions.

Information about fast water response techniques also has been gathered within the fast water project and included in a fast water field guide. Recommendations are provided in this report to integrate the information gathered, ensure the best use of response equipment, and review existing regulations and procedures for fast water requirements.

17. Key Words

fast water	oil boom	VOSS
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EXECUTIVE SUMMARY

This report describes the efforts of the U.S. Coast Guard Research and Development Center to identify performance gaps for responses to oil spills in currents over one knot and to identify potential equipment and techniques to close these gaps. An initial assessment indicated potential improvements to fast water containment and recovery were possible because the existing present technology and training were limited (Coe and Gurr, 1999). This assessment also reported that the threat was real because between 1992 and 1997, 58 percent of all oil spills occurred on waterways with currents that routinely exceeded one knot. Potential equipment and techniques were demonstrated in the field on both coasts of the U.S. and tested at Ohmsett, the National Oil Spill Response Facility.

Two pieces of equipment that were demonstrated in the field, the Boom Vane and Boom Deflectors, can enhance the oil recovery performance of booms in fast water conditions. Both systems reduce the amount of rigging hardware required to deflect oil towards the shore for recovery or away from sensitive areas. Both systems perform best in steady currents. The Boom Vane is especially useful when a boat is not available to deploy anchors out in the current. The District Response Assist Team (DRAT) from both USCG District 1 and District 13 each has one vane in its inventory and has been using them during exercises.

The assessment report (Coe and Gurr, 1999) specifically identified three systems that had been developed for fast currents but had never been tested with oil. The Vikoma Fasflo from England, the High Speed Circus from Finland, and the Current Buster from Norway were tested at Ohmsett. To ensure that the tests were consistent, a fast-current testing protocol was developed using the USCG High Speed Skimmer (HSS) and all four systems were tested in the summer of 2000 using the protocol. The tests indicated that all of the systems can efficiently collect oil in two knots of current. The two larger systems, the HSS and the Current Buster, can work effectively up to 3.5 knots in the absence of waves. The HSS was able to recover some oil up to five knots. Although the size of the Current Buster did not permit tow speeds over 3.5 knots, the trends indicate that it can efficiently recover oil at higher speeds. All of the systems are small enough to be deployed from vessels, although some heavy lifting and rigging may be required. All of the skimmers were affected by the flow created by the lead-in booms.

Another series of tests was conducted during the summer of 2000 at Ohmsett in order to increase the state-of-the-art in fast water response. The systems were selected from proposals in response to a Broad Agency Announcement (BAA) seeking improvements to containment and recovery capabilities in currents from three to five knots. The systems included USCG HSS (JBF DIP600) Design Modifications, Towing Forces on Fast Water Diversion Booms, Flow Diverters, Floating Oil Sorbent Recovery Systems, and a Zero Relative Velocity (ZRV) Rope Mop Skimming System (Stream Stripper). Improvements have been made in the HSS that increase Throughput Efficiency (TE) to over 60 percent at three knots and over 35 percent at four knots. A simple equation was developed for use in stationary or advancing deflection booms that requires that the user know only the current velocity and the projected area of the boom. The prototype flow diverters can help to deflect oil up to 19 feet to one side. Use of sheet sorbent booms can be more effective and may be easier to handle for sheen spills than conventional sorbent booms. The Stream Stripper TE performance exceeded 80 percent at two knots and over 60 percent at three knots.

An effort was made to adapt the submergence plane concept to the USCG Spilled Oil Recovery System (SORS) and Vessel of Opportunity Skimming System (VOSS). A redesign of the system was needed because of the tendency for the plane to rise out of the water at higher speeds; a half-scale model was built and tested at Ohmsett. Recovery efficiency was over 60 percent at 2.8 knots and over 30 percent at 4.2 knots. This could help buoy tenders maneuver more easily. The system, however, does not appear to collect light oil very well; therefore, additional work is needed so that a full range of oils can be recovered. In addition, the submergence plane configuration does not perform well in low speeds. Sufficient flow to drive the oil down the plane is not created at speeds less than one knot.

A fast water guide, "Oil Spill Response in Fast Currents, A Field Guide," was developed during this project. This guide can be used in conjunction with equipment evaluations to develop a systematic approach to responding to oil spills in fast waters. This guide brings together all of the information needed for fast water response and will assist CG and commercial responders to plan, train for and execute safe and efficient responses.

Steps that should be taken to ensure that equipment is in the right place and can perform the required tasks are:

- Encourage the use of equipment such as the Boom Vane, Boom Deflectors, and Flow Diverters in areas where high-speed currents are always present. These systems should be stored downstream in an easily accessible area where trained crews can quickly deploy them.

- Include fast water response techniques in the regulations for facilities and Oil Spill Response Organizations (OSRO). The definition of fast water areas can be taken from current tables, actual data, or the analysis conducted in Coe and Gurr (1999). The OSRO would meet requirements if it had small draft boom and contingency plans that indicate knowledge of fast water response techniques. Fast water exercises should be periodically conducted.

- Evaluate the performance and location of CG VOSS and SORS systems in fast water areas. This includes the time to deploy and the recovery performance. Locate the HSS where it will be the most useful. A risk-based assessment could provide some guidance in lieu of actual exercises.

- Disseminate the information in the field guide, “Oil Spill Response in Fast Currents, a Field Guide.” Cooperate with the U.S. Environmental Protection Agency and inland responders to keep the guide up-to-date. Work with area committees, Marine Safety Offices and possibly American Society for Testing and Materials (ASTM) committee F-20 (hazardous substances and oil spill response).

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INTRODUCTION

The United States Congress passed the Oil Pollution Act (OPA) of 1990 that redirected oil response efforts to ensure that a future spill the size of the Exxon Valdez could be contained and cleaned up. One area that was not addressed specifically by this legislation, nor in any other regulation, was emergency response to oil spills in fast currents. As a result, little had been done to adequately address equipment and training needed to perform containment and recovery of oil in currents greater than one knot. In 1997, the U.S. Coast Guard R&D Center began a project to identify and close any performance gaps within the Coast Guard and the response industry for response in fast currents.

The project's goals were to provide information on deployment strategies and techniques, and to identify equipment that could improve recovery capabilities in situations where existing systems do not work well. An initial assessment was conducted and included threat evaluation, equipment capabilities, strategy identification, and techniques and training issues. This assessment culminated in "Control of Oil Spills in High Speed Currents, A Technology Assessment," a report published in 1999 (Coe and Gurr, 1999). The conclusions from that report were:

- Fast water oil spill threats are significant. Between 1992 and 1997, 69 percent of transported oil was moved on waterways that routinely exceed one knot. During this same period, 58 percent of all oil spills occurred in these same waterways. This represents a total of 4.5 million gallons of oil.

- There are benefits to fast water containment and recovery. In the absence of a response, more shoreline may be contaminated or the oil may mix in the water column and be deposited on the bottom of a waterway. Oil on the shoreline or the bottom of a waterway increases the environmental damage and cleanup costs.

- Present capabilities are limited. Some of the existing containment and recovery systems can be utilized in currents up to three knots, but only if used correctly. Very little equipment is effective in currents above three knots.

- Fast water technology is limited. Very little work has been done in the past 20 years to increase the technology needed to contain and recover oil in fast currents.

- Fast water response training is limited. Responders have limited opportunity to learn how to apply fast water response technology. As a result, techniques are not implemented correctly.

- Regulations and guidelines ignore fast water considerations. Fast water is not listed as a factor in response capabilities or in training, and there are no incentives for manufacturers to develop equipment for fast water conditions

As a result of these conclusions, the fast water project accomplished the following efforts:

- Field Demonstrations: Demonstrated potentially useful equipment in actual field scenarios.

- Technology Development: Identified potentially useful equipment that had never been evaluated or taken past the prototype stage. These systems were tested at Ohmsett, the National Oil Spill Test Facility in Leonardo, New Jersey that is run by the Minerals Management Service (MMS).

- Training Initiatives: Developed a response guide that can be used for training and during response to an oil spill.

This current report will describe the efforts and provide new information that has not been contained in any previous official report, as well as utilizing information contained in public literature (See Table 1).

Table 1. Publications.

Hansen, K. A. (2001a). "Development of a Fast Water Field Guide," Proceedings of the Twenty-fourth Arctic and Marine Oil Spill Program (AMOP) Technical Seminar, Environmental Canada, Ottawa, ON, pp. 237-250.
Hansen, K. A. (2001b). "Evaluation Fast water Oil Recovery Equipment," Proceedings of the Twenty-fourth Arctic and Marine Oil Spill Program (AMOP) Technical Seminar, Environmental Canada, Ottawa, ON, pp. 251-274.
Hansen, K. A. (2001c). "Fastwater Techniques and Equipment Evaluation," Proceedings of 2001 International Oil Spill Conference, Tampa, FL, Mira Digital Publishing, Inc., (CD-ROM), pp 1347-1353.
Hansen, K. A. (2000). "Equipment Evaluation of Fast Water Oil Recovery Equipment," Proceedings of the Twenty-Third Arctic and Marine Oil Spill Program (AMOP) Technical Seminar, Environment Canada, Ottawa, ON, pp. 429-445.
Swift, R. M., P. Dugan, P. Norse, R. Steen, B. Celikkol, C. W. Doane, and K. A. Hansen (2001). "Flexible, Submergence Plane Oil Containment Systems," Proceedings of 2001 International Oil Spill Conference, Tampa, FL, Mira Digital Publishing, Inc., (CD-ROM), pp. 1355-1359.

FIELD DEMONSTRATIONS

Two pieces of newly developed equipment – boom deflectors and boom vanes – were identified as having potential use in fast currents. These systems were demonstrated in 1999 on the Columbia River, Martha's Vineyard (Hansen, 1999) and in New York Harbor (Hansen, 2000). The results of these demonstrations are discussed below.

Boom Deflectors

Boom deflectors help oil spill booms retain a straight shape in fast water currents. Boom deflectors are made from aluminum and are 6.5 feet long and 16 inches high with a 5-foot long, 12-inch high wing (see Figure 1). For deployment, a deflector is placed between each section of boom. The wing uses the force of the water to push the boom out into the current and the shape of the boom is maintained as long as a steady current continues. Maximum deflection is obtained using the maximum angle of the wing. The angle of a wing can be changed manually from a small boat when the boom is deployed. Short sections of boom, about 50 feet long, are recommended for use in higher currents.

Figure 1. Boom Deflector.

Boom deflectors move boom out into the current at an average angle of about 15 degrees at current speeds of one to three knots. They probably work best with rigid foam-filled boom. Deflectors can be used to deflect oil with one end of the boom free (see Figure 2). This method is especially useful when deflecting oil away from a sensitive area. The second method is to use deflectors in line with boom that is attached at both ends. The deflectors will straighten out the boom and reduce the tension required to keep its shape. This use should improve the performance of booms by maintaining a constant angle of the boom with respect to the current without the use of additional lines to the shore.

During one demonstration on the Columbia River, a 15-degree boom arrangement using 350 feet of small 6-inch x 6-inch foam-filled boom and six deflectors was deployed several times. The system was positioned out into the current by attaching the leading edge of the boom to a Danforth anchor. The deflection was easily observed by the displacement of a marker buoy fastened to the leading edge of the boom with a line. This buoy can be seen in the right background in Figure 2. Measured at the attachment point of the boom, the current speed was about 1.7 knots. The deflectors were then attached to a larger 18-inch high boom in a 3.8-knot current and the angle was again estimated by several Coast Guard and industry response representatives to be about 15.

Figure 2. Boom with Deflectors Attached.

As a result of the demonstration, Oil Mop, Inc. of Paducah, KY, has procured a large number of boom deflectors. These deflectors were used successfully to support a U.S. Environmental Protection Agency (EPA) effort to remove oil from an abandoned pipeline under the Missouri River near St. Louis in April 2001. The current during this effort was five knots. These deflectors were also demonstrated during a joint Eighth Coast Guard District and State of Illinois demonstration on the Mississippi River in May 2001.

Boom Vane

A boom deployment system, the Boom Vane, based on the trawl doors used by fishermen was developed in Sweden and the concept was refined by ORC of Sweden (see Figure 3). It weighs about 40 pounds and is about 4.5 feet long. Multiple curved vanes are used to increase the surface area impacted by the current. To deploy the system, a mooring line is attached to the shore upstream and the vane uses the hydrodynamic force of the passing current to pull the boom away from the shore. It can be used in deflection or recovery modes (see Figure 4). This model has a simple control system having either a deployed or a stalled mode. To bring the system into the shore, only one control line is needed to pull on the tail and reorient the vanes to a neutral angle, and the vane can then be pulled in easily. The control line is not shown in Figure 4.

Figure 3. Front View of Boom Vane.

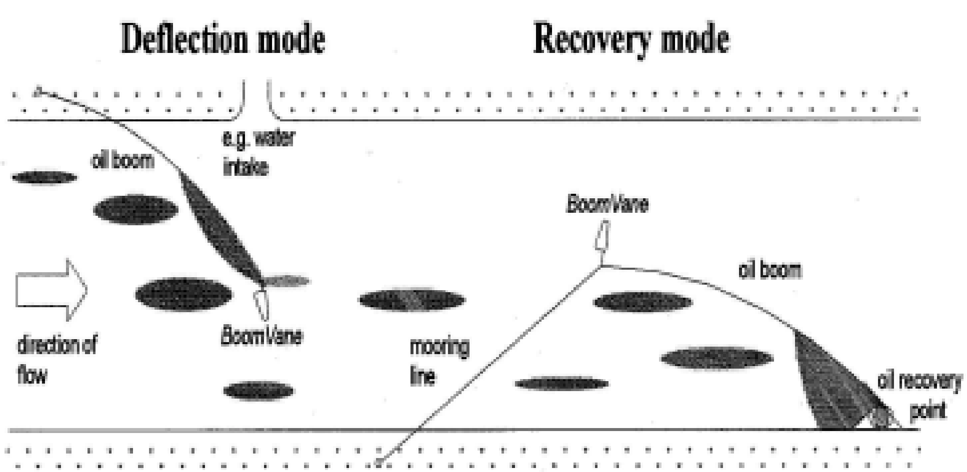

Figure 4. Boom Vane Deployment Modes.

Columbia River Tests

For the first deployment, 400 feet of small 6-inch x 6-inch boom was deployed with the Boom Vane; the resulting boom shape was very good for oil recovery. The current near the Boom Vane measured approximately 1.5 knots. For the second deployment, the Boom Vane was launched with the small boom, and a tension meter was installed on the mooring line. The current was running about three knots. The tension in the mooring line was about 550 pounds at the beginning of the deployment. The vane was stalled using the control line and pulled in towards the shore. When the control line was released, the mooring tension increased to about 700 pounds as the vane swept back out into the current, easily pulling the boom with it.

The third deployment combined the Boom Vane and the Boom Deflectors. An 18-inch boom with the deflectors attached was connected to the end of the Boom Vane. The deflectors were then opened and the end of the boom was released from the shore. The Boom Vane swept upriver before stabilizing with the mooring line at a sharper angle to the bank. The boom with the deflectors again created an angle of about 15 degrees with the current running just under one knot, indicating that these systems can be used together to form a cascading deflection system in a steady current without the use of heavy anchoring equipment.

Other Boom Vane Tests

The Boom Vane was also evaluated for use in tidal estuaries in Martha's Vineyard and New York Harbor. In Vineyard Haven Harbor, the Boom Vane was successfully deployed and the final shape of the configuration is shown in Figure 5. About 150 feet of boom was in the water. Note the shallow angle with respect to the shoreline; this permits the boom to deflect oil towards the beach for recovery. The current was estimated at one knot at the Boom Vane.

Figure 5. Boom Vane Deployed in Vineyard Haven Harbor.

The first task in New York Harbor was evaluating the Boom Vane with the vessel of opportunity skimming systems (VOSS). The system was taken aboard a 34-foot LORI skimmer to determine if the Boom Vane could replace the outrigger boom. It was difficult for the operator to maintain a steady course and speed with the system deployed. For each course change, the Boom Vane moved with respect to the vessel, either closing or opening the pocket. The Boom Vane configuration was later used on a 65-foot vessel (see Figure 6) and the operator was able to maintain a steady course, and the resulting configuration was more stable. A newer version of the Boom Vane is being developed that would make it easier to use on a ship. It appears that using this system could result in a reduced size for the outrigger boom, which is cumbersome.

Figure 6. Boom Vane Deployed from Larger Vessel in New York Harbor.

At Pralls Island, on the West side of Staten Island, 400 feet of 36-inch boom was deployed in the deflection mode with a current close to shore of less than 1/2 knot. Even with this weak current, the Boom Vane was able to hold about 200 feet of boom about 50 feet away from the shore. The final deployment in New York was in the East River and consisted of 36-inch boom arranged in a containment configuration to capture oil on a flood tide. The current was estimated at 3 knots in the middle of the channel. The configuration was set with the oil boom in a "J" configuration (see Figure 7). A collection pocket was formed to protect the shoreline and provide a place to deploy a skimmer. This is not the recommended method of deployment because the location of the pocket away from the shore does not permit access by vacuum or cleanup equipment on the beach.

Figure 7. Boom Vane Deployment on East River.

Summary of Field Demonstrations

The Boom Vane and Boom Deflectors can enhance the oil recovery performance of booms in fast water conditions. Both systems reduce the amount of rigging hardware and effort required to either deflect oil towards a recovery point on the shore or away from sensitive areas. This reduces the number of personnel needed to use these systems. They are generally unaffected by small changes in current so tending them is easy. They both perform best in steady currents and are not affected by small changes in currents or waves. They are more difficult to use in tidal currents and should be deployed only when strong and consistent currents exist. The Boom Vane is especially useful when a boat is not available to deploy anchors out in the current. The

District Response Assist team (DRAT) from USCG District 1 and the team from District 13 each have one vane in their inventory. These vanes are being used during oil spill containment exercises.

EQUIPMENT EVALUATION AND DEVELOPMENT

Background

For many years, the Coast Guard has funded development of oil spill containment systems for use in fast water response. Most of the efforts have concentrated on how to cover more area by increasing the speed of advancing skimmers. In 1979, the Coast Guard developed a Zero Relative Velocity (ZRV) skimmer that attained high performance in tests at speeds up to six knots at Ohmsett, the National Oil Spill Test Facility in New Jersey. This skimmer incorporated a sophisticated belt system that was almost impossible to maintain (Breslin, 1980). In the early 1990’s, the Coast Guard evaluated booms and skimmers to use with the VOSS and the Spilled Oil Recovery System (SORS) for use on the Juniper class buoy tenders (see Figure 8). These systems perform well only at speeds up to about 1.5 knots (Marine Research, 1999), and must be pulled out of the water if the vessel needs to transit faster.

Figure 8. USCG SORS Deployed on Buoy Tender.

In 1996, the Coast Guard conducted tests as part of a competitive procurement to develop a system that could attain higher oil recovery speeds. The higher speed would permit faster oil recovery and also allow the vessel to maneuver using only the main propellers. All four of the systems tested were able to achieve oil recovery efficiencies (RE), the percent of oil recovered in the total amount of liquid collected of greater than 50 percent with emulsion at speeds up to three knots. Three out of the four systems also recovered light oil over 50 percent. Two systems had high RE at five knots (DeVitis et al., 1996). The system that was eventually procured was the JBF DIP600. The first skimmer that was delivered was subjected to additional tests in 1997. The throughput efficiency (TE), the percentage of oil collected of the total oil encountered with heavy oil, was 68 percent at three knots and 78 percent at four knots. For lighter oil, the values were above 38 percent at four knots (DeVitis et al., 1997). The DIP600 combined with the Fast-Sweep boom is called the Coast Guard’s High Speed Skimmer (HSS) system. The HSS currently is not operational.

Ohmsett Tests

The assessment report (Coe and Gurr, 1999) specifically identified three systems that had been developed for fast currents but had never been tested with oil. These were the Vikoma Fasflo from England, the Blomberg Circus from Finland, and the Current Buster from Norway. To ensure that the tests were consistent, a fast-current testing protocol was developed using the HSS and then all four systems, including the HSS, were tested at Ohmsett in the summer of 2000 using the protocol.

USCG HSS Tests (DIP600/JBF)

The HSS was designed as a high-speed inclined skimmer employing the dynamic inclined plane (DIP) principle (see Figure 9). The skimmer is 20 feet long and 8 feet wide, with an overall height of 6.8 feet and a draft of 4.5 feet. The complete skimmer dry weight is 7500 pounds. Four air inflatable urethane pontoons that attach to the hull with strapping provide floatation. The belt is typically operated at zero relative velocity (ZRV), which is defined as the belt rotational speed equal to the velocity of the fluid passing through the skimmer. When oil reaches the belt's end, buoyant forces cause the oil to surface into the collection well where a Desmi DOP250 offload pump is located. Free water is allowed to escape through vent holes located at the bottom of the stern.

Figure 9. HSS being Lowered into Test Tank.

The oils used for this test were Hydrocal 300 (a light oil) and Sundex 8600T (a heavier oil), which are standard test oils used at the Ohmsett facility. The systems were tested under both calm and harbor chop surface conditions. System performance was quantified in terms of TE, a percentage measurement that quantifies the volume of oil collected versus the volume encountered, and Recovery Efficiency (RE). For these tests, the skimmer encountered all of the oil that was distributed.

Figure 10 illustrates the effects of increasing relative currents (tow speed) versus TE performance. It should be noted that the TE values were consistently higher when recovering Sundex than when recovering Hydrocal. Not shown is the highest TE value obtained while recovering Hydrocal, 88 percent at 1.5 knots. It is not clear why the skimmer performed better at 5 knots in harbor chop than in calm water.

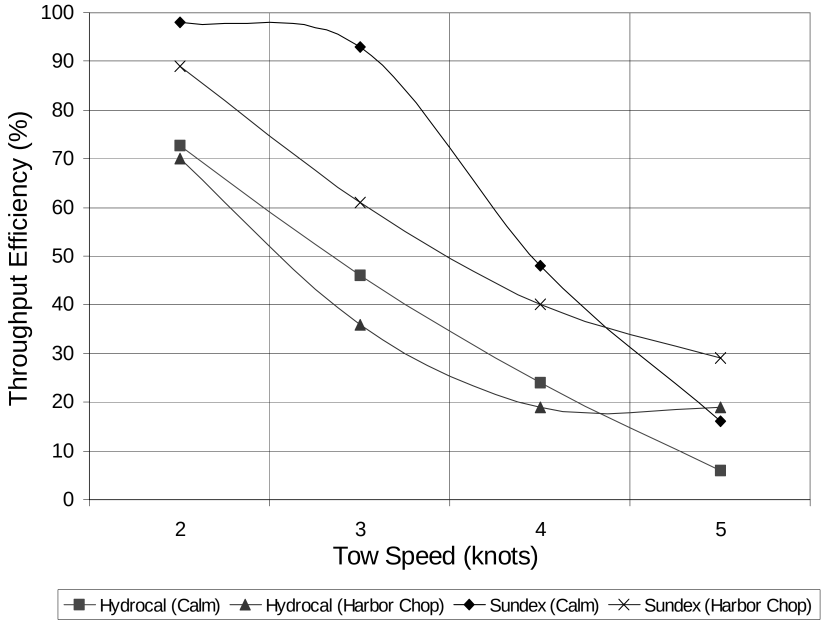

Figure 10. Throughput Efficiency versus Tow Speed.

The belt speed was varied for one series of runs to determine the skimmer's performance if the speed did not match the ZRV. The results indicate a decrease in TE values for belt speeds slower than ZRV and an increase in TE with the belt operating faster than ZRV when recovering Hydrocal test oil (see Figure 11). Recovery operations of light oil with a failed belt system would degrade performance, but would not render the skimmer useless.

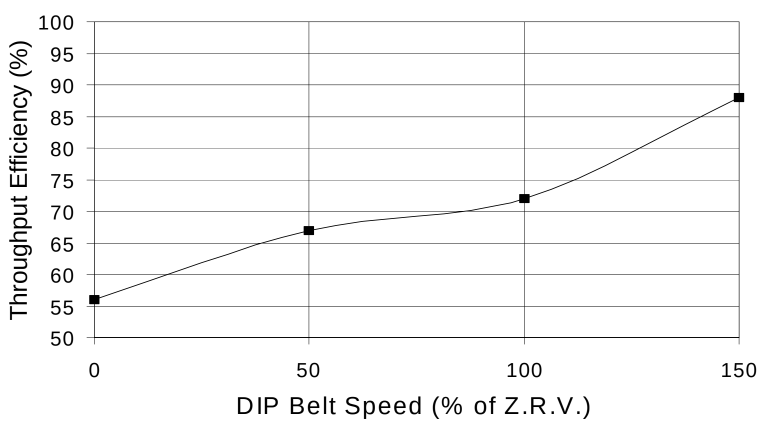

Figure 11. Throughput Efficiency versus Belt Speed for Hydrocal Oil.

RE was evaluated in a series of tests to quantify the short-term results for offload pumping rates greater than, less than and equal to the encounter rate. Figure 12 illustrates actual RE values obtained at 2.0 knots while recovering Hydrocal test oil in calm surface conditions. As expected, lower offload pump rates allowed for collected oil to accumulate and time for some separation to occur, resulting in higher RE values.

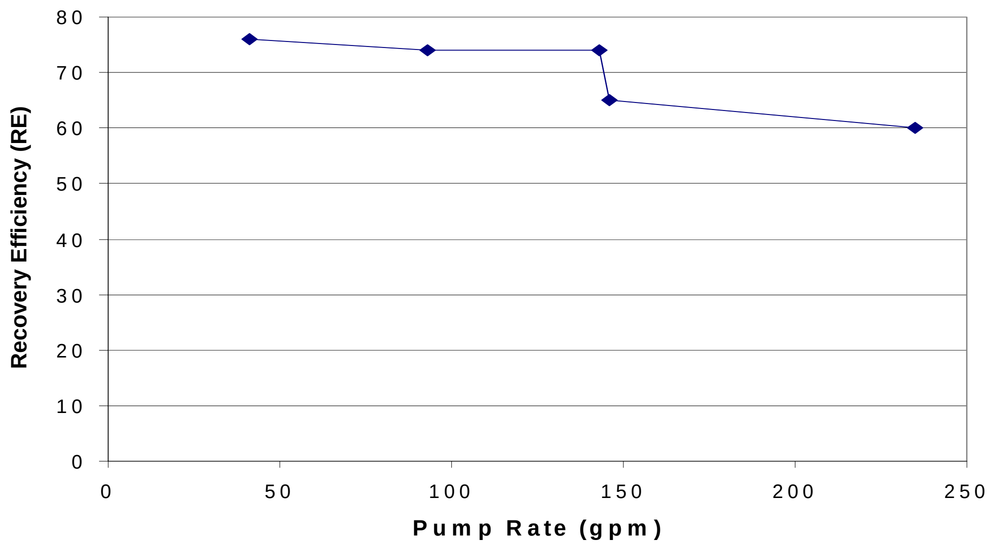

Figure 12. Recovery Efficiency versus Pump Rate for HSS.

<u>Vikoma Fasflo Tests</u>

The Fasflo is an advancing weir-type skimmer designed to encounter spills at speeds up to six knots. The skimmer body and pontoons are constructed of marine-grade aluminum, as shown in Figure 13. It is 13 feet long, 7.25 feet wide, and about 3 feet high; it weighs 770 pounds. Outboard pontoon style floats filled with closed-cell foam provide buoyancy. The system uses two deflection booms to channel the oil into a narrow opening. The next section opens, allowing a decrease in velocity, which provides a quiet zone, and allowing gravity separation. Water escapes through the bottom of the device while oil is collected past a self-adjusting weir and pumped out. There are multiple methods to adjust the system.

Figure 13. Fasflo Skimmer from Vikoma.

The Fasflo skimmer was subjected to the fast current protocol tests at the Ohmsett Facility. At 2 knots, the Fasflo Skimmerskimmer effectively recovered high percentages of the oil slicks it encountered in calm water, and the TE values averaged 77 percent for the Hydrocal and 89 percent for the Sundex. Values of TE averaged 24 percent for Sundex at 3 knots. The system could not recover Hydrocal at 3 knots nor could it recover any oil in harbor chop. Above 2 knots, a stagnation condition occurred forward of the collection well and flow was assisted over the weir only by the induction created by the offload pump. Some companies have used this system in shallow streams by anchoring the skimmer to the bottom and directing all of the flow into it.

High Speed Circus Tests

The High Speed Circus is a device developed by CAPT Blomberg of Sweden and is being marketed by Foilex of Sweden. The arrangement (seen in a staging area in Figure 14) is designed to channel the water and oil into the circular lagoon. The oil stays on the surface due to its buoyancy while the slant of the walls and the circular flow force the water to rotate out and underneath the deflectors. Oil can be removed by a skimmer mounted in the middle of the collection well or with a suction hose. The unit shown in Figure 14 is 5.6 feet long, 3.3 feet wide, and about 4 feet high; it weighs about 285 pounds. It is designed for inshore use in currents up to 3 knots.

Figure 14. High Speed Circus.

The High Speed Circus was mounted against a plywood panel supported by aluminum framing (shown in Figure 15), to simulate the side of a vessel. A Foilex Mini Well Skimmer that was self-adjusting and operational for a 6-inch vertical range was mounted in the center of the collector. The recovery tests performed ranged from 1.0 to 3.0 knots and only Hydrocal was used. A maximum TE of 90 percent was obtained at 2.0-knot tow speeds in calm surface conditions. The maximum TE value obtained at 3.0 knots was 50 percent with a corresponding RE value of 11 percent. The system was not able to contain oil in harbor chop conditions. The manufacturer makes larger circus units that would be more effective at higher current speeds.

Figure 15. High Speed Circus Collector.

Testing the NOFI Current Buster

The NOFI Current Buster Skimmer consists of a sweep with netting (Vee-Sweep) with an open apex, a tapered channel, and a separator (see Figure 16). The dimensions are 50 feet across the sweep mouth, with an overall length of 91 feet and a draft of 44 inches. The sweep and collector guide the spilled oil to the tapered channel that serves as a skimming device and then into the separator. Water is allowed to flow out through an outlet in the bottom of the separator. Any floating skimmer can be used to remove the oil from the separator. The Current Buster system is inflatable (see Figure 17) and can be disassembled and shipped on one pallet.

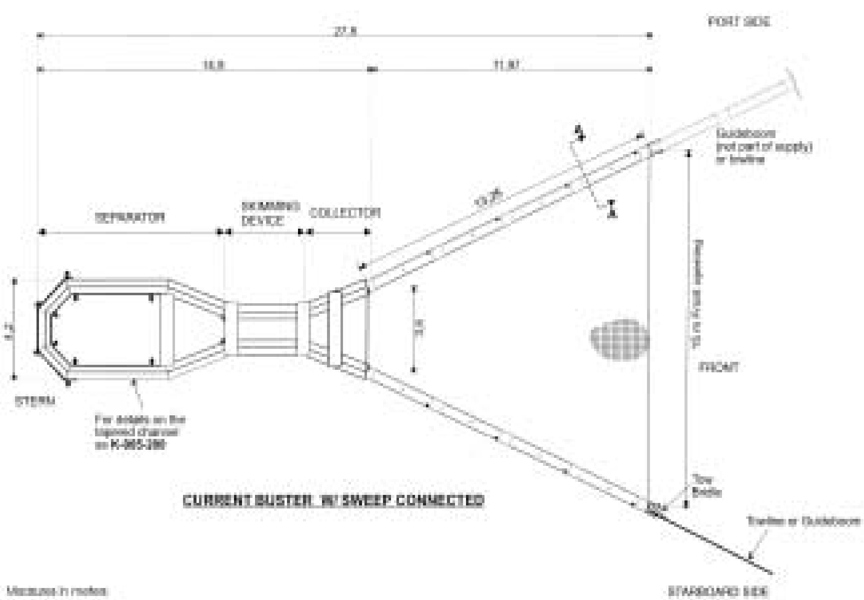

Figure 16. Current Buster Skimmer with Sweep Boom Connected.

Figure 17. Current Buster in Ohmsett Tank.

The Current Buster collected oil at the highest TE than any other system evaluated at speeds over 3 knots. The average values for TE were 65 percent for harbor chop and 91 percent in calm water at 3.5 knots for both oils. Attempts to test at 4 knots resulted in an overfull separation tank and loss of freeboard.

Summary of 1999 Ohmsett Tests

The two skimmers that worked best at the higher speeds were the NOFI Current Buster and the HSS. Significant time and money have been invested in the development of both systems. The Ohmsett tests were the first for the High Speed Circus, the Fasflo and the Current Buster at high speeds with oil. The tests indicate that all four of the systems can efficiently collect oil in calm water with a current of 2 knots. The two larger systems, the HSS and the Current Buster, work effectively up to 3 knots and 3.5 knots, respectively. The HSS was able to recover some oil at tow speeds up to 5 knots. Although the size of the Current Buster did not permit tow speeds over 3.5 knots, the trends indicate that it can recover oil at higher speeds. All of the systems are small enough to be deployed from smaller response vessels, although some heavy rigging and lifting are required.

An issue identified during this testing is the influence of the lead-in booms on the flow into the skimmer. First, a wider sweep width increases the area that can be skimmed, but it also increases the amount of flow introduced into a skimmer. A large amount of water can influence the skimmer's operation, especially if the opening for the water to escape is small. In addition, most conventional booms are not smooth, having seams and connectors along their length that create complex wave and flow patterns that can affect the movement of the oil. All of the skimmers in this test had problems with complex flows, especially the Fasflo because of its narrow opening. To reduce water intake and wave making, the lead-in booms should be seamless, rigid, and have a shallow draft and high freeboard.

Tests at Ohmsett in 2000

Another series of tests was conducted at Ohmsett in the summer of 2000 in order to increase the state-of-the-art in fast water response. The systems were selected from proposals in response to a Broad Agency Announcement (BAA) seeking improvements to containment and recovery capabilities in currents from three to five knots. The systems and contractors included:

- USCG High Speed Skimmer (HSS) Design Modifications; MAR, Incorporated
- Towing Forces on Fast Water Diversion Booms; SL Ross Environmental
- Flow Diverters; Computer Systems Corporation, Advanced Marine
- Floating Oil Sorbent Recovery Systems; Computer Systems Corporation, Advanced Marine
- Rope Mop Skimming System (Stream Stripper), RO-CLEAN DESMI and Hyde Products, Inc.

USCG HSS

During tests at Ohmsett in 1999 to verify the protocol for fast water tests, oil could be seen leaving the bottom of the HSS when viewed from under the water (DeVitis et al., 2000). The water loss may have been due to the large amount of water impinging on the belt and being forced down under the skimmer. The momentum created by this large volume of water could carry some of the oil past the end of the belt and under the bottom plate (see Figure 18). A proposed modification was to position a plate in front of the angled belt to deflect most of the water that the skimmer encountered underneath the bottom plate. Reducing the amount of water mixing with the oil would keep the slick from being pulled off the belt and more of the oil would end up in the collection well. The performance parameter used for this test was TE.

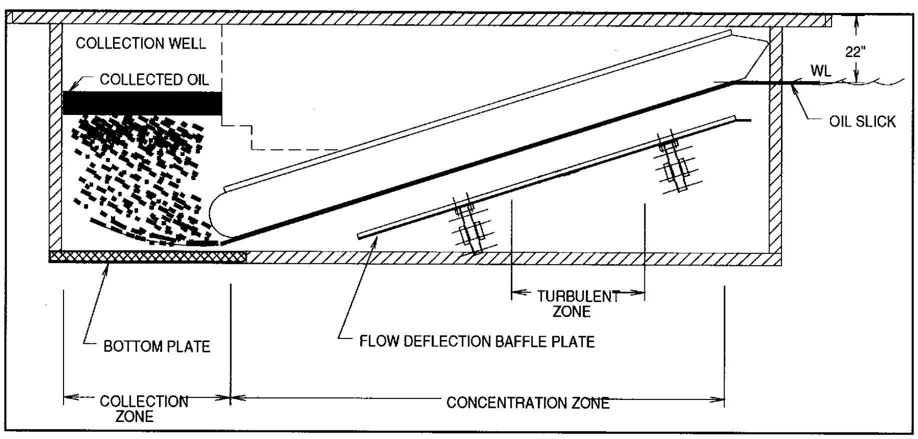

Figure 18. Cross-section of the HSS with Baffle Plate Installed.

Of the six possible baffle plate adjustment combinations, four were employed based on results obtained during early testing. Setting number three in calm water conditions resulted in the highest overall performance with setting number four showing slightly better performance at the higher speeds. Setting number three is defined as positioning the baffle plate 16 inches from the DIP belt at the mouth and 12 inches at the bottom. For setting number four, the front of the baffle was positioned 12 inches from the belt and the rear positioned at eight inches from the belt. A comparison of the results obtained in this study with data from the July 1999 study, indicated a significant increase in TE at 2 and 3 knots in calm surface conditions for both baffle positions (see Figure 19). At 2 knots, the TE for setting number three was 86.4 percent, a 19 percent improvement; and at 3 knots, the TE was 68.1 percent, a 48 percent improvement. For vessel operations at 4 to 5 knots, setting four resulted in performance four times better than the 1999 Canflex boom configuration.

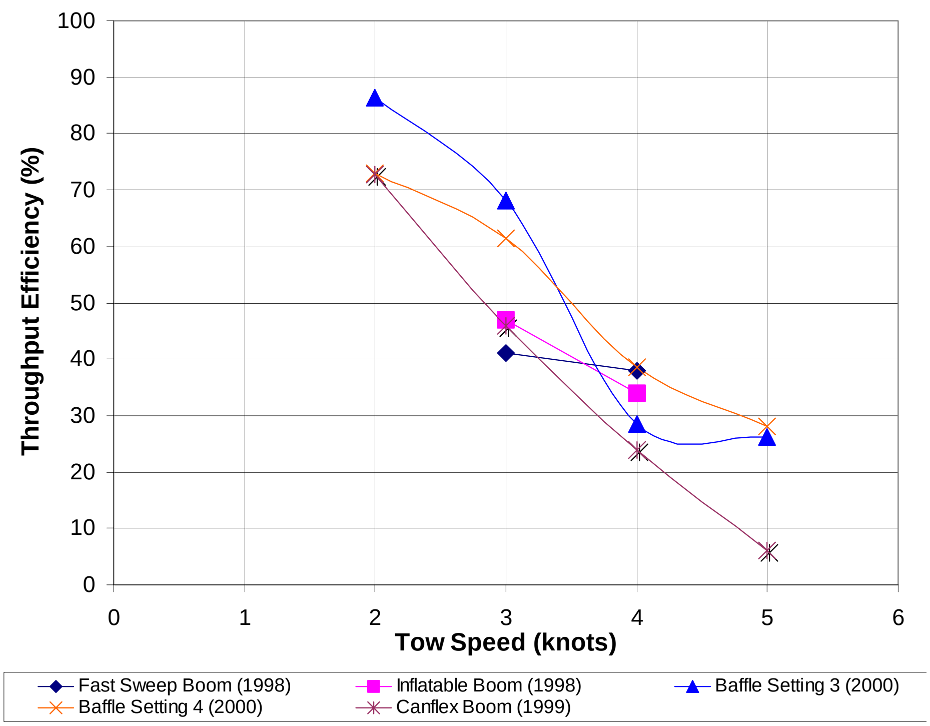

Figure 19. Graph of HSS Historic and 2000 Data.

Towing Forces on Diversion Booms

The objective of this effort was to quantify the forces at shallow angles (10 degrees to 30 degrees) at various drafts and to provide an easy method for calculating the tension on the boom. The test boom section (see Figure 20) consisted of a 24-inch high by 100-foot long, continuous sheet of 85-oz/yd^2 polyvinyl chloride coated (PVC) polyester barrier panel, with two longitudinal 5/16-inch plastic-coated steel cables in 3/8-inch pockets to provide tension.

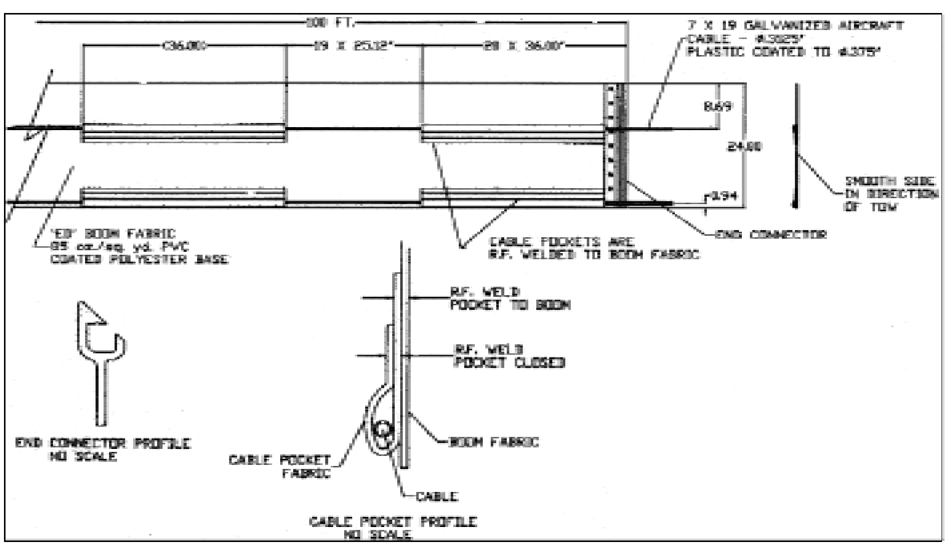

Figure 20. Test Boom Components.

To measure tension forces in the boom, a load cell was mounted on each of the two tow points at the towing bridge; one on each of the top and bottom cables of the leading end of the boom (see Figures 21 and 22). A load cell was attached also to the leading end of the side cable to measure the transverse load on the boom. Suspenders were installed to keep the boom upright.

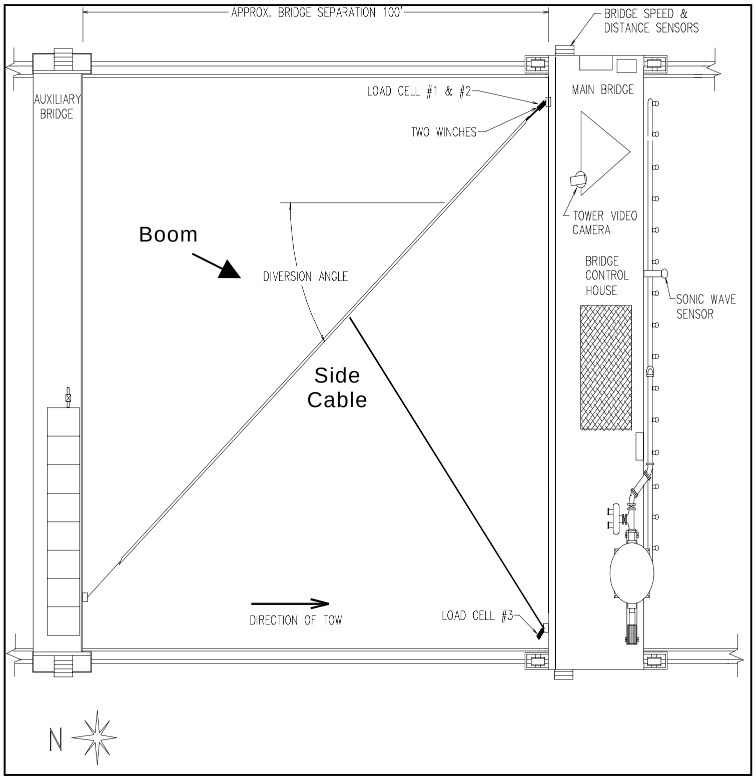

Figure 21. Test Setup for Towing Forces on Fast Water Diversion Booms.

Figure 22. View of Boom, Showing Suspenders.

The data for each test run were tabulated with the recorded load cell readings, tension loads (after adjustment for pre-tension loads), and longitudinal and transverse components for the side load test runs. The resulting total longitudinal load was then correlated with tow speed. The correlation was done assuming that the load varied as a function of the square of the tow speed:

{ EMBED Equation.3 **}**,

where: T=tensile force, lb_f,

K=constant, lb_f /(ft^2 x $knots^2$),

A=projected area of the submerged portion of the boom, ft^2, and

V=tow speed, knots.

The projected area of the boom was calculated based on the boom draft and the length of the boom normal to the water current (i.e., the direction of travel):

{ EMBED Equation.3 **}**,

where A = projected area of the submerged portion of the boom, ft^2,

d = boom draft, ft,

L = boom length, ft (100 ft), and

θ = diversion angle (10°, 20°, 30°).

The value of the constant K is listed in Table 2 for the various boom configurations. Tests were performed with the side cable engaged and disengaged. The correlation for the 20 degrees diversion angle data was statistically poor so the value of the constant may be too high. The value of the constant for the side cable engaged (side load) is lower because it essentially cuts the boom in half and it also does not permit the boom to sag to create more water resistance. In general, the values of the constant are consistent with similar formulas for estimating boom tension and validate the approach of using the projected area as the independent variable in the calculation. It is recommended that a value of 2 be used for calm water and a value of 3 to 4 be used in the presence of waves**.** These data collected for the towing forces on diversion booms can be used to help design lead-in booms for boom deployments and skimmer manufacturers.

Table 2. Value of Constant K for Various Boom Configurations.

Diversion angle	Boom Draft, in.	Calm condition		Regular Waves	Harbor Chop
		no side load	side load		
10°	9.2	1.69	1.51	--	--
10°	12.7	2.06	1.88	--	--
20°	9.2	2.17	1.57	--	--
20°	11.6	4.87	2.72	--	--
30°	8.0	3.60	1.87	--	--
30°	12.7	3.83	2.36	3.19	4.66
maximum		4.87	2.72	--	--
average		3.04	1.99	--	--

Flow Diverters

Flow diverters are composed of a series of wing-like hydrofoils. The system is designed to attain a steady-state angle to the current that changes the surface current and thus diverts the oil towards the shore. Moving the oil closer to the shore allows recovery. This concept was initially investigated in the St. Lawrence River (Eryuzlu and Hauswser, 1977) and has been refined by CSC Advanced Marine. Each prototype floating catamaran assembly consisted of two paravanes mounted to a 4-link frame, as shown in Figure 23. Each assembly had a 3.5-foot beam length, a depth of 33 inches and an operational draft of 24 inches. The paravanes were constructed of fiberglass/resin, and the assembly weighed approximately 167 pounds. A pair of control cables connected to the frame allowed the operator to manually adjust the attack angle of a group of foils during operation.

Figure 23. Flow Diverter Assembly.

Figure 24 is an overhead view of the test setup, showing two assemblies in place. A wire rope grid was assembled over the slick area to aid in estimating the diversion distances of the oil. During testing, two rope lines were suspended between the Main and Auxiliary Bridges and manually aligned over the paravane to obtain lateral distances from the direction of flow. The paravane angle and the oil slick offset were measured directly from the placement of these two lines by simple trigonometric methods. The system was set up to obtain the maximum offset of the oil.

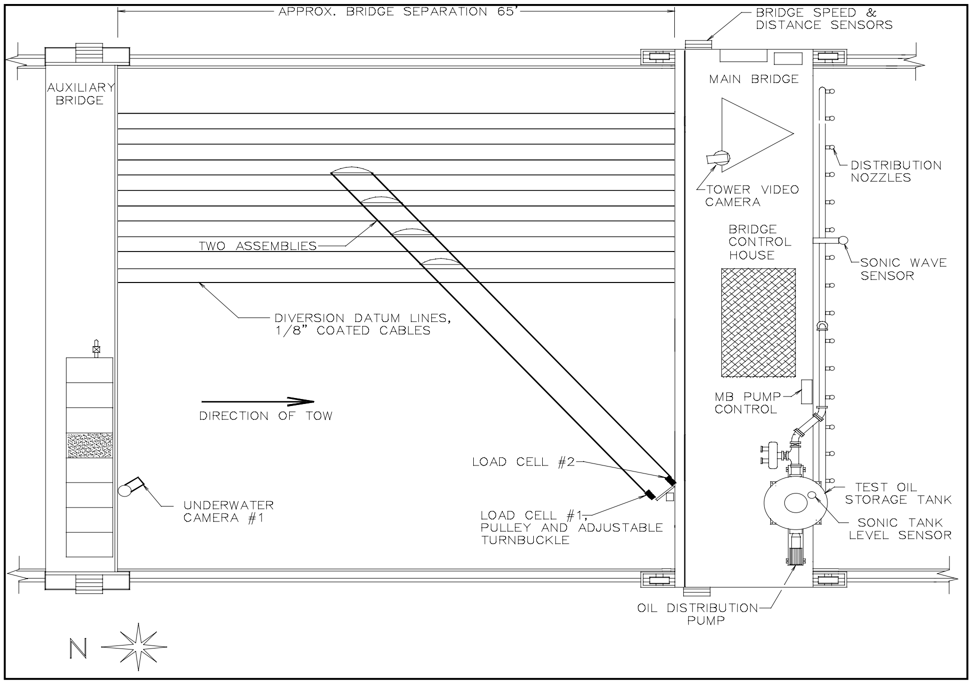

Figure 24. Flow Diverter Test Setup.

The first segment of this test series was performed with one set of paravanes (two individual paravanes linked together). The paravanes were towed at speeds ranging from 2 to 5 knots in calm water. Sundex oil was distributed on the water surface during the initial runs. The lateral distance of the oil was offset by 8 feet at 2 knots to 9.5 feet at 5 knots. The second segment of testing was performed with two sets of paravanes (four individual paravanes). The offset distances ranged from about 10 feet at 2 knots to 19 feet for one run at 5 knots. Figure 25 shows the range of values attained for various angles of attack of the paravanes. For the test parameters evaluated, those that provided the best results were in a 5-knot current while encountering diesel oil (19 feet). Figure 26 clearly illustrates the efficiency of the diverted oil being consolidated into a solid oil windrow. The flow diverters provide a tool that can control oil on the surface of the water without the use of vessels.

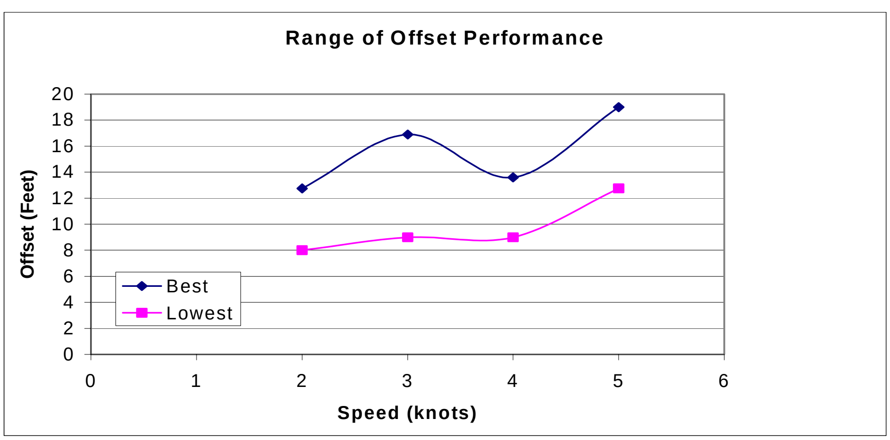

Figure 25. Displacement of Oil at Various Speeds.

Figure 26. Four Paravanes at 2 Knots (left) and 3 Knots (right).

Sheet Sorbents

MYCELX Technologies Corporation (formerly Mother Environmental) has designed prototype floating oil sorbent recovery systems for swift currents to overcome conventional sorbent boom limitations. The recovery systems are designed to maximize the oil contact surface area and to repel water and absorb oil with minimum contact time without restricting flow. Three different sorbent booms were designed and fabricated for this study. Each was constructed from a base material that was treated with the patented product MYCELX.

Boom 1 (see Figure 27) incorporates MYCELX, approximately 1/8-inch thick Polypropylene (PP) felt material sewn over a 20-foot long high-tension rope with closed-cell tubular polyethylene floatation on its leading edge. A “toboggan” device was designed and placed in the apex of the boom above the waterline to keep the boom afloat and in direct contact with the oil during the higher speed tows.

Boom 2 (Figure 28) is shown while encountering diesel fuel. The design incorporates MYCELX infused; PP felt material approximately 1/8-inch thick, sewn together with a MYCELX Sheen Devil on a 20-foot long, high-tension rope. No “toboggan” was used with this type of boom since it did not plane during the high tow speeds. The “Sheen Devil” portion consisted of a 1/8-inch closed-cell foam mat doubled over twice and sewed over the line. The mat extended approximately 16 inches past the line and had slits cut into the mat, approximately 1-inch wide, to form a fringe effect.

Boom 3 (see Figure 29) was a variation of the CSC Terraguard product and was designed to be deployed with the Sheen Devil facing down into the water to help the boom plane up on the current. The design incorporated eight layers of 0.77 ounce per square yard PP material sewn together with a MYCLEX Sheen Devil on a 20-foot long high-tension rope. All tests of Boom 3 were conducted with the “toboggan” device to keep the boom afloat and in direct contact with the oil.

Figure 27. Boom 1: MYCELX Infused PP Felt Boom.

Figure 28. Boom 2: Composite Boom, Tested with Diesel Fuel.

Figure 29. Boom 3: Composite Boom.

The sorbent booms were rigged and towed at 2, 3.5, and 5 knots. Test runs began by accelerating the sorbent boom assembly to the predetermined tow speed. The oil was spilled from distribution nozzles designed to provide a slick as evenly distributed as possible while maintaining a 100 percent encounter rate. Each of the sorbent booms was weighed (when dry) by being suspended from a mechanical scale.

To determine the sorbent boom's absorption effectiveness, measurements were taken in two ways. The first method measured the amount of oil not recovered by the sorbent boom. Effectiveness was calculated as the percentage of oil recovered to the volume encountered (TE). This method did not work due to errors in measuring the small amounts of oil that made it past the booms. The second method was to measure and determine the weight of the sorbent boom, both before and after oil recovery, and to determine the final amount of oil recovered by weight. Prior to obtaining the post-test weight, the boom was suspended in air to allow the free water to drain. The second method measured recovered oil volumes of 1.5 to 3.7 gallons or about 2.5 to 8 percent of the oil distributed. Another way to display the results is the wet weight to dry weight ratio, as shown in Figure 30. It was determined that this method worked fairly well in determining effectiveness but it is difficult to make conclusions with a low number of tests.

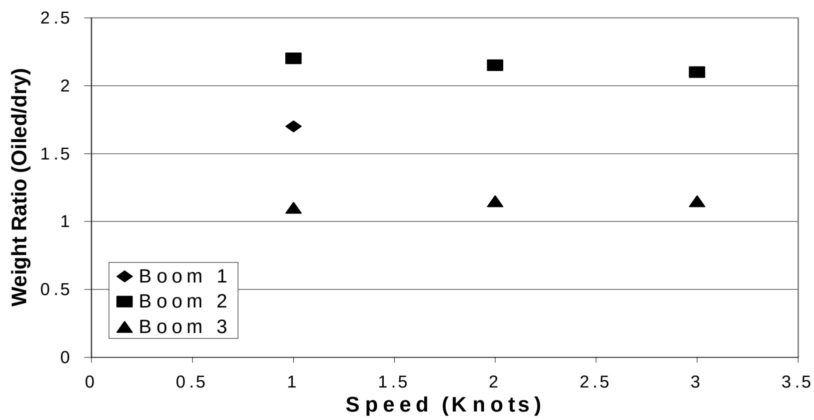

Figure 30. Sorbent Boom Performance.

Another evaluation method involves looking at each boom type qualitatively. When towed, Boom 1 created a bow wave that allowed the surface oil and water to flow above the sorbent material. This condition minimized the contact time that was essential for the sorbent boom to function. The addition of two toboggans provided enough floatation to achieve some planing of the boom over the encountered oil slick. The base sorbent material used to fabricate Boom 2 was the same as that for Boom 1 and incorporated the Sheen Devil material into the boom design. This arrangement provided sufficient floatation to enable the boom to plane over the oil slick with only a minimal amount of water and oil flow over it. Upon visual examination, the Sheen Devil closed-cell polyethylene did not appear to absorb a significant amount of oil. Boom 3 did not appear to absorb oil as rapidly as Boom 1 and 2, but it did remain stable. Analysis of the extracted fluid (from Boom 3) indicated the highest percentage of oil found, 93 percent.

It has been demonstrated that these booms would not be efficient in collecting large quantities of oil. The proper application of these booms would be to recover trace oil amounts, or oil sheen, from the water's surface. The material did not soak up enough oil, primarily because of the boundary level formed between the water and the oil. The Versipad, with its multifine layers, recovered the oil most effectively.

Stream Stripper (ZRV Rope Mop)

The ZRV rope mop system is a well-proven method of recovering oil, with the capability of working in waves, with trash, and on a variety of oils. No major advancements have been made on lightweight towable ZRV units since the 1970s. The new ZRV Rope Mop Skimming System can be towed and is designed to be as light as possible so that it will ride over the waves. The prototype mop skimmer is comprised of a 19-foot long lightweight catamaran that incorporates 13 oleophilic rope mops operating between the hulls. Drive pulleys mounted at the bow rotate the mops. The pulleys are driven principally by a chain drive connected to a paddle wheel at the stern of the catamaran. The paddle wheel is replaced with a small hydraulic motor fitted to the drive pulleys at the front in the event that it cannot provide sufficient power to rotate the mops. The paddlewheel and hydraulic motor were used independently during this study. Figures 31 and 32 show a profile and frontal view, respectively, of the rope mop skimmer. The oil is recovered from the mop with a “stripper” mechanism mounted forward of the paddle wheel and into a tray that spans the width of the catamaran.

Figure 31. Profile of Rope Mop Skimmer.

Figure 32. Frontal View of Rope Mop Skimmer.

Initial testing evaluated the power capabilities of the prototype paddle wheel as the drive power source for the application, and the paddle wheel was adjusted to different elevations to optimize the available waterpower. Three settings were used until the paddles were placed 11-5/8 inches into the water. This last setting provided the highest rotational paddle wheel speeds and appeared to convert all the available waterpower into drive power. This final setting was used for all of the paddle wheel tests. The skimmer was not tested with oil at 5-knot tow speed due to excessive slapping of the paddles into the water.

Tests using the paddle wheel for power were performed with Hydrocal 300 test oil in calm and harbor chop surface conditions. Evaluations continued using the hydraulic motor with the paddle wheel removed with both the Hydrocal and heavier Calsol oil. During some of these tests, the oil recovery rate of the 13 mops was higher than the offload pump capacity and resulted in collection trough overflowing. The volume of the collection trough was calculated at 19.75 gallons. A larger trough or a higher speed off-load pump would increase the system's performance. The main performance parameter was TE, and the results are plotted in Figure 33. All of the runs at 2, 3.5, and 4 knots used the paddle wheel for power. The spread in the 3-knot data is the result of good performance in heavy oil and oil leakage from the collection tray before it could be pumped off. The harbor chop runs indicate little reduction in TE performance. The results are similar to or even better than those from other systems at these speeds; further development of this prototype could provide a very useful system for work in fast currents

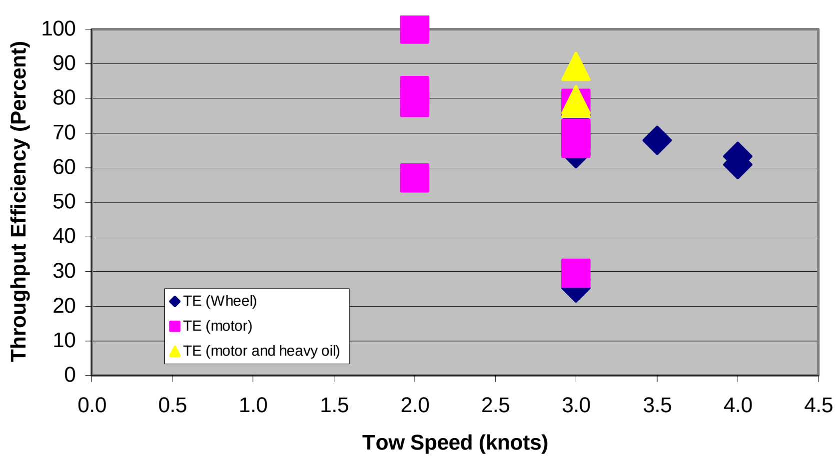

Figure 33. Throughput Efficiency Performance of Stream Stripper.

Oil Thickness Measurements

The operator can get the best performance from some skimmers by knowing the thickness of the oil. This information ensures that the pump is only operated when a sufficient amount of oil has been accumulated, therefore, reducing the amount of water collected. This knowledge is especially true for the High Speed Skimmer. A system to measure oil thickness has been developed by Marin Tech, AB of Norway, and the use of the HSS provided the opportunity to evaluate this oil thickness gauge. The sensor unit for the oil thickness measuring system (MOTS) is about 12 inches long (see *USCG HSS Tests (DIP/JBF)* section above for detailed information on the HSS) and contains a depth gauge and an upward-looking sonar sensor. The sonar sensor measures the distance up to the water/oil interface. The system calculates the oil thickness by subtracting the sonar measurement from the depth measurement. During the HSS tests, the MOTS was mounted ahead of the skimmer and then in the collection well. When the MOTS was mounted forward of the skimmer (see Figure 34), the motion of the skimmer and the waves in front of the skimmer prevented the system from detecting the thin (5 millimeters) slick entering the skimmer. It is not clear if a thicker slick would have been detected.

Figure 34. Thickness Gauge Mounted on HSS.

The unit then was mounted in the collection well inside a PVC pipe to minimize turbulence and to reduce sound reflections near the sensor (see Figure 35). A slot was cut on one side and holes drilled near the bottom of the pipe to permit the oil and water to circulate. Foam was placed at the bottom of the pipe to eliminate the multiple bounces of the signal between the surface and the bottom of the skimmer. The main outputs were the oil thickness and the amount of oil below the pump. The oil thickness is the difference between the sonar reading (A in Figure 36) and the depth measurement (B in Figure 36). The amount of oil under the pump (D in Figure 36) is shown with the two sets of filters. Typical output is shown in Figure 37. The spikes in the oil below pump chart (see Figure 37) are the system detecting groups of oil droplets as they migrate to the surface. A better arrangement of the sensor could reduce or even eliminate this cloud effect (Marin Tech, 2000).

Figure 35. PVC Tube in HSS Collection Well.

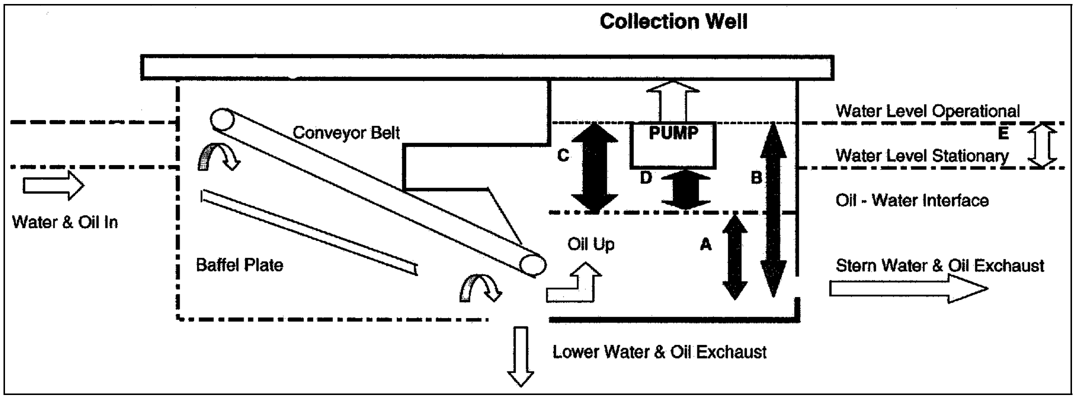

Figure 36. Measurement Parameters.

This thickness measurement device shows potential in helping an operator determine when to offload the skimmer. The current procedure requires the operator to pump until water is seen or to have an observer at the hose outlet to observe when water is being pumped instead of oil. Both of these methods are inefficient and require multiple personnel. An automatic system could be implemented to control both the belt and pumping systems for about $25,000.

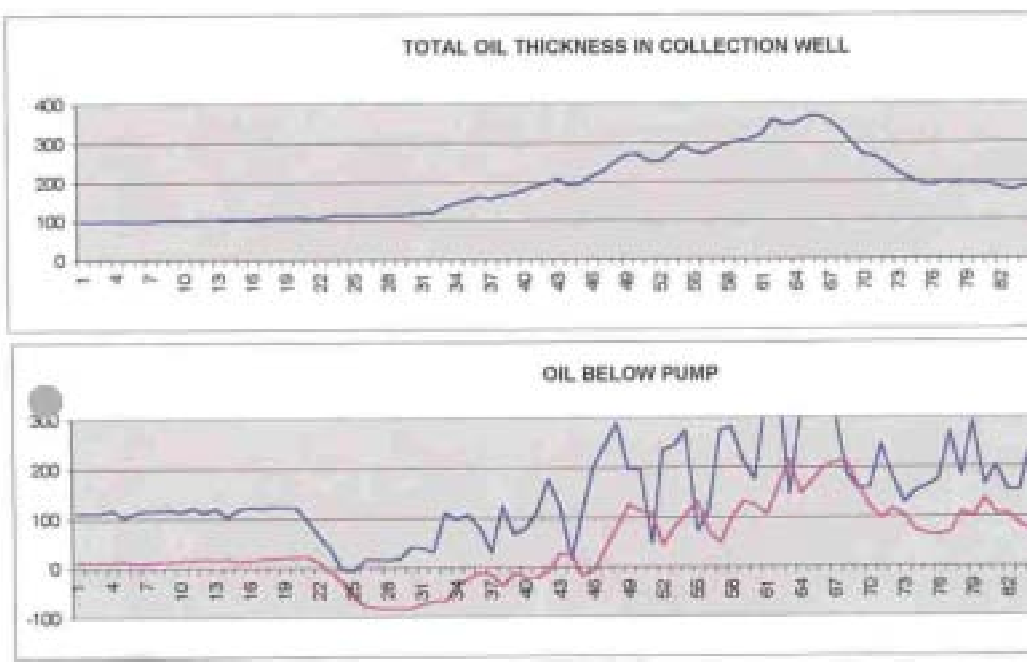

Figure 37. Sample Oil Thickness Data.

Efforts at the University of New Hampshire

The U.S. Coast Guard and the Minerals Management Service (MMS) have been supporting oil spill containment research at the University of New Hampshire (UNH) since 1996. The effort has focused on the development of a flexible submergence plane barrier for fast water applications. A summary of the effort is given in Swift et al., 2000. The submergence plane was chosen after analysis because the concept permitted use of a flexible design that could easily be stored or shipped. The prototype design, called the Bay Defender (see Figure 38), was tested at Ohmsett in 1997 and 1998. It collected up to 82 percent of heavy oil at 2 knots and over 77 percent of light oil at 1.5 knots. Less than 50 percent of the light Hydrocal oil was collected at 2 knots.

Figure 38. Bay Defender.

As part of this project, an effort was made to adapt the submergence plane concept to the U.S. Coast Guard SORS and VOSS systems. The idea was to use the submergence plane configuration as a nosepiece for the CG FastSweep system that is the main boom section of the existing systems. A redesign of the system was needed because of the tendency for the plane to rise out of the water at higher speeds. A hydrofoil was designed and mounted to the bottom of the system to provide a downward force (see Figures 39 and 40). A half-scale model was tested at Ohmsett (see Figure 41). Recovery efficiency was over 40 percent at speeds up to three knots (Swift et al., 2001). This improves the maneuverability of the buoy tenders. This system does not appear to collect light oil very well, and additional work is needed on this system so that a full range of oils can be recovered. In addition, the submergence plane configuration does not perform well at low speeds. Sufficient flow to drive the oil down the plane is not created at speeds less than 1 knot.

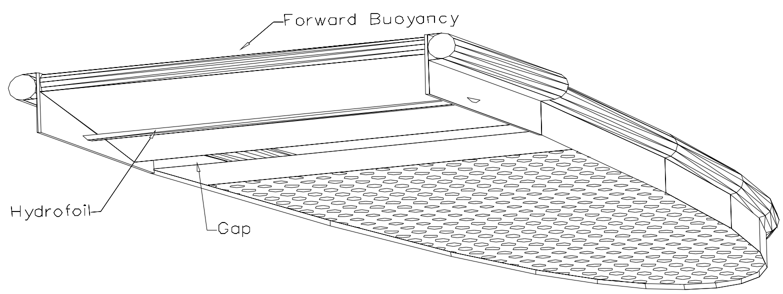

Figure 39. Underside View of University of New Hampshire System.

Figure 40. Bow View of Hydrofoil.

Figure 41. Half-scale Model Testing at Ohmsett.

Performance Comparisons

The information gathered about fast water skimmers can be used in evaluating the capabilities of the Coast Guard's VOSS and SORS equipment for fast water response. The performance of the Coast Guard's systems in fast water recently became a concern when a VOSS system was scheduled to be moved out of the St. Louis area. In May 2001, USCG District 8, the Atlantic and Gulf Strike Teams, the Marine Safety Office (MSO) St. Louis, the R&D Center, and the State of Illinois together demonstrated a VOSS on a ferry. The water level was higher than normal and the current was only about two knots. The demonstration proved that the equipment could be installed on a vessel of opportunity, but the performance in fast currents over two knots remain untested. It is not clear if this system can be used in inland rivers.

Of the systems tested were those that can be used in a VOSS or SORS are the HSS, the NOFI Current Buster, and the UNH/SORS system. The UNH/SORS configuration was tested as a half-scale model and the data were scaled up to predict how a full-scale system might perform (Swift et al., 2001). This calculated performance is probably conservative because the longer length of the full-scale system allows the oil droplets more time to rise to the surface. The likelihood of the droplets making it past the barriers is reduced.

The performance results for heavy Sundex oil are shown in Figures 42 and 43. In speeds up to 3.5 knots, the Current Buster generally outperformed the other systems. An open-ocean version is now on the market. The UNH system, both the tested one-half scale and the predicted full scale, performed well, except at 1 knot. The lower speed does not appear to force the oil down and under the submergence plane, so that oil escapes out the sides. The difference between the HSS data in 1997 and 1999 is the method of offloading the collection well. Pumping only at the end of the run in 1999 resulted in lower TE values.

TE performance for the lighter Hydrocal oil is shown in Figure 44. The UNH system was not evaluated using this oil, but a larger configuration of a submergence plane skimmer, the Bay Defender, did not perform well (Swift et al., 2000). Improvements were made to the performance of the HSS but it is still well below the NOFI values.

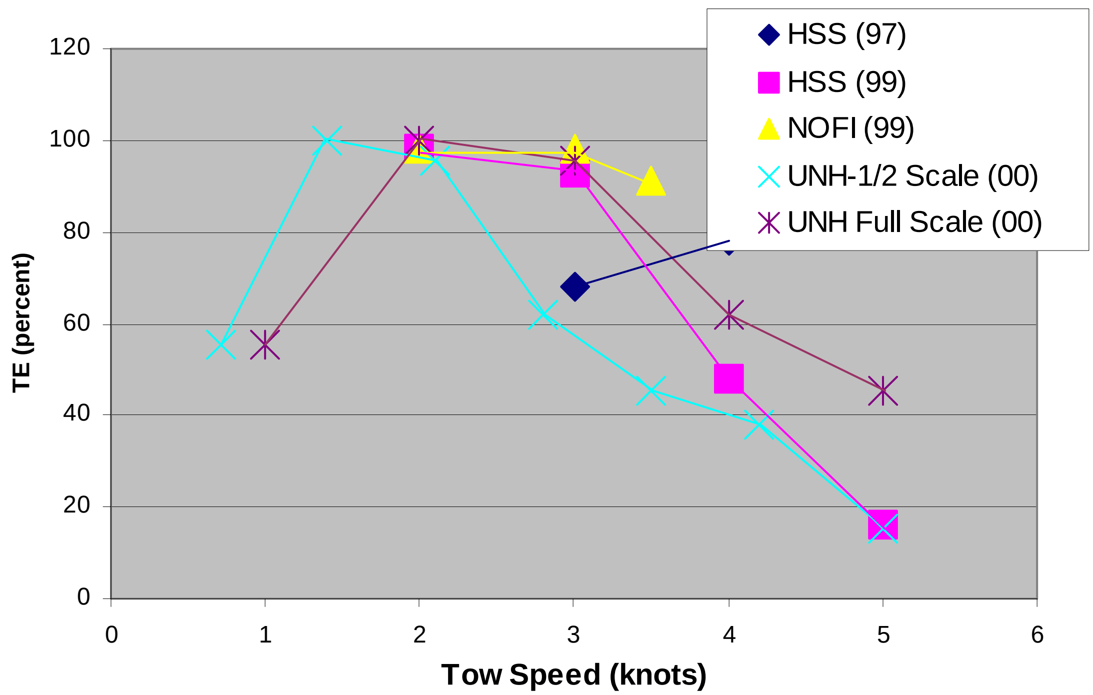

Figure 42. Throughput Efficiency Performance with Sundex Oil in Calm Water.

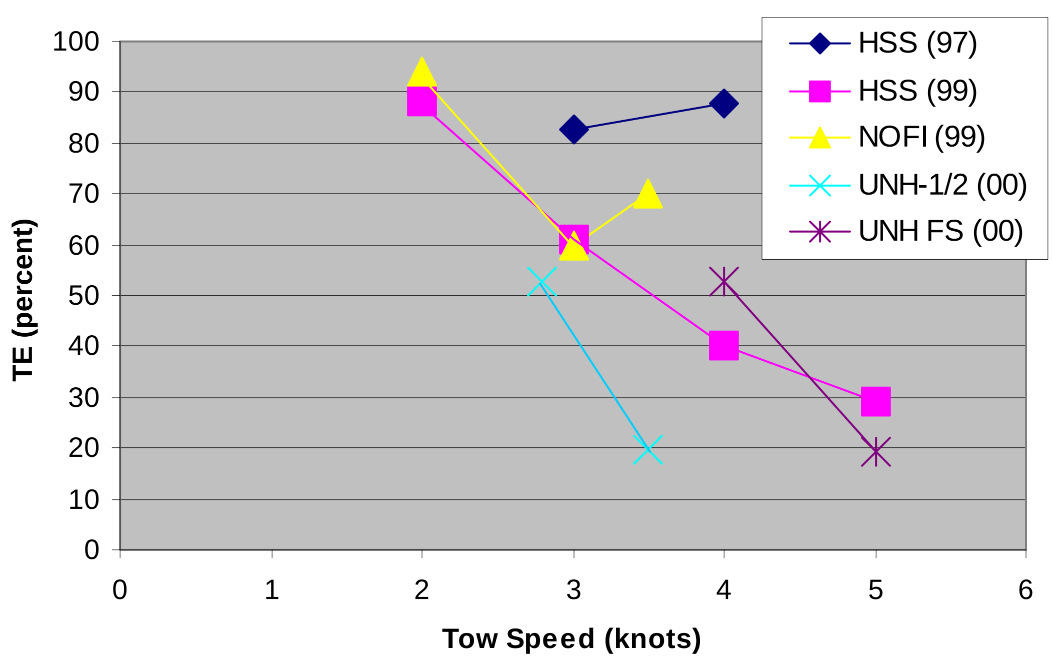

Figure 43. Throughput Efficiency Performance with Sundex Oil in Harbor Chop.

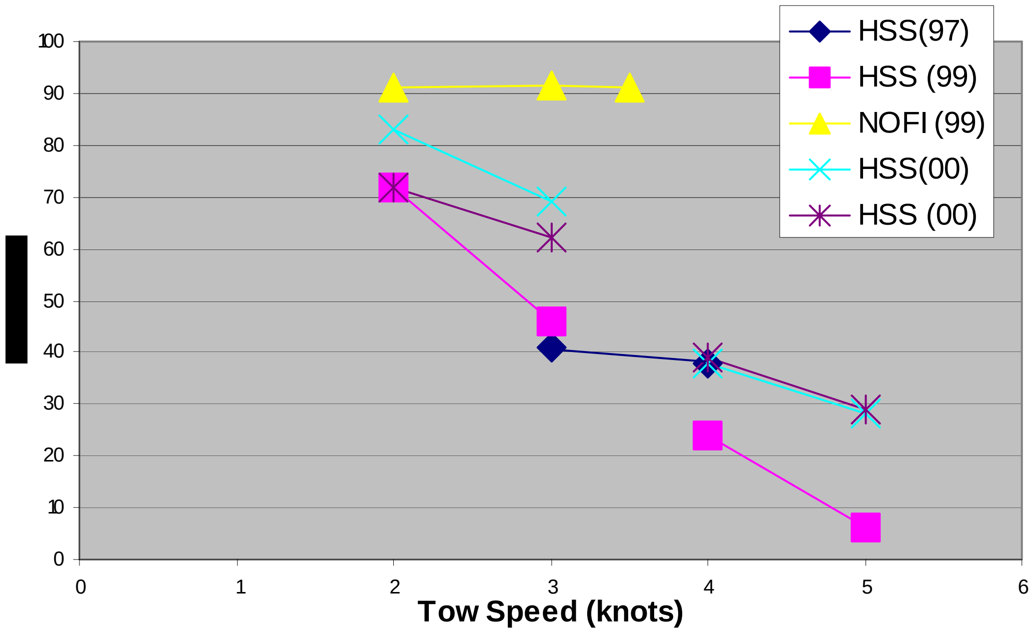

Figure 44. Throughput Efficiency Performance with Hydrocal in Calm Water.

There are practical considerations associated with some of the systems. Although the HSS can be lifted by cranes on Coast Guard buoy tenders, it weighs 7500 pounds, and is difficult to move, deploy, and retrieve. The UNH/SORS full-scale system requires an area of at least 35 feet by 20 feet just to assemble the nosepiece. The Current Buster is robust and portable and it can be stored on one large pallet. It also seems to perform well in waves (Counterspill Research, 2000). In addition, the Current Buster Separator can be connected to the existing USCG Fast-Sweep boom, and the Desmi skimmers in the Coast Guard inventory can still be used.

The implication of these results for the Coast Guard is the requirement for buoy tenders to perform oil spill recovery. Current operating procedures require that buoy tenders not exceed 1.5 knots, even when simply transiting with the SORS deployed. The equipment described here can increase the SORS capability to as much as four knots. This recovery speed would be extremely useful for large offshore spills; it would permit the buoy tenders to be more maneuverable. The last major decision is the location of the fast water capability. The first few hours are critical for response in a fast water environment and the equipment should be located where personnel are available to launch the system quickly. This would preclude locating many units with the Coast Guard Strike teams. The equipment can be set up in time for use only if a continuous spill occurs.

Training Issues

Another product that can contribute to the potential success of responses in fast water is the "Oil Spill Response in Fast Currents, A Field Guide." This guide brings together all of the information needed for oil containment and recovery in currents over one knot. An initial guide was developed based on the previous report (Coe and Burr, 1999). Additional information was added based on the field tests of equipment (Hansen, 1999, 2000) and tests at Ohmsett (DeVitis et al., 2000, 2001) conducted as part of this project. In June 2000, a working group composed of USCG, U.S. EPA, and commercial oil spill response representatives met and reviewed the preliminary draft, providing valuable input.

This field guide has been developed so that it can be used for training or responding to spills. This document begins with a decision-matrix that identifies various fast-water scenarios and provides recommended strategies. It then links to other sections of the document that contain details concerning unique hydrodynamic considerations, descriptions of scenarios and tactics, specific equipment descriptions, equipment deployment recommendations, and addresses logistics concerns. Specific sections discuss unique response issues regarding non-tidal and tidal rivers and canals, small streams, creeks and culverts, coastal areas, harbors and bays and breachways and harbor entrances. The guide includes chapters on unique booming techniques, skimming techniques in fast water, and special conditions, such as oil under ice. A chapter on support equipment addresses mooring and anchoring, boat selection and temporary storage. Thirteen appendices provide additional check-off sheets, details on vector analysis, boom force calculations, culvert flow calculations, heavy oils and safety to name just a few. Diagrams are provided that show the preferred equipment configurations. Whenever possible, photographs are also provided to reinforce the concepts. Links to appropriate Internet sites are also supplied.

This guide will specifically assist Coast Guard Marine Safety Units in working with Coast Guard operational units during an emergency response. It will also permit on-scene commanders and area supervisors to define techniques and terminology for responders in the field. It is available in hardcopy, on a CD-ROM, or can be downloaded from the RDC Internet Site. A training video and portable decision guide are being developed to facilitate the information contained in the guide for use by the Coast Guard and commercial responders (Hansen and Coe, 2001).

SUMMARY AND RECOMMENDATIONS

The systems and information developed as a result of this project are being utilized now and will result in improved fast water response.

- Boom deflectors and Boom Vanes have been purchased in several locations throughout the U.S and are being used for training and responses.

- The improvements to the HSS are being incorporated into a design modification for the system that will allow USCG buoy tenders to maneuver without the use of the bow thruster, a major performance improvement. It will also permit them to transit at a higher speed.

- The Current Buster and the UNH/SORS submergence plane skimmer could increase the SORS and VOSS operating speed to as much as 4 knots.

- The calculation for towing forces on diversion booms has been included in the fast water field guide. This is a major improvement over the previous complicated method. The equation for the towing forces can also be used by skimmer manufacturers to help design lead-in booms.

- Improvements already have been made in the flow diverters and the Stream Stripper as a result of tests within this project.

- A system from Norway that can accurately measure the amount of oil on the water surface has been evaluated and may be useful in many recovery applications.

- Presentations about the field guide have been made to multiple government and industry meetings and have generated a large number of requests for copies of the guide. Even those who have little experience or do not have the time and funds to attend specific fast water response training can greatly benefit from the information contained in the field guide. Because water currents routinely exceed 1 knot in all of the Coast Guard's Areas of Responsibility, all marine safety and operational units should be able to use this document to provide direction to their personnel and guidance when monitoring contract cleanup efforts.

Steps that should be taken to ensure that equipment is properly located and can perform the required tasks are:

- Encourage the use of equipment such as the Boom Vane, Boom Deflectors, and Flow Diverters in areas where high speed currents are always present. These systems should be stored downstream in an easily accessible area where trained crews can quickly deploy them.
- Evaluate the use of the Boom Vane for SORS and VOSS. The use of this device could reduce the size of the outrigger boom that is now required.
- Review the existing regulations for facilities and Oil Spill Response Organizations (OSROs) for fast water response techniques. Fast water areas can be identified using current tables, actual data, or the analysis done in Coe and Gurr (1999). Regulations should designate that an OSRO can qualify for fast current response if it has small draft boom and contingency plans that indicate knowledge of fast water response techniques. Fast water exercises should be periodically conducted.
- Disseminate the information in the field guide "Oil Spill Response in Fast Currents, a Field Guide" as much as possible. Cooperate with the U.S. Environmental Protection Agency and inland responders to keep the guide up-to-date. Work with area committees, Marine Safety Offices and possibly American Society for Testing and Materials (ASTM) committee F-20 (hazardous substances and oil spill response). This guide, that presents all of the information needed for response in fast currents, will assist CG and commercial responders.

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