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Environmental Protection Technology Series

OHMSETT "HIGH SEAS" PERFORMANCE TESTING: MARCO CLASS V OIL SKIMMER

Industrial Environmental Research Laboratory
Office of Research and Development
U.S. Environmental Protection Agency
Cincinnati, Ohio 45268

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OHMSETT "HIGH SEAS" PERFORMANCE TESTING: MARCO CLASS V OIL SKIMMER

by

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Contract No. 68-03-0490

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FOREWORD

When energy and material resources are extracted, processed, converted, and used, the related pollutional impacts on our environment and even on our health often require that new and increasingly more efficient pollution control methods be used. The Industrial Environmental Research Laboratory - Cincinnati (IERL-Ci) assists in developing and demonstrating new and improved methodologies that will meet these needs both efficiently and economically.

This report describes performance testing under a variety of conditions of a commercial, sorbent belt, oil skimmer used by the U.S. Navy. Based on this preliminary series of tests, judgments on controllable settings for optimizing operational efficiency can be made. The methods, results, and techniques described are of interest to those interested in specifying, using or testing such equipment. Further information may be obtained through the Resource Extraction & Handling Division, Oil and Hazardous Materials Spills Branch in Edison, New Jersey.

David G. Stephan
Director
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ABSTRACT

A MARCO Class V oil skimmer was tested at the U.S. Environmental Protection Agency's OHMSETT facility to determine the device's "high seas" performance characteristics. Performance data was obtained for several simulated offshore wave conditions at various collection speeds. Skimmer efficiency was determined at various belt speeds and induction pump rates in order to define optimum skimmer settings and to better define oil/water separator needs. This report of testing done under Contract No. 68-03-0490, Job Order No. 22, by Mason & Hanger-Silas Mason Co., Inc., for the U. S. Environmental Protection Agency covers the period September 27, 1976 to October 1, 1976 with work completed January 14, 1977.

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ABBREVIATIONS AND SYMBOLS

ABBREVIATIONS

BWD	--backward
bbls	--barrels
cm	--centimeters
m^3/s	--cubic meters per second
DWP	--deep water ports
°C	--degrees Celsuis
gals	--gallons
GPM	--gallons per minute
HC	--harbor chop
HP	--horsepower
IT	--interfacial tension
m	--meter
m^3	--cubic meters
m/s	--meters per second
m^2/s	--meters squared per second (viscosity measurement)
mm	--millimeters
min	--minute
N/m^2	--newtons per square meter
OHMSETT	--Oil and Hazardous Materials Simulated Environmental Test Tank
OPER	--operator
OPT	--optimum
%	--percent
lbs	--pounds
lbs/in	--pounds per inch
RPM	--revolutions per minute
Sp. Gr.	--specific gravity
ST	--surface tension
VDU	--vacuum distillation unit
w/	--with
w/o	--without
h	--wave height
l	--wave length

ACKNOWLEDGMENT

J.E. Sholander, Naval Surface Weapons Center, Dahlgren Laboratory, Dahlgren, VA and J.H. Friel, Naval Sea Systems Command, Supervisor of Salvage, Washington, D.C. provided valuable help during planning and testing phases. The skimmer was loaned for testing through the courtesy of the Naval Sea Systems Command, Supervisor of Salvage, Washington, DC.

P.L. Forde, MARCO Pollution Control, Seattle, WA provided expertise in operation of the skimmer and information on the skimmer's operating principles.

SECTION 1

INTRODUCTION

Increased U.S. dependence on oil shipped by water, together with increased size of oil-carrying tankers and offshore docking facilities (deep water ports), create a greater probability of a major spill, and indicate a need for oil containment and clean up devices capable of operating in wave and current conditions found in the offshore environment. Recent oil spills, such as the *Argo Merchant*, emphasize the problem of trying to clean up massive oil spills in the offshore environment.

A MARCO Pollution Control Class V Oil Skimmer was tested at the U.S. Environmental Protection Agency's Oil and Hazardous Materials Simulated Environmental Test Tank (OHMSETT) in Leonardo, N.J. Objectives of the test program were to:

1. Determine performance characteristics of the skimmer operating in "high seas conditions" generated in the OHMSETT test tank.

2. Determine oil/water separation needs for the skimmer output.

3. Determine optimum skimmer mechanical operating settings.

SECTION 2

CONCLUSIONS

HIGH SEAS PERFORMANCE

The oil recovery rate of the MARCO Class V skimmer rose 60%, from $3.7 \times 10^{-3} m^3/s$ to $5.9 \times 10^{-3} m^3/s$ as tow speed increased from 0.51 to 1.54 m/s in calm water. Only a 17% increase, from $3 \times 10^{-3} m^3/s$ to $3.5 \times 10^{-3} m^3/s$, was found in a 0.6 m HC wave over this same tow speed range.

Changing the tow speed from 0.51 to 1.54 m/s did not affect recovery efficiency in either calm water or in the 1.2 m HC wave. But the recovery efficiency declined 32%, from 73.6% to 36.8%, in the 0.6 m HC wave over this same speed range.

Throughput efficiency declined 30%, from 98.5% to 67.9%, as speed increased from 0.51 m/s to 1.54 m/s in calm water. The throughput efficiency dropped 64% in the 0.6 m HC wave and 33% in the 1.2 m HC wave over this same speed range. Thus, increased tow speed caused oil loss to increase in all cases.

Recovered fluid water content ranged from a minimum of 21.9% to a maximum maximum of 65.8%. In terms of a water volume rate, this covered a range from $1.5 \times 10^{-3} m^3/s$ to $1.8 \times 10^{-3} m^3/s$ (because tests recovering large fluid volumes contained less water than tests recovering smaller fluid volumes). The addition of settling tanks between the skimmer and the separator would lower these figures considerably, since about 20% of the water in the recovered fluid separated out in 15-30 minutes.

Optimum skimmer operating settings were different for each wave height condition tested. In calm water, a filterbelt speed of 0.94 m/s with the induction pump pressure setting of $5.2 \times 10^6 N/m^2$ and a tow speed of 1.03 m/s produced the best results. A filterbelt speed of 0.64 m/s and a pressure setting of $3.4 \times 10^6 N/m^2$ with a tow speed of 0.51 m/s worked best in the 0.6 m HC wave.

It should be noted that because of limited time, this test series was severely abbreviated, with little opportunity for repeating tests.

SECTION 3

RECOMMENDATIONS

This test program was too abbreviated. A more complete program should evaluate the effects of varying speed, wave conditions, oil type and thickness, and device operating parameters such as belt speed and induction pump speed.

Problems were encountered in measuring the large volumes of fluid recovered by the skimmer. Because several small tanks were used, to hold the collected fluid, an inconveniently large number of samples from each test resulted, each requiring a separate laboratory analysis. Use of a single larger tank would reduce both the sample load and analysis time. A more efficient system for collecting the recovery fluid, decanting the settled water, and sampling the remaining emulsion should be designed prior to additional testing.

An oil/water separation system to process the fluid recovered would make the unit more useful. Preferably, the system would be placed in the recovery line before the onboard storage tanks so that only oil would need to be stored aboard (while the separated water would be pumped back to the sea).

SECTION 4

TEST DEVICE

The MARCO Class V Oil Skimmer is a self-propelled, self-contained boat 11-m long with a beam of 3.7 m (Figures 1 and 2). Maximum speed of the vessel is 2.6 m/s. A motor-driven hydraulic drive and a 360° rotatable propeller provide maneuverability. Table 1 gives a condensed list of specifications.

The MARCO Class V skimmer may either propel itself to the spill site and pick up the spill under its own power, or be towed to the site at higher speeds (Figure 3). Wider swaths at the spill site may be swept by the addition of collection booms to the skimmer (Figure 4).

Oil collection is performed by an inclined conveyor with a continuous filterbelt which retains the oil and lets the water pass through (Figure 5). Figure 6 shows the belt passing between rollers which squeezes the oil from the belt into a collection tank. Belt porosity (to water) permits waves to pass through the belt. An induction pump (Figure 7) is used behind the belt to aid in water flow through the filterbelt and to minimize the formation of a head wave forward of the belt. Figure 8 shows a cross-section of the collection system. Appendix B provides an explanation of the filterbelt's operating principle.

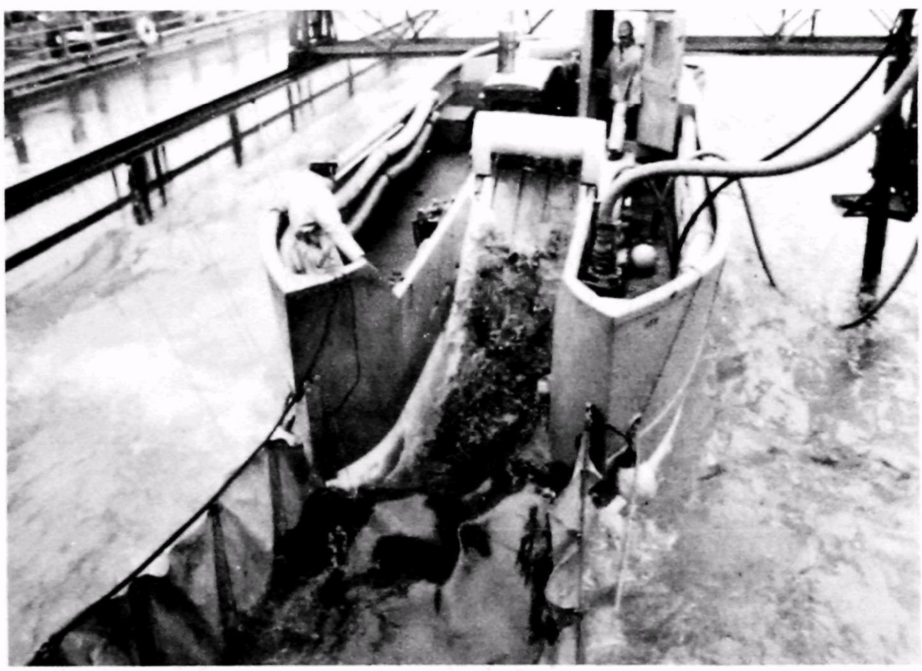


Figure 1. MARCO Class V skimmer during OHMSETT wave testing.

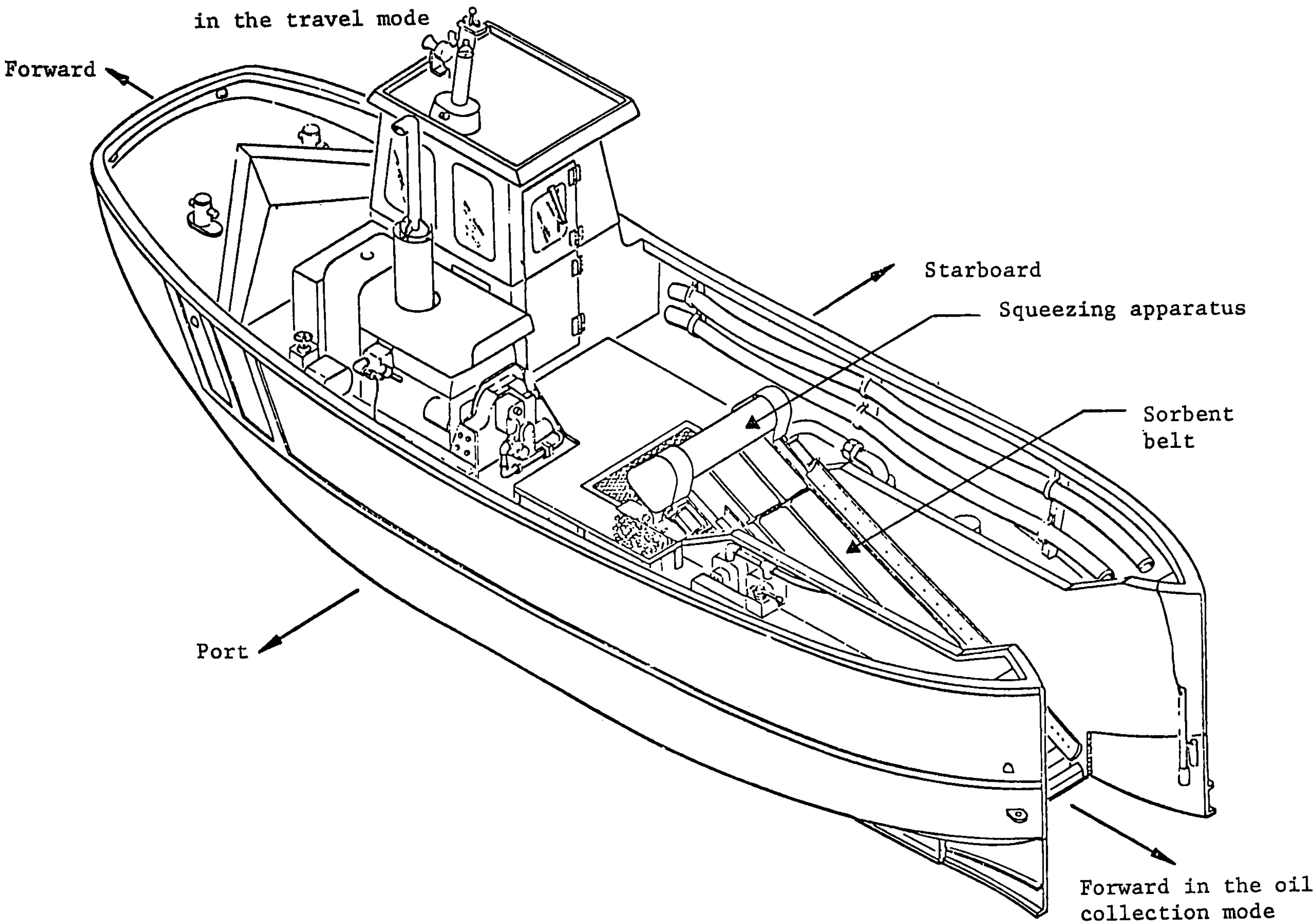


Figure 2. MARCO Class V Skimmer.

TABLE 1. CONDENSED SPECIFICATIONS MARCO CLASS V OCEAN SKIMMER

Particulars	English	Metric
Length, Overall	36'-0"	10.97 m
Beam, Overall	12'-0"	3.66 m
Displacement, R.F.S.	16,480 lbs.	750 kg
Nav. Draft. R.F.S.	3'-6"	1.07 m
F.O. Capacity	75 gals.	0.38 m^3
F.W. Capacity	None	None
Oil Slops Cap. (42 US gal/bbl)	40 bbls.	6.4 m^3
Shrinkage (Saltwater)	1360 lbs./in.	240 kg/cm
Freeboard R.F.S. Amidships	18"	0.46 m
Freeboard 1/2 F.O., Full Slops	8"	0.20 m
Free Sweep Width	6'-0"	1.83 m
Maximum Belt Submergence	3'-3"	1.0 m
Filterbelt Flow, m^3/hr at 0.51 m/s	7850	1740 m^3/hr
Induction Pump	(1) at 20 HP	(1) at 14914 W
Maximum Rated Flow	8000 GPM	1817 m^3/hr

Propulsion	
Main Engine	(1) at 100 HP, at 2900 RPM
Speed, R.F.S.	2.6 m/s
Propulsion Unit	MARCO Hydraulic Drive 360° Rotation

Equipment	
Offload Pump	(1) Progressive Cavity 45.4 m^3/hr

Mode of Operation	
Navigate	Forward or Backward (BWD)
Being towed, high speed or rough sea	Forward
Oil Skimming	BWD, w/ or w/o Diversion Booms

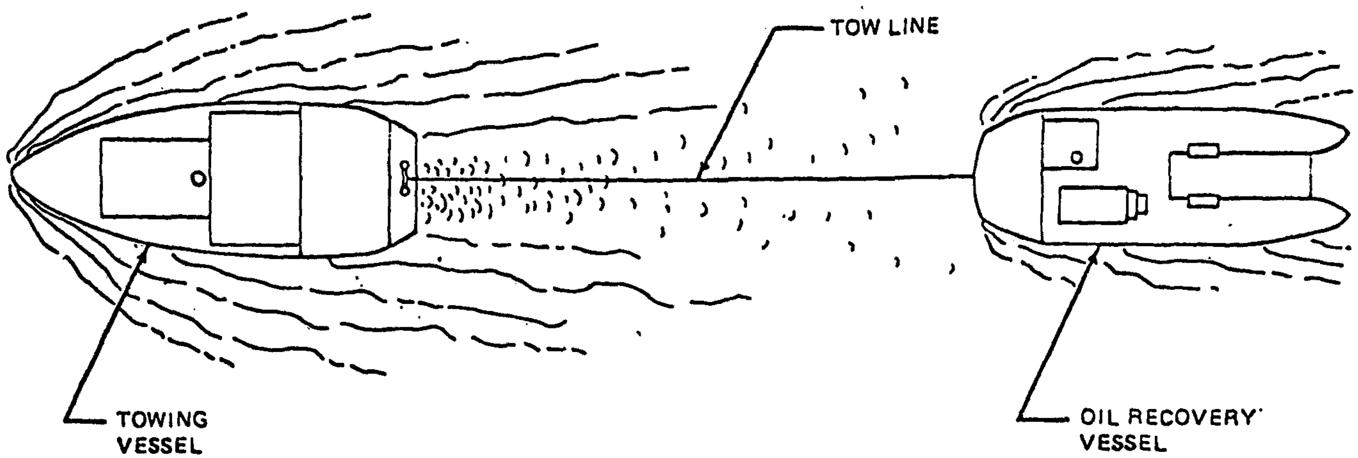


Figure 3. MARCO Class V skimmer under tow (transport only).

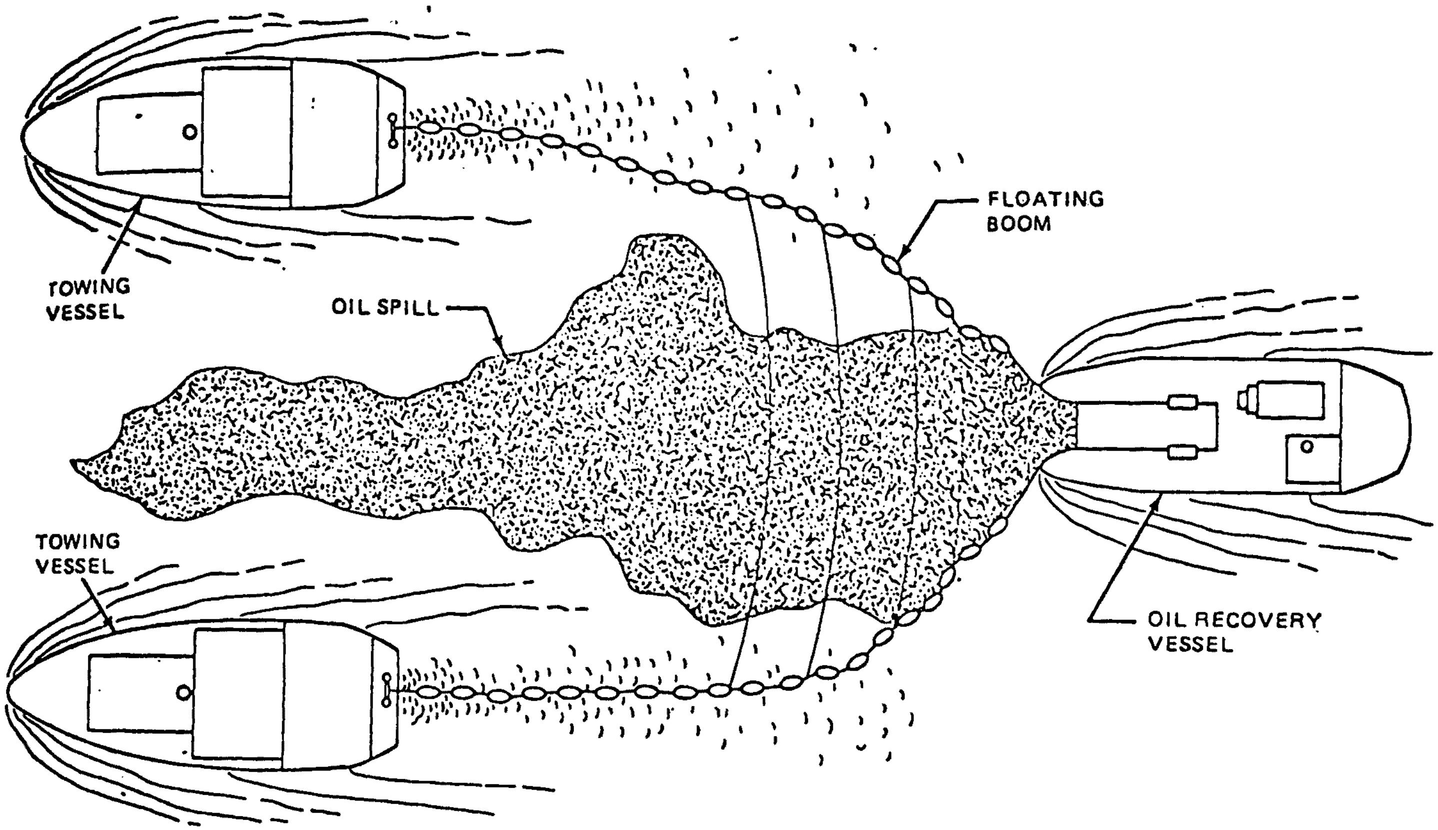


Figure 4. MARCO Class V skimmer towed for oil recovery.

Figure 5. MARCO filterbelt during oil recovery.

Figure 6. Squeeze roller assembly removing oil from the filterbelt.

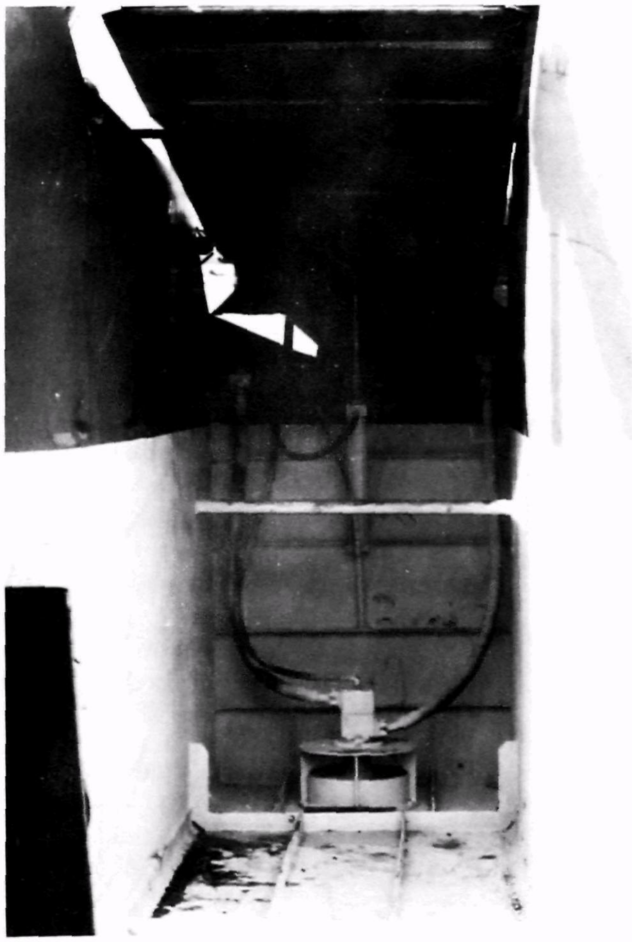


Figure 7. Induction pump mounted in skimmer bottom behind and below the filterbelt (conveyor shown here in the "up", or travel position).

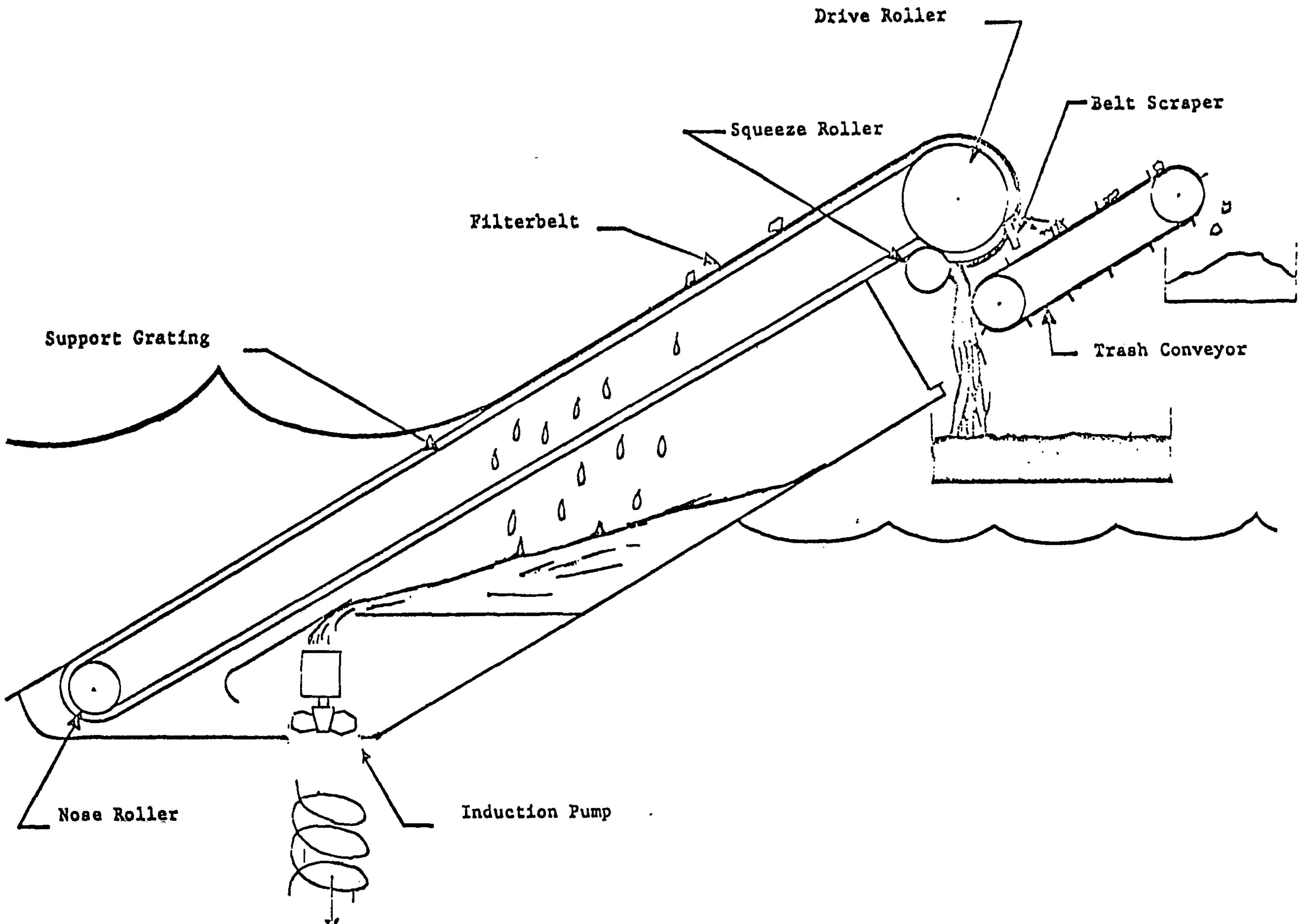


Figure 8. Cross-section diagram of the filterbelt.

SECTION 5

EXPERIMENTAL PROCEDURES

The test plan (Table 2) was designed to evaluate performance of the MARCO Class V Oil Skimmer under conditions as close as possible to those expected at an offshore oil spill. The skimmer was towed (to simulate currents) at speeds of 0.51, 1.03, and 1.52 m/s through calm water and through 0.6 m and 1.2 m harbor chop waves. The test fluid used was a straight grade lubricating oil with the observed properties given in Figure 9. Oil film thickness was held constant at three millimeters for all test runs. Manpower distribution is shown in Figure 10.

Determination of optimum skimmer mechanical settings (belt speed and induction pump rate) was also incorporated into the test matrix. Utilizing a best guess for a starting point, then testing at and around that point in an iterative scheme, the optimum settings were found.

Unusual elements of the procedure for testing this device were:

1. Pre-wetting the belt.

2. Determining steady state.

3. Determining emulsion characteristics.

The conditions of the first run with oil each day were duplicated in a second run, and the results were compared. The first was considered a dry-belt test run, while later runs were considered wet-belt runs. No consistent differences were observed between dry-belt and wet-belt tests.

Steady state was considered to be reached during a test when the composition of the recovered oil/water mixture did not vary substantially with time. The skimmer output was sampled every five seconds after the oil encountered the sorbent belt.

Discrete quantities of the recovered fluid were collected through a sample port on the exit side of the recovery pump. Analysis of the oil/water composition gave recovery efficiency. The remainder (majority) of the recovered fluid was held in 0.82 m^3 translucent, polyethylene containers and allowed to settle. The containers then had three distinct layers: oil (with a small percentage of water) on top, emulsion (high percentage of water) and water (with a small percentage of oil) on the

TABLE 2. PROPOSED TEST MATRIX.

Test no.	Oil type	Belt speed m/s	Induction pump rate $m^3/s x 10^{-3}$	Tow speed m/s	Wave hxl m	Oil thick. mm
1	Sun 1650	Opt. A	None	0.51	0	3.0
2	Sun 1650	Opt. A+ .15	None	0.51	0	3.0
3	Sun 1650	Opt. A- .15	None	0.51	0	3.0
4	Sun 1650	Opt. A*	Opt. A	0.51	0	3.0
5	Sun 1650	Opt. A*	Opt. A+	0.51	0	3.0
6	Sun 1650	Opt. A*	Opt. A+	0.51	0	3.0
7	Sun 1650	Opt. A*	Opt. A*	0.51	0	3.0
8	Sun 1650	Opt. B	None	1.03	0	3.0
9	Sun 1650	Opt. B+ .15	None	1.03	0	3.0
10	Sun 1650	Opt. B- .15	None	1.03	0	3.0
11	Sun 1650	Opt. B*	Opt. B	1.03	0	3.0
12	Sun 1650	Opt. B*	Opt. B+	1.03	0	3.0
13	Sun 1650	Opt. B*	Opt. B-	1.03	0	3.0
14	Sun 1650	Opt. B*	Opt. B*	1.03	0	3.0
15	Sun 1650	Opt. C	None	1.52	0	3.0
16	Sun 1650	Opt. C+ .15	None	1.52	0	3.0
17	Sun 1650	Opt. C- .15	None	1.52	0	3.0
18	Sun 1650	Opt. C*	Opt. C	1.52	0	3.0
19	Sun 1650	Opt. C*	Opt. C+	1.52	0	3.0
20	Sun 1650	Opt. C*	Opt. C-	1.52	0	3.0
21	Sun 1650	Opt. C*	Opt. C*	1.52	0	3.0
22	Sun 1650	Opt. C*	Opt. C*	1.52	0	3.0
23	Sun 1650	Opt. B*	Opt. B*	1.03	0.6x9.1	3.0
24	Sun 1650	Opt. A*	Opt. A*	0.51	0.6x9.1	3.0
25	Sun 1650	Opt. A*	Opt. A*	0.51	0.6 HC	3.0
26	Sun 1650	Opt. B*	Opt. B*	1.03	0.6 HC	3.0
27	Sun 1650	Opt. C*	Opt. C*	1.52	0.6 HC	3.0
28	Sun 1650	Opt. A*	Opt. A*	0.51	1.2 HC	3.0
29	Sun 1650	Opt. B*	Opt. B*	1.03	0.6 HC	3.0
30	Sun 1650	Opt. C*	Opt. C*	1.52	1.2 HC	3.0
31	Sun 1650	Opt. D	None	2.03	0	3.0
32	Sun 1650	Opt. D+ .15	None	2.03	0	3.0
33	Sun 1650	Opt. D- .15	None	2.03	0	3.0
34	Sun 1650	Opt. D*	Opt. D	2.03	0	3.0
35	Sun 1650	Opt. D*	Opt. D+	2.03	0	3.0
36	Sun 1650	Opt. D*	Opt. D-	2.03	0	3.0
37	Sun 1650	Opt. D*	Opt. D*	2.03	0	3.0
38	Sun 1650	Opt. E	None	2.54	0	3.0
39	Sun 1650	Opt. E .15	None	2.54	0	3.0
40	Sun 1650	Opt. E- .15	None	2.54	0	3.0
41	Sun 1650	Opt. E*	Opt. E*	2.54	0	3.0
42	Sun 1650	Opt. E*	Opt. E+	2.54	0	3.0
43	Sun 1650	Opt. E*	Opt. E-	2.54	0	3.0

Notes-- Opt. A, B, C, D, or E designates the best initial estimate of what that optimum setting should be.

Opt. A+ = 0.15 means to increase the setting by 0.15
Opt. A- = 0.15 means to decrease the setting by 0.15
Opt. A* = designates the optimum value found via testing.

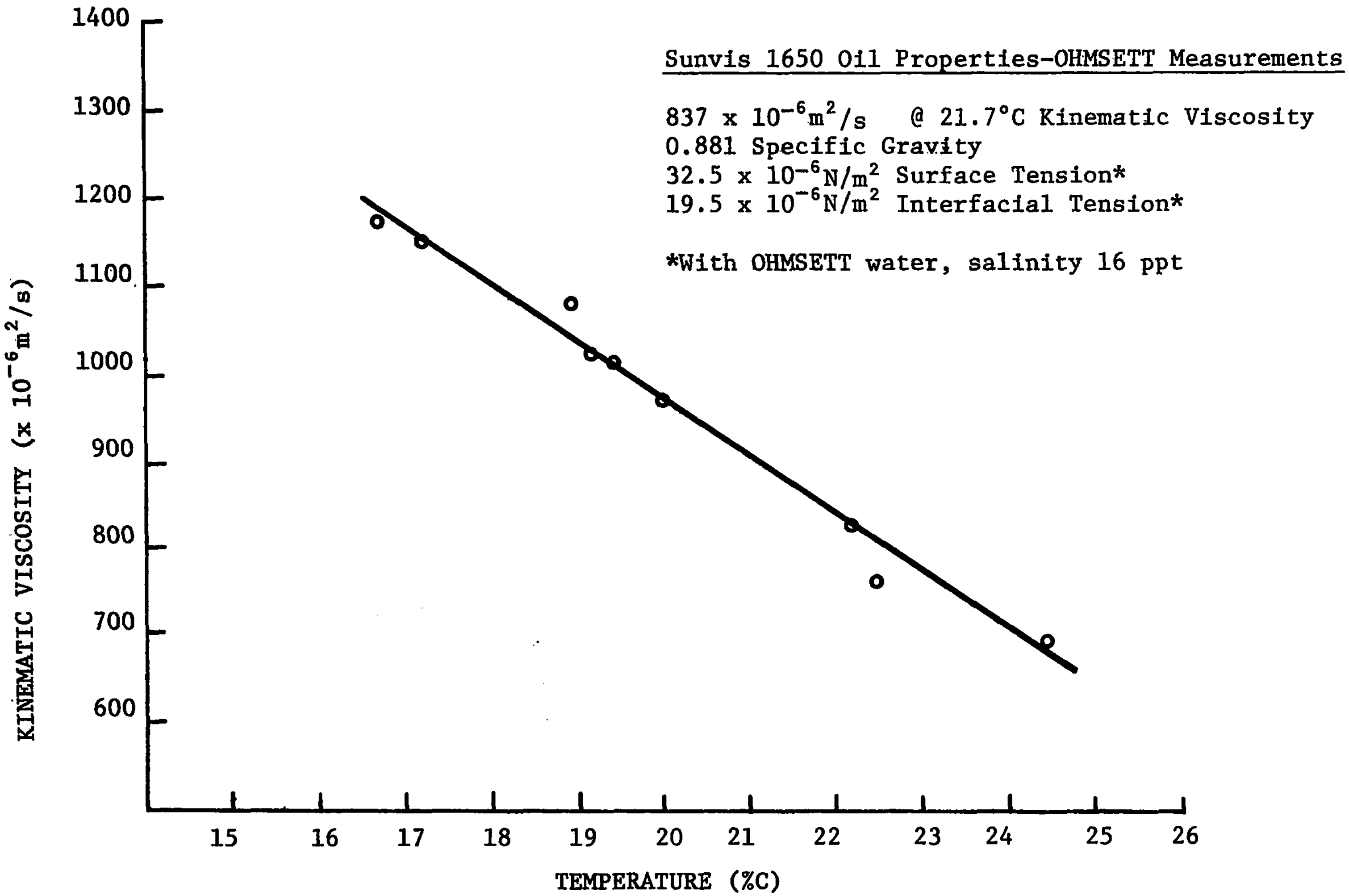


Figure 9. Graph of kinematic viscosity as a function of temperature for Sunvis 1650 oil.

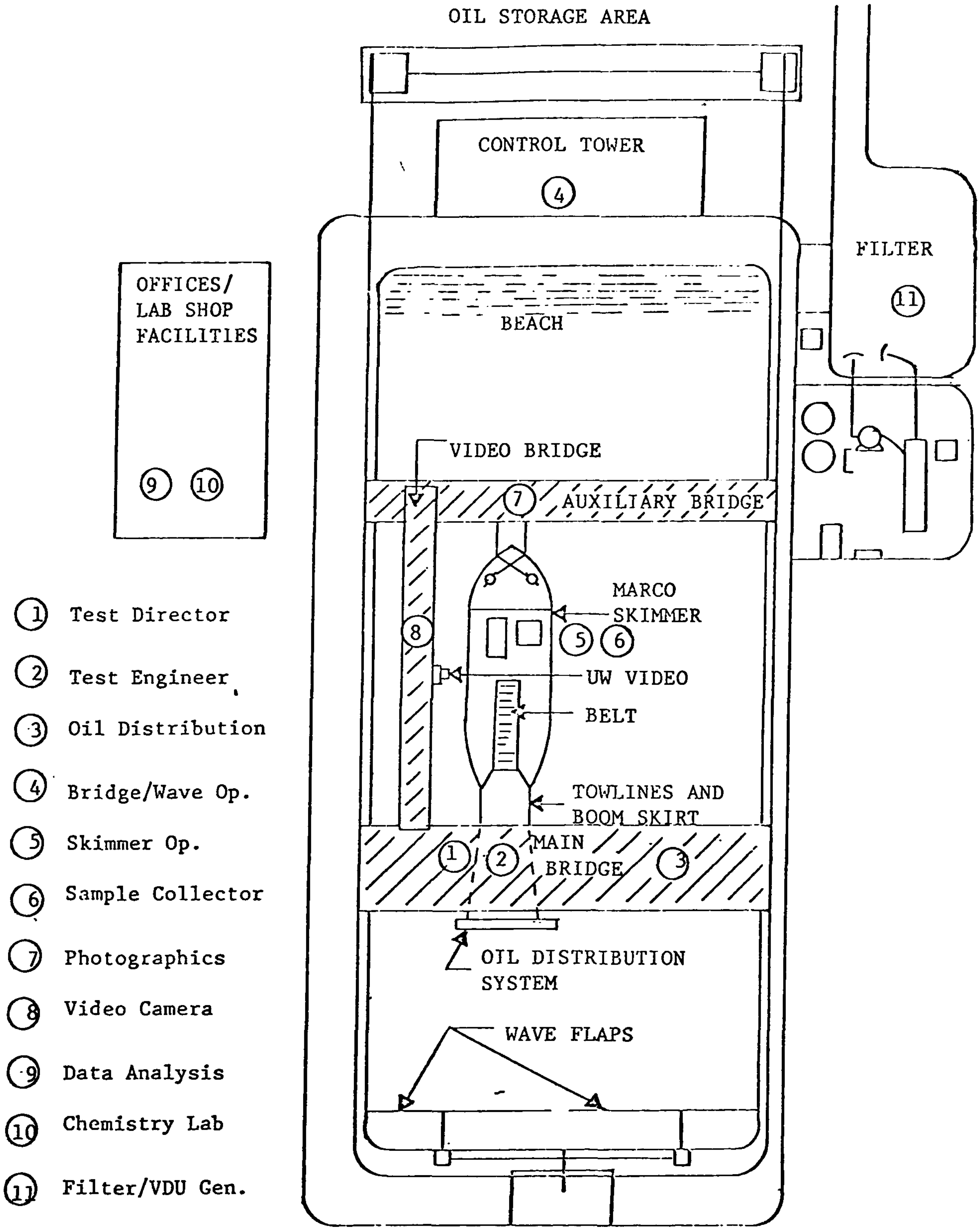


Figure 10. Test tank layout of MARCO V.

bottom. Laboratory analysis of each fraction gave the actual oil content of the fluid recovered by the skimmer. From this total sample came data for the recovery rate and throughput efficiency.

The analysis procedure also measured the degree of emulsification caused by the belt and oil laydown. To determine emulsification properties, percent water was measured at various centrifuging times to produce a curve of percent water vs. centrifuge time. Centrifuging continued until the water measurement did not change. This point on the curve was used to find total water and total oil contents in the recovered fluid.

Oil was distributed from the main bridge onto the water into the mouth of the two V-booms which angled back to the skimmer's mouth. Usually, 100% of the oil was encountered by the skimmer.

SECTION 6

RESULTS AND DISCUSSION

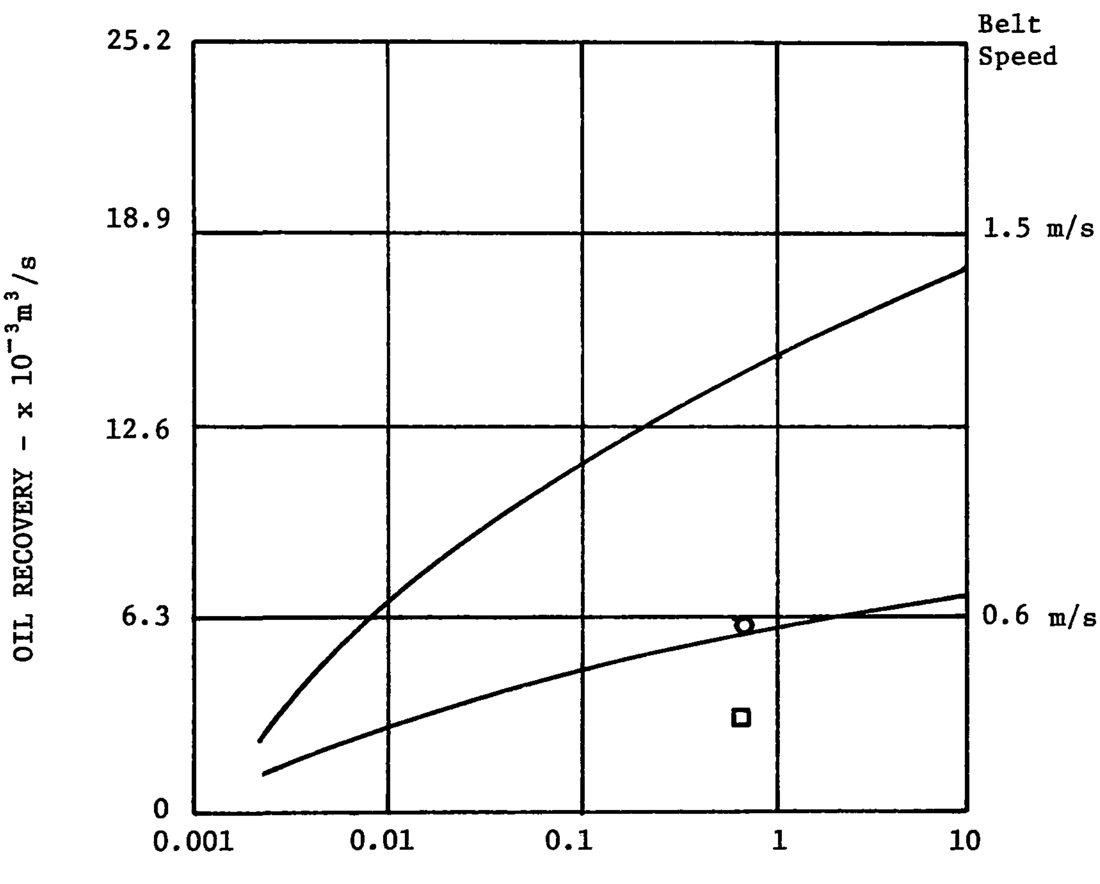
The highest oil recovery rate in calm water was $6.6 \times 10^{-3} m^3/s$ at a tow speed of 1.03 m/s. Recovery rate increased with speed because belt capacity was never reached during these tests. Data obtained in the OHMSETT test program with a 3 mm thick oil slick are plotted together with curves of maximum (oil-saturated belt) oil capacity from MARCO Pollution Control in Figure 11. Both data points are well below the maximums as shown by the curves.

Increased tow speed and wave severity both resulted in decreased throughput efficiency. The maximum observed efficiency of 99% occurred in calm water at a tow speed of 0.51 m/s. Increased speed caused oil to be washed out of the belt in calm water, lowering throughput efficiency up to 31%. Oil droplets washed out of the belt were ejected from the skimmer by the induction pump (Figure 12). Waves lowered calm-water efficiency 18 to 59% at comparable tow speeds in the 0.6 m HC wave and 40% in the 1.2 m HC. This reduction results from skimmer motion in wave conditions, coupled with waves throwing oil over the booms used to funnel it into the skimmer.

Increased tow speed caused no effect on the average recovery efficiency of 78% in calm water. This result is comparable with those determined by MARCO Pollution Control (Figure 13). Harbor chop waves decreased recovery efficiency at all speeds with declines of 50% observed at higher speeds and also with the higher wave condition. HC wave test recovery rates dropped by 20 to 58% compared to the calm water results. Again, causes were pitching of the skimmer in the waves and splashing of oil over the funnel booms.

Results are summarized in Table 3. The full matrix of tests actually conducted is given in Appendix C, Table C-1.

BASIS: 4 Pores Per cm Material
Belt Saturation
2.54 cm thick x 91.4 cm wide Belt



O = Recovery rate (OHMSETT Testing) @ 1.54 m/s
□ = Recovery rate (OHMSETT Testing) @ 0.51 m/s
both with 3 mm thick slick

Figure 11. Oil recovery for the MARCO Class V.

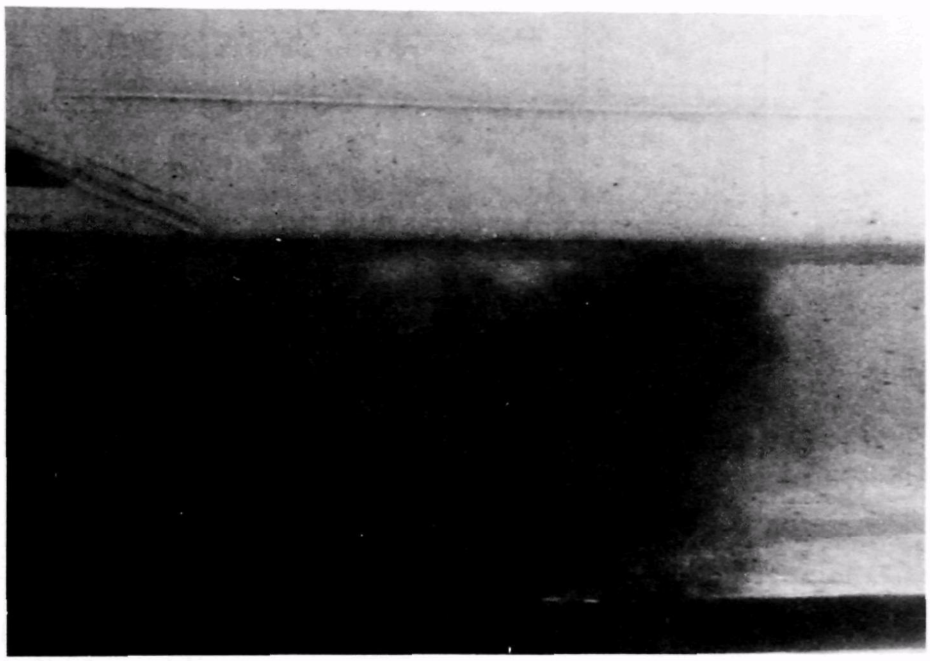
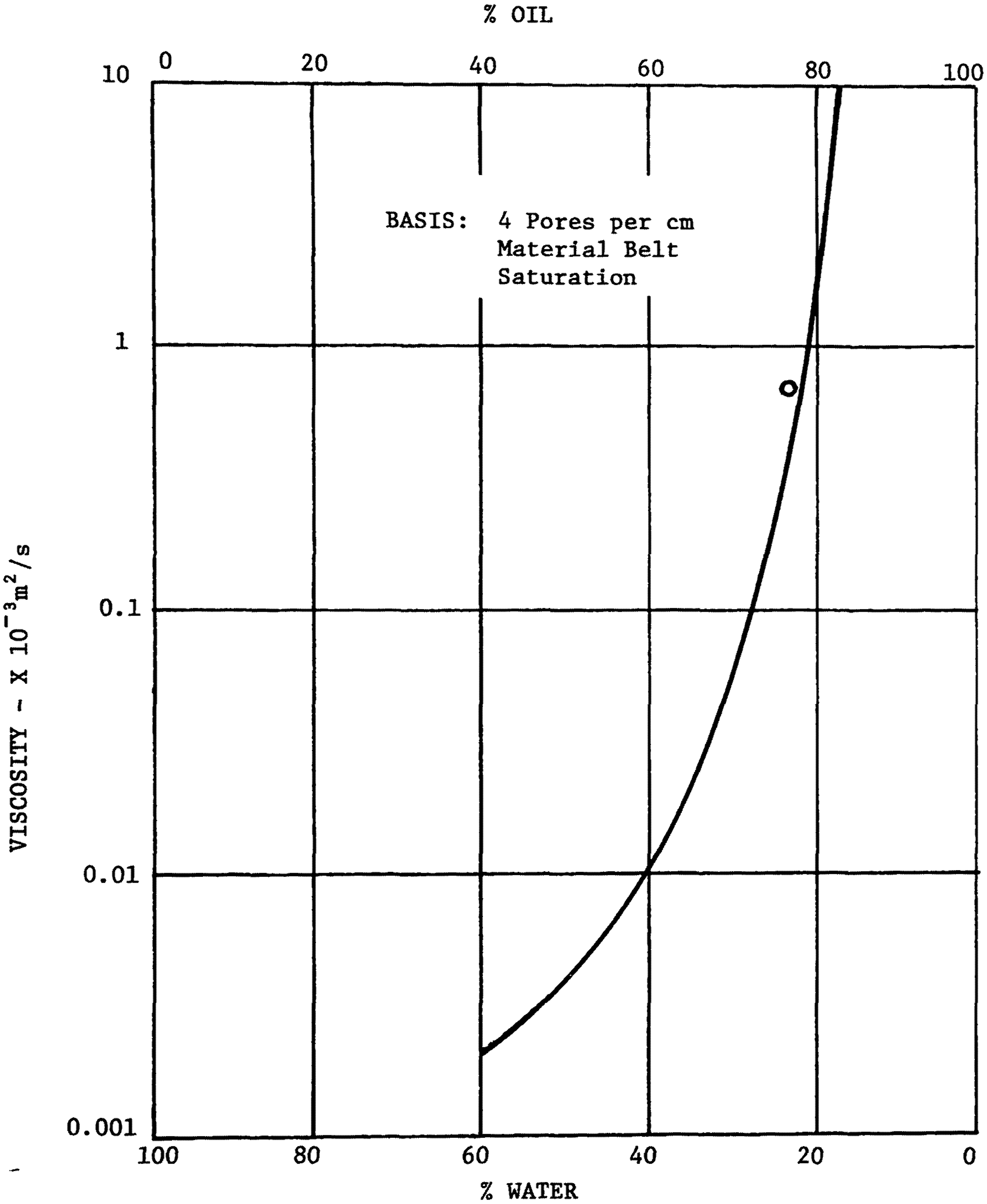


Figure 12. Oil droplets ($850 \times 10^{-6} m^2/s$ Kinematic Viscosity) washed from the filterbelt being ejected from the skimmer by the induction pump.



O = OHMSETT test data average in calm water

Figure 13. Water retention characteristics (recovery efficiency) of filterbelt.

TABLE 3. SUMMARY OF RESULTS

Wave	Calm			0.6 m HC			1.2 m HC		
Tow Speed m/s	0.51	1.03	1.54	0.51	1.03	1.54	0.51	1.03	1.54
Recovery Efficiency %	78.1	77.9	76.8	73.6	50.8	36.8	35.4	34.2	----
Recovery Rate $x10^{-3}m^3$ /s	3.7	6.6	5.9	3.0	3.3	3.5	----	2.8	----
Throughput Efficiency %	98.5	92.9	67.9	76.1	44.6	27.7	59.6	39.8	----

$$\text{Recovery Efficiency} = \frac{\text{Oil Recovered } (m^3)}{\text{Total Fluid Recovered } (m^3)} \times 100$$

$$\text{Recovery Rate} = \frac{\text{Oil Recovered } (m^3)}{\text{Total Recovery Time (sec)}}$$

$$\text{Throughput Efficiency} = \frac{\text{Oil Recovered } (m^3)}{\text{Oil Distributed } (m^3)} \times 100$$

BIBLIOGRAPHY

1. Norton, R.W. and D.W. Lerch. An Oil Recovery System for San Francisco Bay Area. In: Proceedings of the Conference on Prevention and Control of Oil Pollution. American Petroleum Institute, Washington, D.C., 1975. pp. 317-322.

2. Smith, F.M. Developing a Total Oil Spill Cleanup Capability in the San Franciso Bay Area. In: Proceedings of the Joint Conference on Prevention and Control of Oil Pollution. American Petroleum Institute, Washington, D.C., 1973. pp. 21-26.

APPENDIX A

OHMSETT DESCRIPTION

United States Environmental Protection Agency

Figure A-1. Photograph of OHMSETT.

The U.S. Environmental Protection Agency is operating an Oil and Hazardous Materials Simulated Environmental Test Tank (OHMSETT) located in Leonardo, New Jersey. This facility provides an environmentally safe place to conduct testing and development of devices and techniques for the control of oil and hazardous materials spills.

The primary feature of the facility is a pile-supported, concrete tank with a water surface 203.3-m long by 19.8-m wide and with a depth of 2.44 m. The tank can be filled with either fresh or salt water. The tank is spanned by a towing bridge with a capability of towing loads up to 15422.4 kg at speeds to 3.05 m/s for a duration of 45 seconds. Slower speeds yield longer test runs. The towing bridge is equipped to lay oil on the surface of the water several feet ahead of the device being tested, such that reproducible thicknesses and widths of oil slicks can be achieved with minimum interference by wind.

The principle systems of the tank include a wave generator and beach, and a filter system. The wave generator and absorber beach have capabilities of producing minimum reflection waves to 0.61-m high and 24.38-m long, as well as a series of reflecting, complex waves meant to simulate the water surface of a harbor or estuary. The water is clarified by recirculation through a 1.26 m^3/s diatomaceous earth filter system to permit underwater photography and video imagery, and to remove the hydrocarbons that enter the tank water as a result of testing. The towing bridge has a built in skimming board which can move oil on to the North end of the tank for cleanup and recycling.

When the tank must be emptied for maintenance purposes, the entire water volume 9842 m^3 is filtered and treated until it meets all applicable State and Federal water quality standards before being discharged. Additional specialized equipment will be used whenever hazardous materials are used for tests. One such device is a trailer-mounted carbon treatment unit which is available for removal of organic materials from the water.

Tests at the facility are supported from a 650 square meter building adjacent to the tank. This building houses offices, a quality control laboratory (which is very important since test oils and tank water are both recycled), a small machine shop, and an equipment preparation area.

This government-owned, contractor-operated facility is available for testing purposes on a cost-reimbursable basis. The operating contractor, Mason & Hanger-Silas Mason Co., Inc., provides a staff of twelve multi-disciplinary personnel. The U.S. Environmental Protection Agency provides expertise in the area of spill control technology, and overall project direction.

For additional information, contact:

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Edison, New Jersey 08817
Phone: 201-321-6631

APPENDIX B

FILTERBELT PRINCIPLES

The characteristics of the filterbelt material are all-important in the oil pick-up process. If both water and oil can, by virtue of belt characteristics, flow into the belt at the same rate, the separation of the two can occur in or on the belt.

The flow-through filterbelt principle developed by the Martin Marietta Corporation Research Department solves the problem of allowing relatively free water flow but capturing and removing oil. In this system, open cell polyurethane foam is used which has relatively large cell dimensions. A number of considerations were involved in selecting the pore dimensions:

a) Flow-Through Ability

The pores should be large for minimum resistance to the flow of water through the belt so that the actual encounter of oil carried by the water to the belt is maximized.

b) Water Retention

The pores should be large enough to permit water to drain completely and rapidly from the foam after removal from the water surface. The pore size is very important in this regard. If the pore (which is oleophilic and hydrophobic) is too small, droplets of water will be held up by water surface tension forces, and a large volume of water is retained in the foam. A droplet of water cannot stably reside in foam of pore size larger than 0.25 cm, and minimum water pickup is achieved. All MARCO skimmers provide for onboard gravity oil/water separation and water decanting which further reduces the actual water content in the recovered mixture. This water is pumped overboard ahead of the operating filterbelt where entrained oil is recaptured.

c) Oil Retention

Pore size is related to oil retention capability as well as to water retention, even though the physical mechanisms by which each is held are different. A water droplet cannot fall through a small hydrophobic pore, but oil adheres to the oleophilic material by wetting. The significant factor to consider, therefore, is maximizing oil retention and minimizing water retention. However, as the oil viscosity increases, the oil begins to be transported on the surface of the filterbelt rather than throughout the belt and recovery ratios may vary considerably.

Presenting Spill Oil to the Filterbelt

The MARCO filterbelt conveyor selectively lifts spilled oil off the surface of waves or calm water. Collected oil and associated debris are carried via the conveyor system to segregated storage onboard MARCO oil spill recovery vessels.

Inboard hull shapes and fairings of MARCO skimming vessels are shaped to provide a smooth flow of spilled oil and water to the pickup conveyor. The flow of spilled oil to the MARCO collection conveyor is caused by the forward motion of the skimmer vessels and a flow induction propeller(s) located behind the oil conveyor just below the surface. Porosity of the belt plus the flow from the induction pump is used to reduce/eliminate the frontal pressure wave caused by an advancing oil recovery system, by causing the water, under the spilled oil, to flow through the oil collection belt.

High Viscosity Oil Recovery Considerations

Viscous semi-solid oil lays on the surface of the MARCO filterbelt. This oil is most effectively removed from the filterbelt surface by the shearing or stripping action of a "Doctor Blade" addressed against the filterbelt at the head roller. The "doctor blade" is a spring tensioned assembly which is adjustable for penetration into the filterbelt surface or the blade may be quickly raised out-of-position when not required.

Light oils that flow as true liquids are pressed from the 1" thick filterbelt by a tensioned squeeze roller. When operating in a spill with very viscous oils, the polyurethane foam filterbelt can be replaced with the MARCO Bunkerbelt. The Bunkerbelt is an open weave, reinforced belt which transports the oil, "conveyor" fashion, on the surface of the belt. This belt, because of its very porous nature, enables the induction pump to produce a very vigorous flow to the belt. This very vigorous flow is important when processing the heavy, viscous oils, since these oils do not flow easily. The continuous flow of water under the oil helps to collect and transport the oil to the belt, where it can be lifted out of the water.

APPENDIX C

DATA AND GRAPHICS

Data presented was obtained during testing of the MARCO Class V and includes such variables as:

Independent Variables	Dependent Variables
Test Number	Recovery Rate
Oil Type and Properties	Throughput Efficiency
Ambient Conditions	Recovery Efficiency
Oil Distribution Rate	
Slick Thickness	
Wave Condition	
Tow Speed	
Skimmer Equipment Settings	

TABLE C-1. TEST RESULTS MARCO CLASS V OCEAN SKIMMER

DATE	TIME	TEST NUMBER	TEST FLUID PROPERTIES: TYPE OIL	TEMPERATURE °C	VISCOSITY $\times 10^{-6} m^2/s$	SURFACE TENSION $\times 10^{-3} N/m$	INTERFACIAL $\times 10^{-3} N/m$	SPECIFIC GRAVITY	AMBIENT CONDITIONS: AIR TEMPERATURE °C	WIND SPEED m/s	WIND DIRECTION	SLICK PARAMETERS: DISTRIBUTION RATE $\times 10^{-3} m^3/s$	SLICK THICKNESS mm	WAVE CONDITION	TOW SPEED m/s	STEADY STATE TEST TIME sec.	TEST EQUIP. SETTINGS: BELT SPEED m/s	PRESSURE DROP $\times 10^5 N/m^2$	PERFORMANCE CHARACTERISTICS: RECOVERY RATE $\times 10^{-3} m^3/s$	THROUGHPUT EFF. %	RECOVERY EFF. %
9/28	0929	1	Sun 1650	21.7	837	32.5	19.5	0.881	15.5	5.8	E	5.1	11.0	CALM	0.51		0.46	34.4		98.5	78.1
9/28	1058	2	Sun 1650	21.7	837	32.5	19.5	0.881	17.2	3.6	E	5.0	10.7	CALM	0.51		0.46	34.4		81.5	60.0
9/28	1422	1R	Sun 1650	21.7	837	32.5	19.5	0.881	19.5	2.2	E	4.8	10.4	CALM	0.51		0.64	34.4		78.6	51.6
9/28	1457	2R	Sun 1650	21.7	837	32.5	19.5	0.881	21.1	2.7	E	5.4	11.6	CALM	0.51	210	1.22	34.4	2.38	77.8	42.4
9/29	0841	4	Sun 1650	21.7	837	32.5	19.5	0.881	11.1	3.1	E	5.0	10.8	CALM	0.51	135	0.91	48.2	3.73	83.6	54.6
9/29	0928	4R	Sun 1650	21.7	837	32.5	19.5	0.881	12.8	1.8	E	5.0	10.9	CALM	0.51	155	0.91	34.4	3.46	88.7	52.7
9/29	1049	8	Sun 1650	23.9	738	31.7	23.1	0.880	16.1	2.2	E	7.9	8.5	CALM	1.03	70	1.25	51.7	6.49	95.9	59.3
9/29	1130	9	Sun 1650	23.9	738	31.7	23.1	0.880	16.7	3.6	E	9.1	9.8	CALM	1.03	85	1.16	51.7	5.72	89.1	62.7
9/29	1355	10	Sun 1650	23.9	738	31.7	23.1	0.880	20.0	4.5	E	10.7	11.6	CALM	1.03	90	0.94	51.7	6.64	92.9	77.9
9/29	1418	11	Sun 1650	23.9	738	31.7	23.1	0.880	20.0	3.1	E	11.0	11.9	CALM	1.03	72	1.22	68.9	7.91	86.0	68.1
9/29	1441	12	Sun 1650	23.9	738	31.7	23.1	0.880	20.0	3.1	E	11.0	11.8	CALM	1.03	97	1.22	34.4	6.00	88.4	61.0
9/30	1100	15	Sun 1650	23.9	738	31.7	23.1	0.880	16.1	0.0	E	13.3	9.6	CALM	1.54	68	0.91	68.9	5.32	45.3	72.8

(Continued)

TABLE C-1. (Continued)

DATE	TIME	TEST NUMBER	TEST FLUID PROPERTIES: TYPE OIL	TEMPERATURE °C	VISCOSITY x 10^{-6} m²/s	SURFACE TENSION x 10^{-3} N/m	INTERFACIAL x 10^{-3} N/m	SPECIFIC GRAVITY	AMBIENT CONDITIONS: AIR TEMPERATURE °C	WIND SPEED m/s	WIND DIRECTION	SLICK PARAMETERS: DISTRIBUTION RATE x 10^{-3} m³/s	SLICK THICKNESS mm	WAVE CONDITION	TOW SPEED m/s	STEADY STATE TEST TIME sec.	TEST EQUIP. SETTINGS: BELT SPEED m/s	PRESSURE DROP x 10^5 N/m²	PERFORMANCE CHARACTERISTICS: RECOVERY RATE x 10^{-3} m³/s	THROUGHPUT EFF. %	RECOVERY EFF. %
9/30	1135	15R	Sun 1650	23.9	738	31.7	23.1	0.880	16.7	0.0	SE	12.2	8.8	CALM	1.54	71	0.91	68.9	6.57	63.5	77.8
9/30	1322	16	Sun 1650	23.9	738	31.7	23.1	0.880	15.5	0.0	SW	6.3	4.5	CALM	1.54	60	0.91	86.1	5.24	83.1	77.3
9/30	1408	16R	Sun 1650	23.9	738	31.7	23.1	0.880	13.9	0.4	SE	12.7	9.1	CALM	1.54	75	0.91	86.1	5.79	57.1	75.5
9/30	1500	25	Sun 1650	23.9	738	31.7	23.1	0.880	13.3	0.4	SE	6.1	13.1	0.6m HC	0.51	186	0.64	34.4	2.97	76.1	73.6
10/1	0900	26	Sun 1650	23.9	738	31.7	23.1	0.880	15.5	7.6	SW	9.9	10.7	0.6m HC	1.03	80	0.91	51.7	3.31	44.6	50.8
10/1	0946	27	Sun 1650	23.9	738	31.7	23.1	0.880	15.5	6.7	SW	13.6	9.7	0.6m HC	1.54	65	0.61	68.9	3.46	27.7	36.8
10/1	1102	28	Sun 1650	23.9	738	31.7	23.1	0.880	15.5	5.8	SW	4.9	10.5	1.2m HC	0.51		0.61	34.4		59.6	35.4
10/1	1326	29	Sun 1650	23.9	738	31.7	23.1	0.880	15.5	6.3	SW	6.9	7.5	1.2m HC	1.03	60	0.61-0.91	75.8	2.76	39.8	34.2

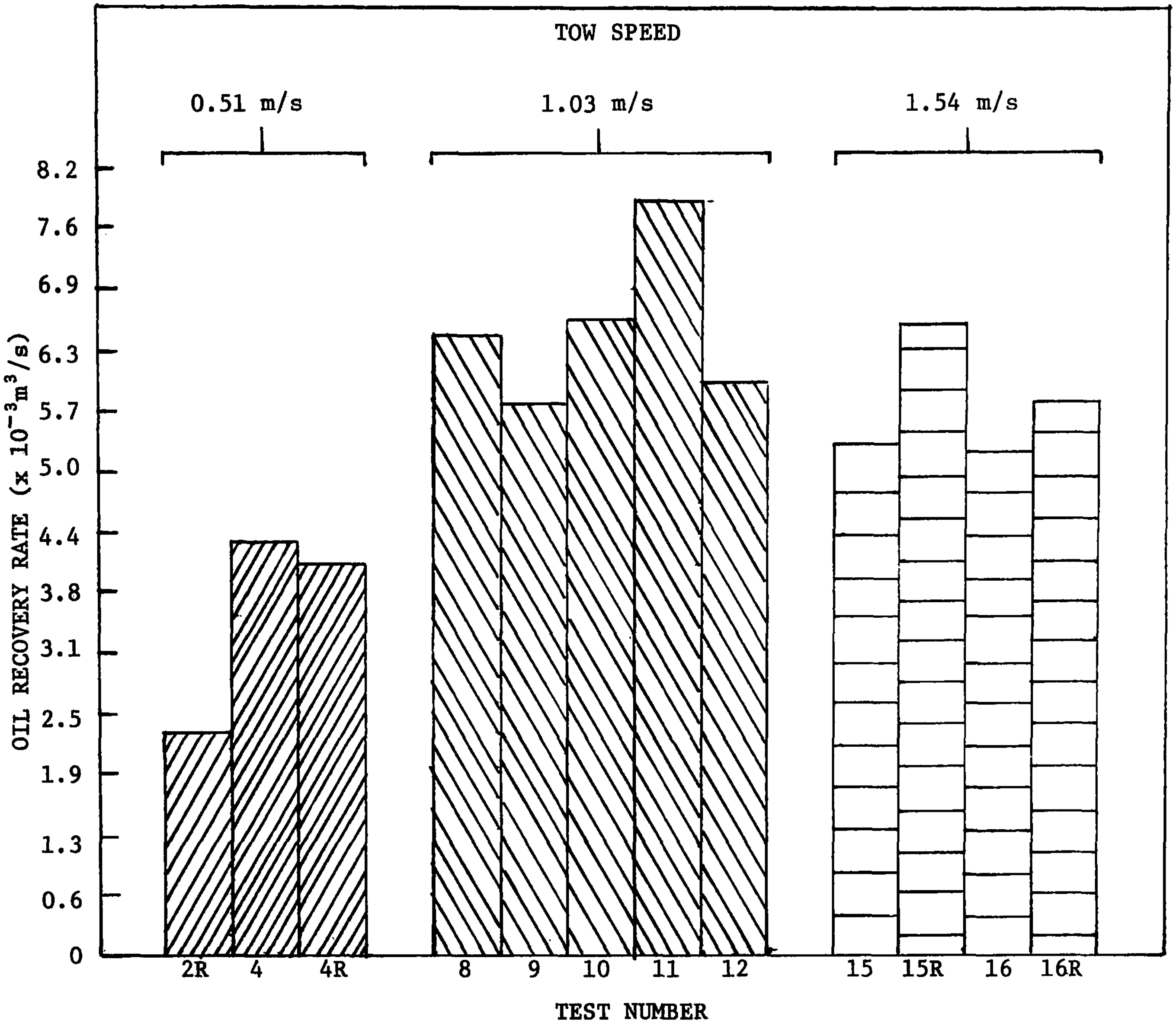

Figure C-1. Oil Recovery Rate for MARCO CLASS V Ocean Skimmer in calm water at various equipment settings with 3 mm thick slick of Sunvis 1650 oil.

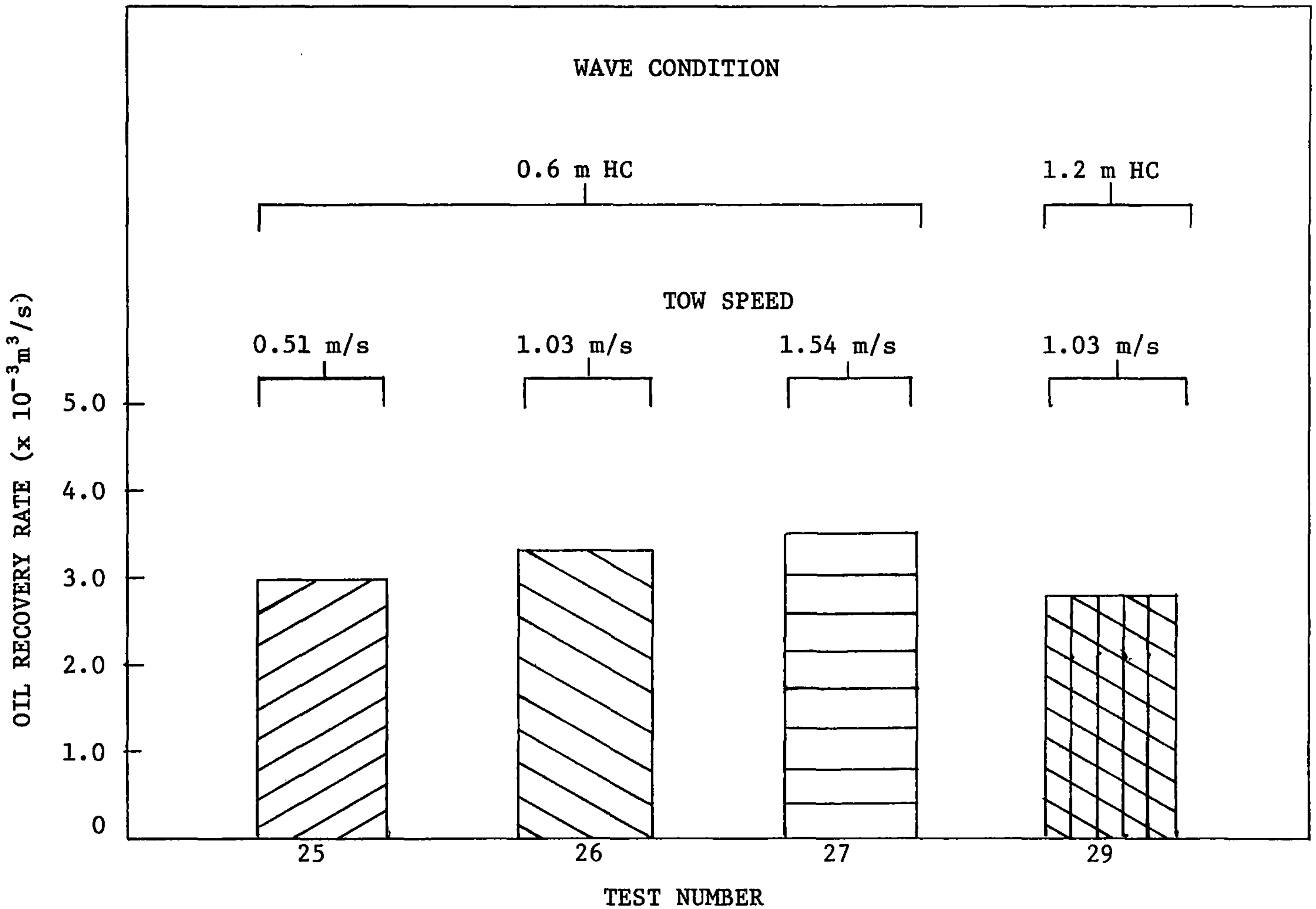

Figure C-2. Oil Recovery Rate for MARCO Class V Ocean Skimmer in 0.6m and 1.2 m Harbor Chops at optimum equipment settings with 3 mm thick slick of Sunvis 1650 oil.

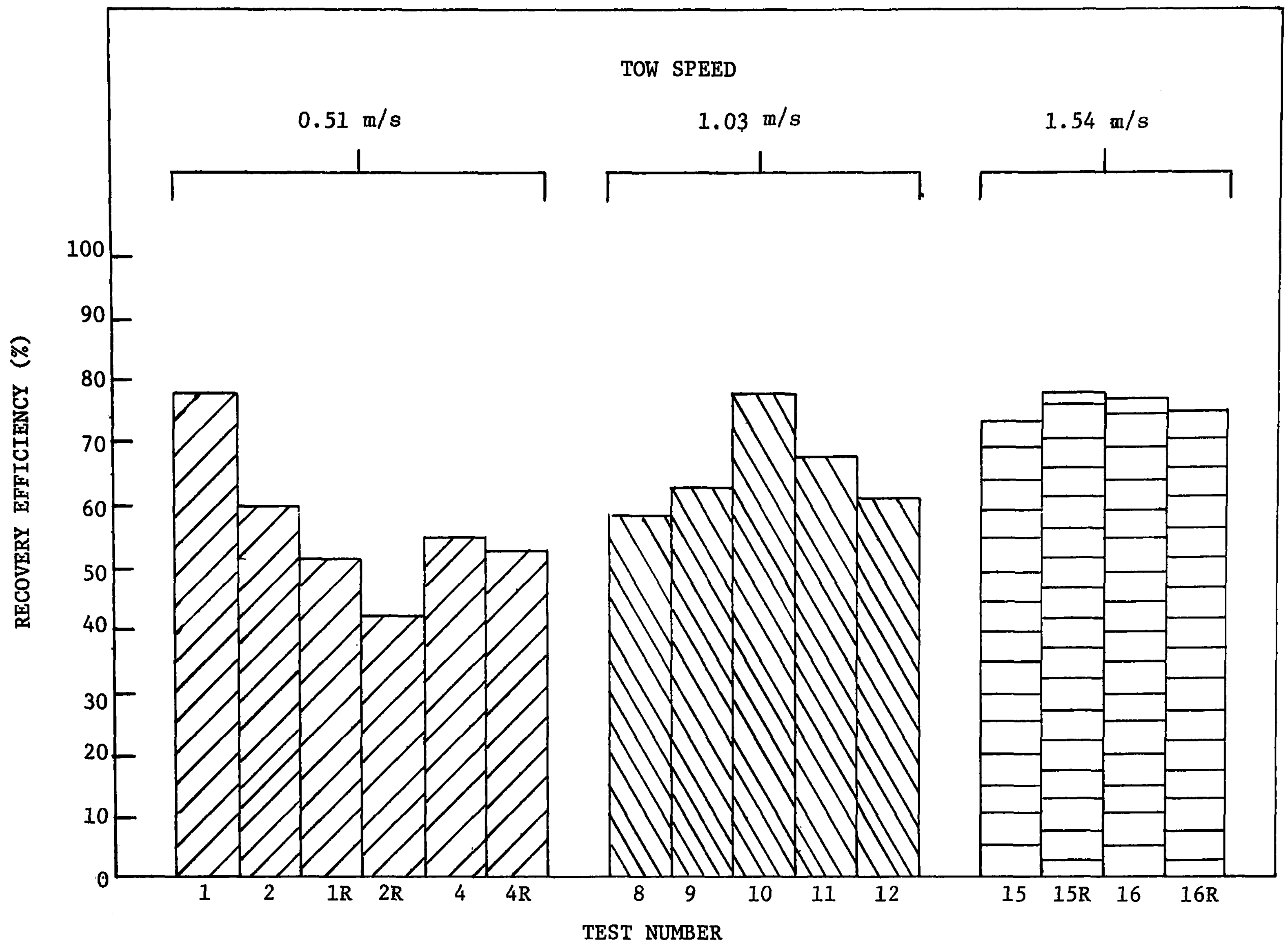

Figure C-3. Recovery Efficiency for MARCO Class V Ocean Skimmer in calm water at various equipment settings with 3 mm thick slick of Sunvis 1650 oil.

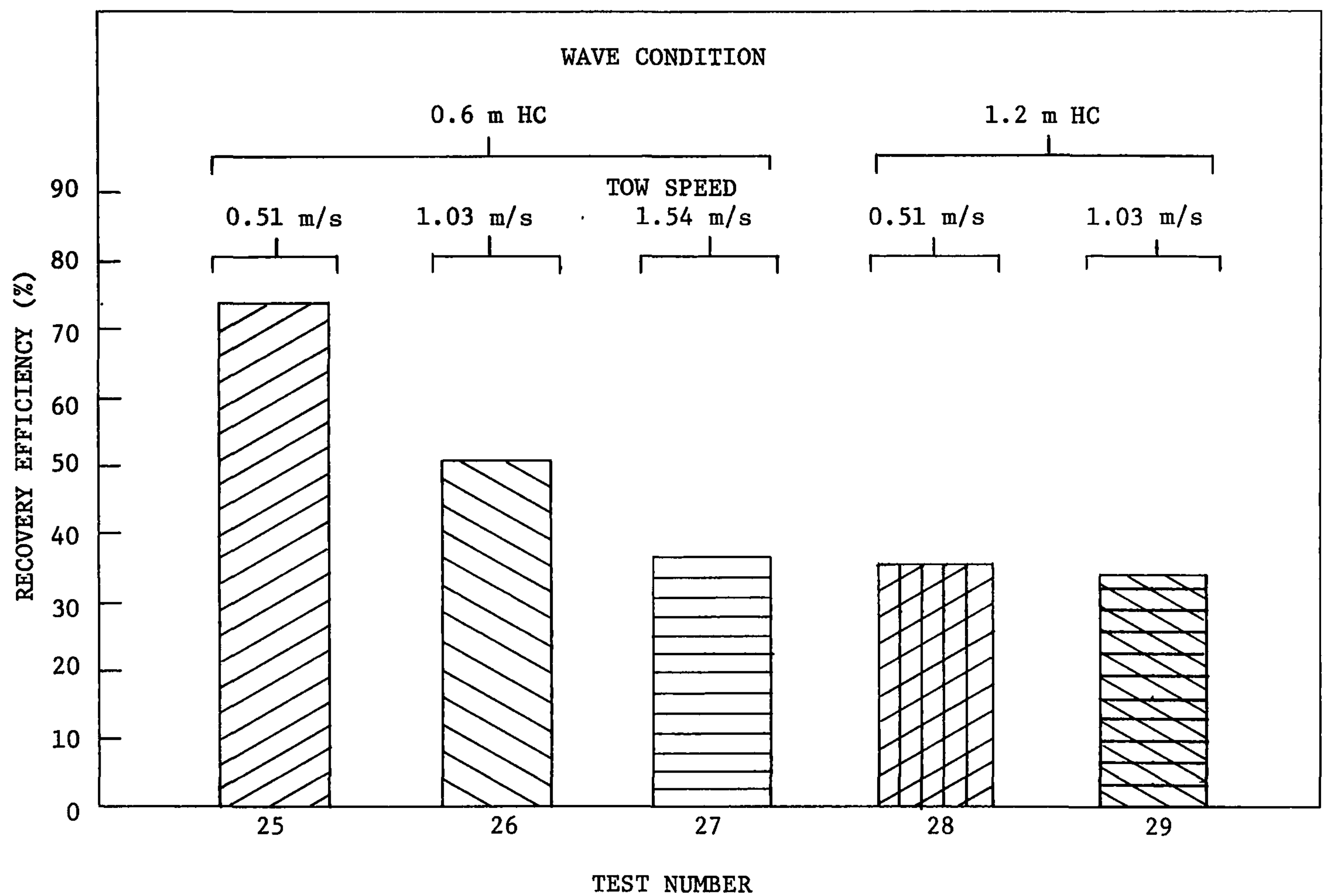

Figure C-4. Recovery Efficiency for MARCO Class V Ocean Skimmer in 0.6 m and 1.2 m Harbor Chop at optimum equipment settings with 3 mm thick slick of Sunvis 1650 oil.

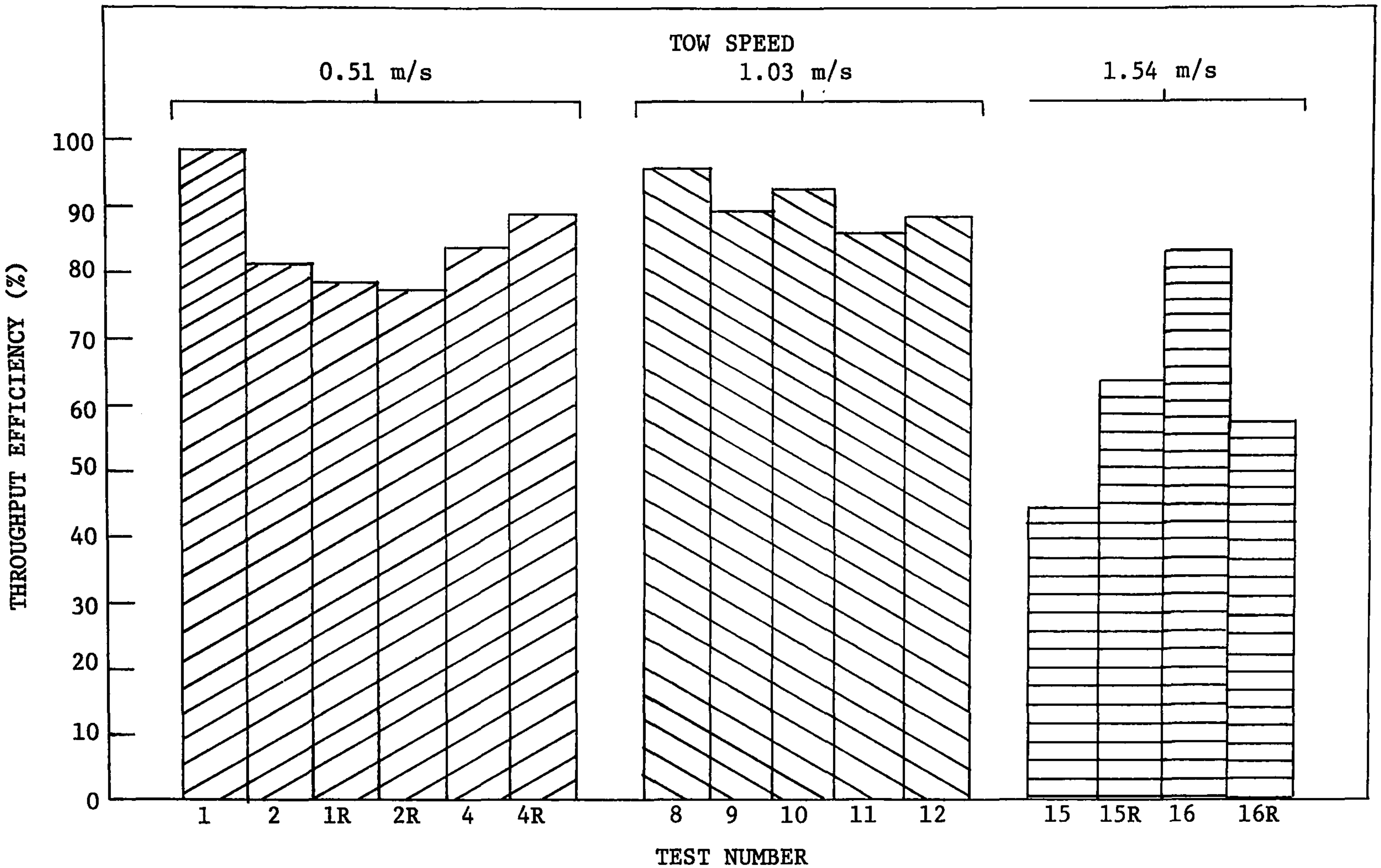

Figure C-5. Throughput Efficiency for MARCO Class V Ocean Skimmer in calm water at various equipment settings with 3 mm thick slick of Sunvis 1650 oil.

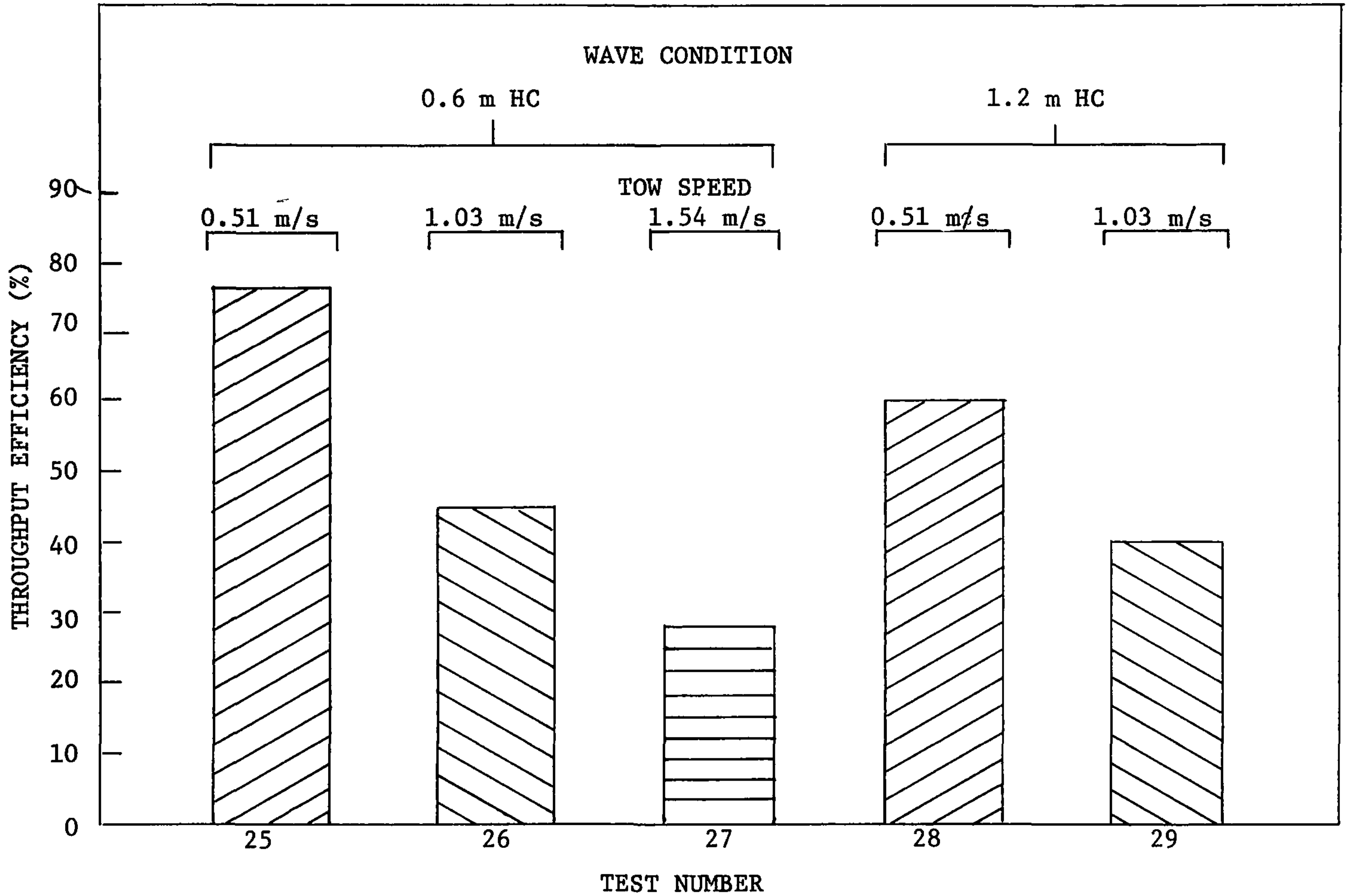

Figure C-6. Throughput Efficiency for MARCO Class V Ocean Skimmer in 0.6 m and 1.2 m Harbor Chops at optimum equipment settings with 3 mm thick slick of Sunvis 1650 oil.

TECHNICAL REPORT DATA

(Please read Instructions on the reverse before completing)

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15. SUPPLEMENTARY NOTES

16. ABSTRACT

A MARCO Class V oil skimmer was tested at the U.S. Environmental Protection Agency's OHMSETT facility to determine the device's "high seas" performance characteristics. Performance data was obtained for several simulated offshore wave conditions at various collection speeds. Skimmer efficiency was determined at various belt speeds and induction pump rates in order to define optimum skimmer settings and to better define oil/water spearator needs. This report of testing done under Contract No. 68-03-0490, Job Order No. 22, by Mason & Hanger-Silas Mason Co., Inc., for the U.S. Environmental Protection Agency covers the period September 27, 1976, to October 1, 1976, with work completed January 14, 1977.

17. KEY WORDS AND DOCUMENT ANALYSIS

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