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An oil/water separator for deballasting applications was designed and fabricated by Naval Coastal Systems Laboratory under Navy contract. Designated OPC-3000, the separator is in use at the Craney Island Fuel Depot, Portsmouth, Va. The separator's coalescing plate and foam design and system installation at CIFD are described. The results of performance evaluations between May and October 1977 are reported.

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During the course of the evaluations, two ship's were deballasted and approximately 2 million gallons (7.6 million liters) of oily wastes were processed by the OPC-3000. The effluent water's oil concentration, between May and October 1977, averaged less than 10 milligrams of oil per liter of water.

The OPC-3000 has been used extensively at Craney Island, and has allowed ballast water and barge delivered wastes to be treated without intermediate storage. As a result, one 50,000 barrel (8 million liters) tank, previously used for oily waste storage at Craney Island, has been returned to clean fuel storage service.

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SUMMARY

This memorandum documents the background, technology, and performance tests of the USN OPC-3000 Coalescing Plate Oil/Water Separator and evaluates the results of those tests. The Navy fostered the development of this separator as a part of its pollution abatement program for shore facilities. Federal legislation and local regulations have imposed stringent controls which fix point source effluent oil content limits at extremely low levels. Since ballast, tank washings, or other wastewaters containing oil must be handled and disposed of in large quantities by naval port facilities, the Navy needs a high-flow-rate separation system to supplement its oily waste treatment facilities.

A prototype model using a coalescing plate/foam filter design was selected by the Naval Supply Systems Command for a test and development program which resulted in the construction of the OPC-3000 at Craney Island Fuel Depot, Portsmouth, Va. After an onsite functional test verified that the system was operational, an evaluation test program of the separator began in February 1977.

The tests consisted of separation processing of deballastings and tank cleanings at high flow rates of 1500-2500 gpm (5700-9500 lpm) and processing of mixed oily wastes from settler tanks and barges at medium flow rates of up to 900 gpm (3400 lpm). These tests indicated that the OPC-3000 can treat ballast or tank cleanings within the EPA effluent concentration limits for oil of 10 mg/l daily average for a 30 day period and 15 mg/l daily maximum. The tests also showed that the separator can process the relatively dirty oily wastes from settler tanks and barges, meet the daily average requirement and be within the daily maximum requirement 95 percent of the time.

CONCLUSIONS

The separator's success in treating the vast majority of oily wastes at Craney Island should make this moderately sized coalescing plate/foam filter configuration an attractive, cost effective alternative to other oil/water separator designs for shore reception facilities. However, to positively ensure that effluent water discharge to the environment will meet local purity criteria, provisions must be made to allow for supplementary treatment of chemically stabilized emulsions.

During the May to July 1977 period of testing, approximately 1.5 million gallons (5.7 million liters) of stored or barge-delivered oily wastes were treated by the OPC-3000. The effluent stream resulting from this treatment never contained more than 30 mg/l oil and contained less than 15 mg/l 95 percent of the time.

Therefore, even though the separator has been operating in a limited test service mode for the relatively short period of three months, it has already produced some considerable savings in storage space and man-hours. All performance evaluations thus far point toward both versatile service and increased savings in the future.

RECOMMENDATIONS

The OPC-3000 has proven itself a useful system at the Craney Island Fuel Depot. Many navy fuel depots face the same problems as CIFD in handling ballast water, tank cleanings, and stored oily wastes; therefore, it is recommended that the coalescing plate/filter design be considered for inclusion in new facilities for handling oily waste.

To extend the range of influents treatable by the OPC-3000, it is recommended that chemical demulsification be studied at CIFD, using the OPC-3000 to process the chemically treated wastewater.

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GLOSSARY AND ABBREVIATIONS

API	American Petroleum Institute.
ASME	American Society of Mechanical Engineers.
Best Available Technology Economically Achievable	Treatment required by July 1, 1983 for industrial wastewaters discharge to surface waters, as defined by Section 301(b)(2)(A) of FWPCA
Best Available Demonstrated Technology	Treatment required by new sources as defined by Section 306 of FWPCA.
Ballast Water	Water taken aboard a vessel to improve its stability or to lower vessel in water.
Bilge Water	Water that accumulates in the bottom of a ship.
CIFD	U.S. Navy Craney Island Fuel Depot, Portsmouth, Va. (Craney Island Fuel Division of the Norfolk Naval Supply Center)
Effluent	The wastewater or ballast water discharged from a point source.
Effluent Limitation	The maximum allowable amount of a specific constituent in the effluent.
Effluent Loading	The quantity of specified materials in the water stream from a unit or plant.
Emulsifier	An agent which promotes the formation and stabilization of an emulsion, usually a surface active agent.
Emulsion	A mixture in which one liquid is finely dispersed in another. Emulsions consisting of oil dispersed in water occur frequently in bilge and ballast water. Reverse emulsions (water dispersed in oil) are common in oil spills.

EPA	Environmental Protection Agency.
FWPCA	Federal Water Pollution Control Act of 1965 as updated by FWPCA Amendments of 1972.
GE	General Electric Company.
gpm	Gallons per minute.
Influent	The flow of wastewaters or ballast waters into a treatment facility.
IMCO	Intergovernmental Maritime Consultive Organization, an agency of the United Nations.
JP-5	Jet aviation fuel, primarily heavy kerosene.
lpm	Liters per minute (Note: metric equivalents given in parentheses are approximate.)
mg/l	Milligram per liter; a measure of concentration which for oil is slightly greater than one part per million.
μ	Micron or micrometer, the millionth part of a meter.
NAVSUP	Naval Supply Systems Command, Washington, D.C.
NCSL	Naval Coastal Systems Laboratory, Panama City, Fla.
NDFO	Navy Distillate Fuel Oil.
NPDES	National Pollutant Discharge Elimination System. Wastewaters discharged directly into surface waterways must be under permit and monitored by the EPA in accordance with the NPDES authorized under Section 402 of the FWPCA.
NSFO	Navy Special Fuel Oil.
OPS-1000	1974 model USN coalescing plate oil/water separator rated at 1000 gpm (3800 lpm)

OSHA	Occupational Safety and Health Administration.
Point Source	An individual facility, site, or other location from which pollutants enter navigable waters.
ppi	Pores per inch (linear).
ppm	Parts per million, by volume; one part per million is slightly less than one milligram per liter for oil having a specific gravity slightly less than unity.
Primary Oil Removal	Processes that allow the separation of oils and sludges from water only by virtue of their differences in density, i.e. unassisted gravity separation.
Secondary Oil Removal	Treatment processes that can remove any additional amounts of oil and suspended solids over and above primary oil removal by the use of filters, coalescers, chemicals, or other means.
Shore Reception Facility (SRF)	A land-based point source that receives and treats ballast, bilge water, tank washings, and other wastewaters from ships and barges.
SWOB	Ships waste offload barge.
Sludge	The solids commonly found in oily wastes.
Weir	Submerged dam used in separator to contain solids, distribute flow, and control water level.

Section 1

INTRODUCTION

1.1 SCOPE

This memorandum documents the background, development, technology, and performance tests of the USN OPC-3000 Coalescing Plate Oil/Water Separator and evaluates the results of those tests. It provides physical and operational descriptions of the OPC-3000 and includes recommendations concerning the adoption of the separator by the Navy for use in port facilities.

1.2 BACKGROUND

1.2.1 Oil Pollution of the Marine Environment

Oil pollution of navigable waters and harbors poses a threat to fish, shell fish, and wildlife dependent on the ecology of the rivers, tidelands, and coastal seas. The magnitude of the problem is illustrated by the huge amount of oil discharged by the world tanker fleet in ballast and wash waters alone. Exxon and the National Academy of Sciences estimate that this amount has already reached 1 million to 1.5 million tons of oil discharged into the ocean annually.[1]

Oil is also the major pollutant generated by U.S. Navy ships and installations, and the prevention or correction of oil pollution is the object of numerous navy research and development projects such as the one covered by this report. The naval policy document on environmental protection states, "The Navy's largest, single, pollution abatement problem is oil. Oil pollution regulations are extremely stringent inasmuch as the discharge of petroleum products into the aquatic environment can create visible, serious and lasting effects on marine life, alter human food resources, render beaches useless and present an opportunity for fire and explosion."[2] Ballast discharged at major navy

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[1]Gray, W.O., Carven, C.J., and Becker, G.L., Exxon Corporation, New York, New York 10020, "International Regulation of the Tanker Industry," *Proceedings of 1977 Oil Spill Conference,* American Petroleum Institute, p. 7, March 1977.

[2]Department of the Navy, *Environmental Protection Manual,* OPNAV Instruction 6240.3D, p. 7-1, 1975.

harbor facilities in the United States is estimated at 557,000 gallons (2.1 million liters) per day.[3] Even greater quantities of bilge oily wastes are generated daily; the contribution from all active ships is estimated to be 4.8 million gallons (18.2 million liters) of bilge per day, though not all of this is discharged in port.[4] Therefore, the Navy's efforts to improve the treatment for such a large quantity of oily wastewaters are of major importance to the conservation of the marine environment of many of the Nation's harbors and estuaries.

1.2.2 Standards and Regulatory Efforts

The last three decades have seen both a sharp increase in the severity of the oil pollution problem and a greater public awareness of the danger involved. National concern led to United States participation in international agreements and publication of U.S. Federal laws prohibiting or restricting discharges of oil. In 1954 the Intergovernmental Maritime Consultative Organization (IMCO), an agency of the United Nations, issued the International Convention for the Prevention of Pollution of the Sea by Oil, which prohibited discharges of oil/water mixture exceeding 100 parts per million of oil within 50 miles (80 km) later extended to 100 miles) of any shoreline. The 1969 Amendment to the 1954 Convention prohibited discharge of any oil or oil mixture within 50 miles of any coast and established limits on discharge beyond the 50-mile limit. For a tanker proceeding enroute at a distance greater than 50 miles, discharge is limited to 60 liters of oil per nautical mile. The total oil discharged with ballast water on a voyage must be less than one fifteen-thousandth of the tanker's capacity or in the case of a new tanker one thirty-thousandth. In October 1973 the IMCO Marine Pollution Conference adopted the goal of eliminating all oil discharged to the sea by 1980.

The Government of the United States, in response to these international agreements, passed the Oil Pollution Act in 1964[5] and the Federal Water Pollution Control Act in 1965 (amended in 1972).[6] Both of

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[3]Waters, D. and Bass, R. L., *Projected 1975-82 Shipboard Oily Waste Generation Rates for 8 Navy Port Complexes*, NAVSEA Report 6157-003, January 1974.

[4]Waters, D. and Bost R., *Shipboard Oily Waste Generation* NAVSEA Report 6159-77-2, June 77.

[5]The Oil Pollution Act was amended by Public Laws 89-551 and 93-119. The latter implements the 1969 and 1971 amendments to the International Convention.

[6]The Federal Water Pollution Control Act (FWPCA) Amendments of 1972 is a complete rewrite of all existing water pollution control laws on the Federal statute books.

these Acts excluded naval vessels. However, Presidential Executive Order 11752, issued in 1973, directed all Federal activities to comply with the water quality standards established in the Federal Water Pollution Control Act and in applicable state and local regulations.

The Navy's directives to comply with these standards and to control pollution caused by its ships and facilities were published in a series of OPNAV instructions starting in 1971 with 6240.3, *Environmental Quality Protection* and culminating in 6240.3D, *Environmental Protection Manual (EPM)*, 1975. The EPM defines policy and prescribes detailed guidelines, standards, and actions responding to Executive Order 11752. In addition, the EPM assigns leadership responsibilities for environmental protection and enhancement at navy activities worldwide. It mandates action to control and abate all environmental pollution caused by naval ships and facilities. The EPM states that oil or oily wastes shall not be discharged from any navy activity or ship within any prohibited zone which includes waters within 50 miles (80 km) of the U. S. coastline and foreign coastal waters. The EPM adds, "The Navy's major goal to be achieved not later than the end of this decade, is the complete halt of all discharges of oil and oily wastes into streams, harbors and oceans by naval shore activities and vessels."

1.2.3 "No Sheen" and Other Effluent Criteria

The FWPCA prohibits the dumping of bilge and ballast waters into the harbors and navigable waters of the United States if such discharge causes a film or sheen upon the surface of the water. Up to now, cost effective oil/water separation technology has not been successful in producing an effluent with absolutely no oil it it. However, efforts have been successful in producing an effluent without irridescent sheen or visible film. It is generally accepted that a sheen can form under certain conditions if the effluent should contain as little as 10 to 15 parts per million of oil. The U. S. Coast Guard and other regulatory bodies have been using the "no sheen" criteria in their effluent negotiations and enforcement measures with industry.

An intensive industry-wide study of separation systems and shore reception facilities recommends a more flexible standard adapted to the rapidly changing quantity and quality of wastewaters processed daily by individual plants.[7] The study considers both the present

[7] Burns and Roe Industrial Services Corp., *Effluent Limitations Guidelines and New Source Performance Standards*, Report to Effluent Guidelines Division, Office of Water and Hazardous Materials, U.S. Environmental Protection Agency, unpublished report prepared by Burns and Roe, South Paramus, N. J., p. II-1, 1976. Prepublication copies of this report, which is scheduled for publication in late 1977, are on file at the EPA, 401 N. Street, S.W., Washington, D. C. 20460.

state of the industry and current research on wastewater treatment, and recommends the following effluent standards:

- Oil and grease effluent rates for ballast processing and USN shore facilities should be limited to 12 milligrams per liter for a 30-day average and 34 milligrams per liter for a one day maximum.

- Oil and grease effluent rates for tank cleanings (which involve greater variability in raw waste load) should be limited to 29 milligrams per liter for a 30-day average and 36.5 milligrams per liter for a one day maximum.

Current practices as of spring 1977 is to negotiate effluent limits on a case by case basis after it has been verified that the best practicable control technology currently available is being applied. The negotiators for naval facilities are usually regional Environmental Protection Agency and navy district pollution control coordinators. Pollutant discharge limits for most navy SRF's have already been negotiated and set in accordance with the National Pollutant Discharge Elimination System (NPDES). Thus far, existing NPDES permits, issued for each SRF, have set effluent concentration limits for oil and grease at 10 mg/l daily average for a 30 day period and 15 mg/l daily maximum.[8] In most cases, interim permits have been set at higher levels.

FWPCA standards for technology and hardware pertaining to naval pollution abatement ashore include application of:

- Best practicable control technology currently available for treatment of effluents by 1 July 1977.

- Best available technology economically achievable for particular categories of point sources by 1 July 1983.

1.2.4 Naval Harbor Pollution Preventions

The Navy's program for halting oil pollution at shore facilities includes an Esso study of oily waste disposal at naval port facilities.[9]

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[8]Navy Environmental Support Office Report 12-001A, *Environmental Status Report on Shore Activities Managed by the Naval Supply Systems Command* (1977 Update), NESO, Port Huenemen, Calif., Appendix C, p. 71-73, July 1977.

[9]Salvesen, R.H., Beerbower, A., and Garabraut, A.R., *Research of Oily Wastes,* series of reports by Esso Research and Engineering Company to Naval Supply Systems Command (Code 0431), Washington, D. C. 20376, 1973.

The Esso study, through a series of reports, identified and quantified all oily wastes generated by navy bulk fuel facilities in the United States. The study also proposed an oily waste treatment program which would employ technology currently available within the 1972-1973 state-of-the-art. The reports, published in 1972-1973, concluded that bulk fuel facilities should be equipped with adequate storage capacity for oily wastes and with combinations of American Petroleum Institute (API) separators and dispersed air flotation (DAF) separators linked if possible to tertiary treatment facilities; e.g., city sewage.[10] These proposed processing systems would ensure adequate separation of oily wastewaters to meet FWPCA standards as well as permit discharge of effluent water to the environment and reclamation of the recovered oil.

In a short range campaign to reduce pollution wherever possible until a comprehensive long term program could be implemented, the Navy acquired off-the-shelf hardware and instituted pollution abatement training for its port facility personnel. In its long term program the Navy started a search for advanced oil/water separation technology. In the research effort Naval Sea Systems Command (NAVSEA) and Naval Supply Systems Command (NAVSUP) were each directed to seek improvements of technology in shipboard and shore based oil/water separation, respectively. The OPC-3000 is one of the products of those searches.

The Navy's oil pollution abatement program also included plans for a series of Military Construction (MILCON) projects for oily waste treatment in port facilities. Naval Facilities Engineering Command (NAVFACENGCOM) was given responsibility for the design and construction of the MILCON treatment systems using the Esso study recommendations and any new technological advances which might become available in the meantime.

1.3 ORIGINS OF THE OPC-3000

As the Navy implemented its program of oil pollution abatement, the Navy Petroleum Office identified the need for a high-flow-rate separator which could process ballast ashore simultaneously with the offloading process and this avoid storage of wastewater. In 1974, NAVSUP, interested in the possible application of coalescing plate technology to this problem, arranged to borrow from NAVSEA a 1000 gallons per minute (380 lpm) coalescing plate separator, designated OPS-1000.

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[10]For a brief survey of oil/water separation technology common to the shore reception facility industry, see Appendix A.

The test series for the OPS-1000 separator in the deballasting mode was conducted at the Naval Station, Mayport, Florida. One of the objectives of the tests was to gain the knowledge and experience necessary to prepare specifications for a technologically advanced shore-based separator with a flow rate capability of up to 3000 gallons per minute (11,400 lpm). The actual separation requirement at Naval Station, Mayport was the processing of bilge and ballast water contaminated with various solid debris and a combination of Navy Special and Navy Distillate fuel oil, marine diesel fuel, and JP5 aviation fuel collected from ships in port by slude barges. The tests clearly demonstrated that it was feasible to use coalescing plate technology to achieve high-flow-rate separation in an on-line real time mode. The OPS-1000 test project at Mayport ended successfully and resulted in a purchase description for a shore-based separator capable of processing 3000 gallons per minute.[11]

Since the completion of the tests in November 1974, Port Services personnel at Mayport have operated the separator to process ships' oily wastes which have been collected in barges. These operations, conducted several times a week at flow rates of 200 to 500 gpm (760 - 1900 lpm), have continued with results that Mayport Port Services personnel have deemed highly satisfactory; the water effluent has been faily uniform in purity, never exhibiting significant sheen, and excess water has been eliminated from the oil output.

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[11]The purchase description and a complete account of the project appears in Naval Coastal Systems Laboratory Informal Report 252-75, *Oil/Water Separator Evaluation*, by J. Mittleman, July 1975.

Section 2

OPC-3000 DESIGN REQUIREMENTS

2.1 GENERAL

In 1974 the Navy, based on prior testing of an earlier separator model (the USN OPS-1000 Coalescing Plate Separator installed at Naval Station, Mayport) and anticipated effluent discharge guidelines, developed a purchase description containing equipment specifications and performance goals for a land based 3000 gallon per minute deballasting oil/water separator system. Those requirements, as modified by joint GE/Navy design review meetings, served as the contract baseline. The salient requirements having a major effect on design are presented here. The purchase description used to negotiate the contract is included in NCSL Informal Report 252-75.[12]

2.2 REQUIREMENTS

The system was designed to meet the following operating requirements:

a. Performance. The influent characteristics to which the separator was designed are shown in Table 1. The design goal for the effluent water quality is 10 ppm maximum oil content and for the recovered oil 5 percent water. The 10 ppm standard was chosen in accordance with a best estimate of the purity requirements for effluents which were likely to be legislated for the 1980 time frame. Selection of the 95 percent criteria for oil allowed for cost effective oil reclamation.

b. Operating. The system was designed to be:

(1) capable of fully automatic operation with the possible exception of the recovered oil removal system.

(2) capable of operating at flow rates up to 3000 gallons per minute (11400 lpm).

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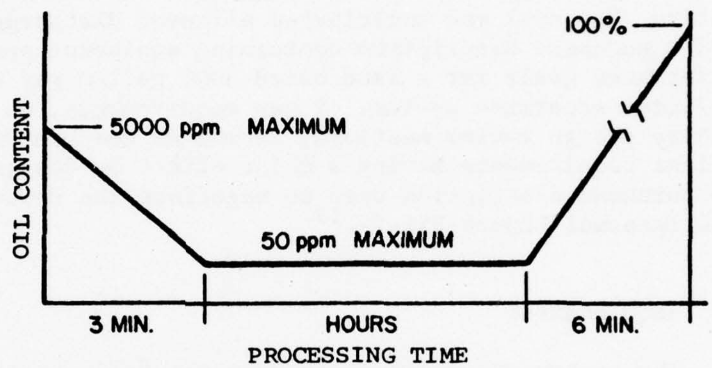
[12] Mittleman, J., *Oil/Water Separator Evaluation*, NCSL Informal Report 252-75, Appendix A, July 75.

TABLE 1

OPC-3000 INFLUENT PROFILE
(Characteristic of Deballasting)

CHARACTERISTIC	DESIGN GOAL
Oil Type	Marine Diesel JP-5 Naval Distillate Fuel Oil (NDFO)[13]
Oil Concentration Profile[14]	



Oil Emulsification (Marine Diesel @ 50 ppm)	15μ mean droplet size (based on prior studies of centrifugal pump effects)
Dirt Concentration	20 mg/l maximum (typical of ballast water)
Flowrate (see footnote 13)	3000 gpm (11400 lpm) maximum (will accept maximum flow rates of most navy oilers)
Temperature of influent wastewater	50°F - 80°F (10°C - 27°C)

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[13]Navy Special Fuel Oil (NSFO) was intentionally excluded because its use is being gradually phased out by the Navy.

[14]Due to brief periods of heavy oil concentration in the influent, possible during initial or final minutes of treatment cycle, it was anticipated that flow rates might have to be reduced during those times. This would permit the oil removal skimmers to keep up with the rapid accumulation of recovered oil in the separator tank. Operational guidelines that would anticipate and handle such contingencies were to be developed during the navy evaluation test at CIFD.

c. Mechanical Design. All pumps, pipes, valves and other mechanical equipment were designed for oil, salt water or a mixture of oil and salt water under anerobic conditions. Use of cast iron is limited and used only with approval from the Navy (to avoid fracture due to thermal shock). Pumps, valves, strainers and piping are rated for 150 psig (11 kg/cm^2).

d. Electrical Design. Liquid level and oil/water interface level sensors are intrinsically safe (to reduce hazard of explosion).

e. Physical Design.

(1) The functional design of the system employs a gravity separation process to the maximum extent possible.

(2) Tanks have sloping bottoms to allow draining.

(3) Means are provided to allow visual determination of the liquid level and oil/water interface at two locations.

(4) Ladders, walkways, and other surfaces of the separator tank, which are subject to human traffic during normal operation, are painted with nonskid paint.

(5) Detection of the oil interface level is provided at two points below the normal operating level in the separator tank. Detection of oil by the first point activates a warning light and an audible alarm. If the oil layer reaches the second detection point, the system shuts down and prevents liquid from leaving the effluent pipe. Upon return to normal level the effluent is automatically allowed to exit via the effluent pipe.

(6) Provisions are made to allow installation of two separate foam coalescing packs (filter assemblies) in series in the separator tank to permit change of packs during operation.[15]

(7) Transparent pipe sections are provided in the effluent water and oil pipe lines for flow visualization.

---

[15]This feature was included to enhance the separator's flexibility for handling sludge or solid particles in ballast or other contaminated wastewaters.

f. Maintenance. The system was designed:

(1) To minimize required preventive maintenance.

(2) For a 15 year life-goal.

g. Interface. The Navy provided the following structural components and power:

(1) Influent piping to system.

(2) Effluent piping and overflow piping to the discharge point.

(3) Oil holding tank.

(4) Piping from oil pump and drainage piping to discharge point.

(5) Protective dike.

(6) 440 volt, 3 phase, 60 cycle electrical power for removal of recovered oil. 115 volt, single phase, 60 cycle power for control circuits.

Section 3

TECHNICAL DESCRIPTION

3.1 INTRODUCTION

The OPC-3000 oil/water separator, constructed for NAVSUP by the General Electric Corporation, was developed to meet the Navy's system requirements and performance goals outlined in Section 2. The system was designed to process ballast, produce a water effluent sufficiently pure to meet environmental regulations, and recover oil sufficiently pure to be reuseable. The system as installed at the Craney Island Fuel Depot (CIFD) is intended for navy-oiler high volume deballasting (Figure 1). However, it has the potential to process other oily wastes such as tank washings and mixed oily waste from settling tanks and barges.

3.2 MAJOR COMPONENTS

The OPC-3000 oil/water separator is a field-erected system which uses factory assembled modules, predesignated government furnished equipment (paragraph 2.2g) and various components built on the site by sub-contractors. The major components of the system are a separator tank, an oil holding tank, influent and effluent piping, an oil pump, and an electrical control subsystem.

3.2.1 Separator Tank

This component, which is the center of the system, is a vertical cylindrical vessel, 23 feet in diameter by 12 feet high (7 meters in diameter by 3.7 meters high), with an open top, and ladders and walkways for access. Installed in the tank are horizonal, parallel coalescing plates, foam filter packs, oil skimmers and various sensing equipment as shown in Figure 2. The oil/water separation process takes place in this tank.

3.2.2 Oil Holding Tank

This container, also called the oil surge tank, temporarily stores the oil after it has been separated from the ballast water. It is a horizontal, cylindrical tank 8 feet in diameter by 13 feet long (2.4 meters in diameter by 4.0 meters long) and has a nominal capacity of 5000 gallons (19,000 liters). Float sensors in the holding tank monitor and control the oil level by automatic activation of the oil removal pump.

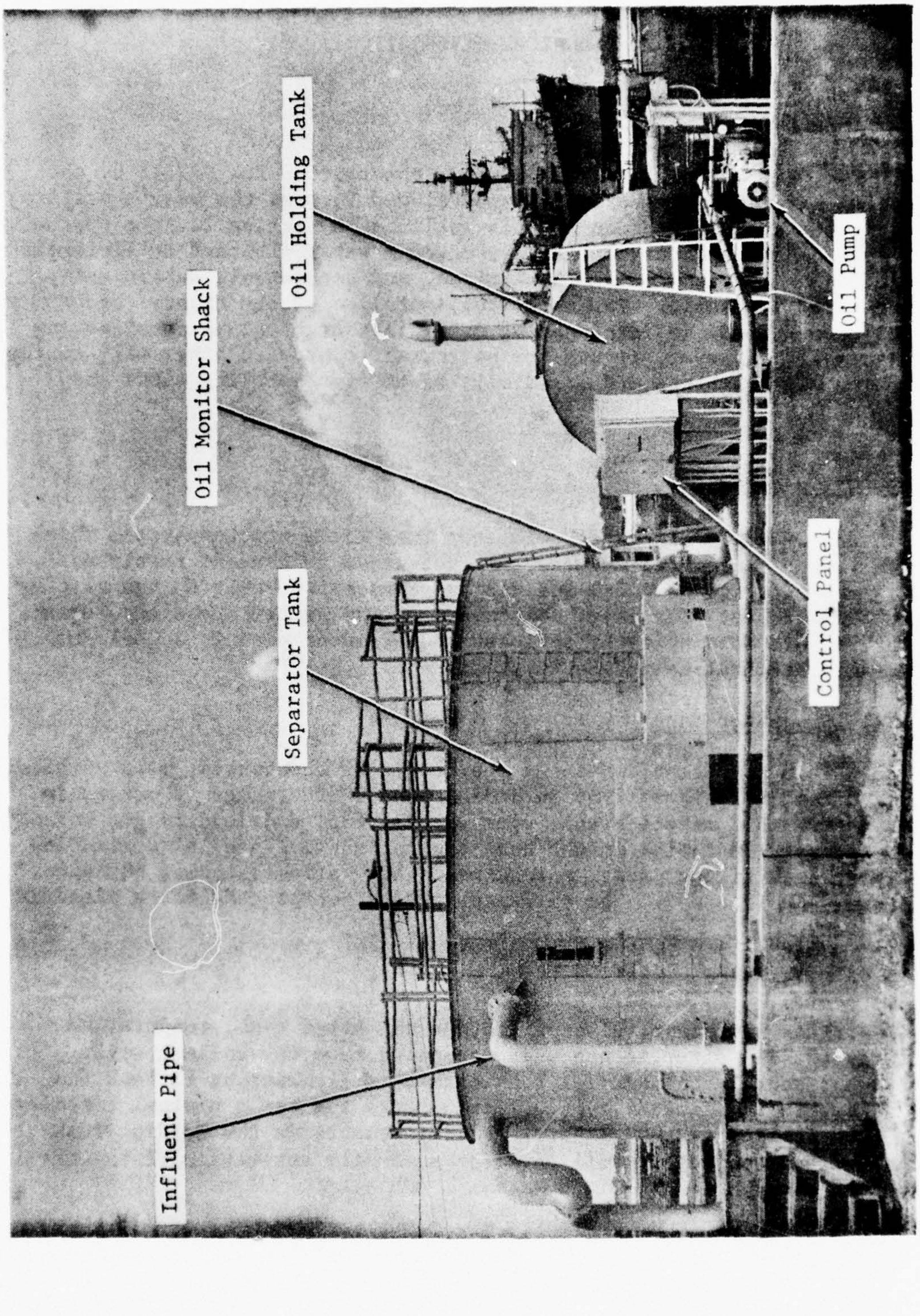

FIGURE 1. OPC-3000 OIL/WATER SEPARATOR SYSTEM

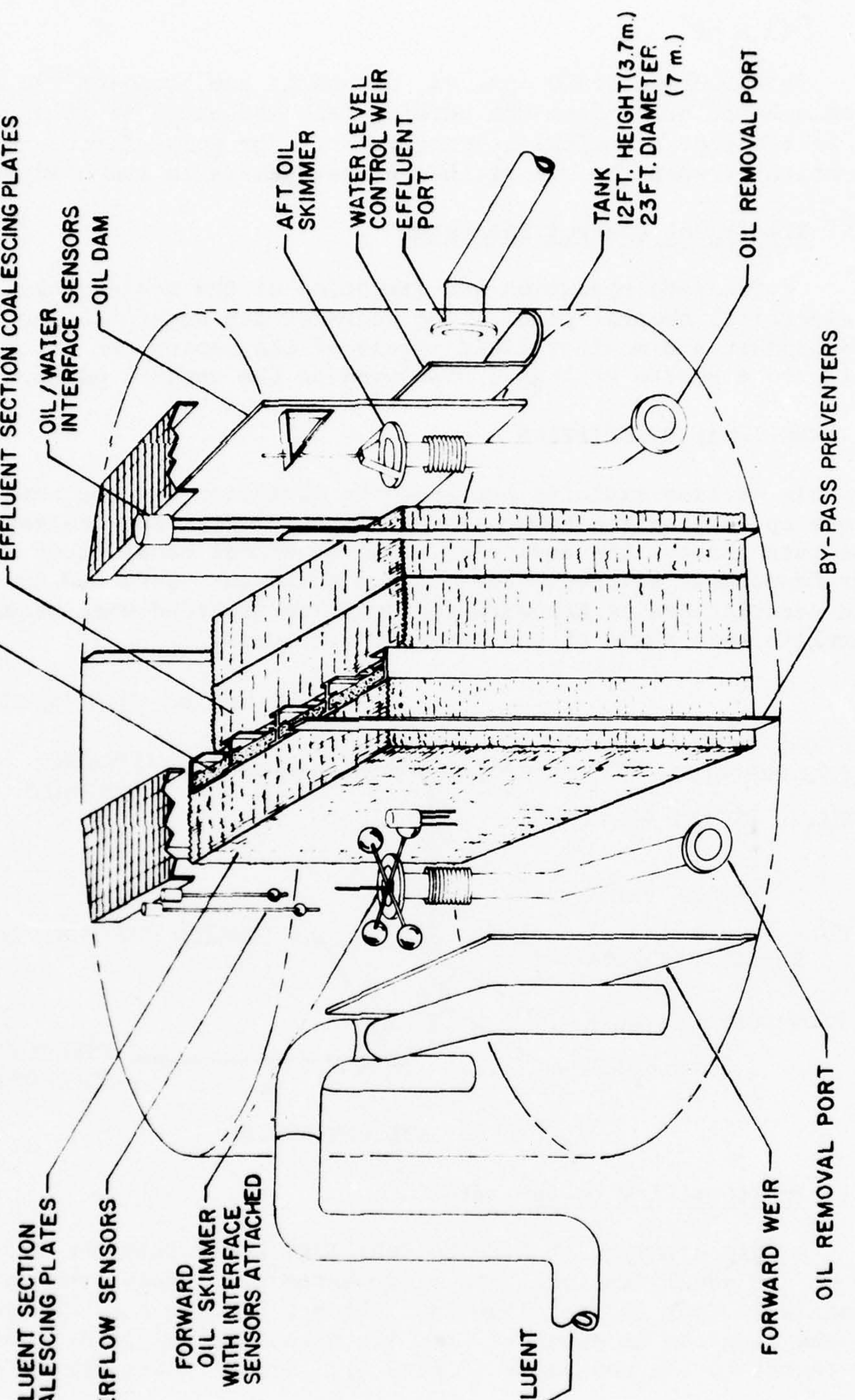

FIGURE 2. OPC-3000 OIL/WATER SEPARATOR

3.2.3 Oil Pump

This 500 gpm (1900 lpm) oil discharge pump removes the separated oil on a batch basis from the holding tank and pumps it to a reclamation facility or a central storage point. The pump starts and stops automatically when the oil reaches preset levels in the holding tank.

3.2.4 Electrical Control Subsystem

Centralized operation and direction of the system takes place at the electrical control panel. The operator can determine the status of the equipment and monitor fluid levels of the separation process by referring to a system of lights displayed on the control panel.

3.3 FUNCTIONAL DESCRIPTION

This section explains the system's operation and the separation process by tracing the flow path of the oily water and its separated components through the equipment. The separator consists of four major functional sections based on the treatment performed in each. Basic descriptions of hardware features are provided when necessary to explain each phase of the separation process.

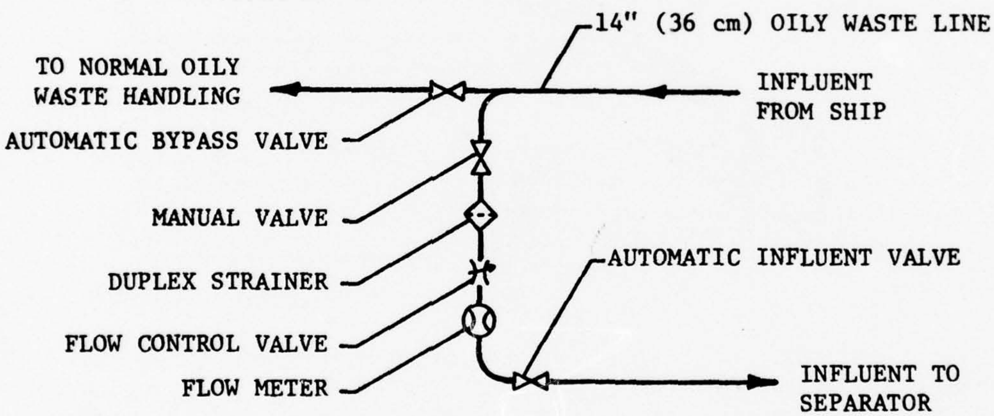

FIGURE 3. INFLUENT PIPING

3.3.1 Influent Flow to Separator

A ship arriving at CIFD to deballast hooks into the oily waste line in the usual fashion. The oily wastes are pumped from the ship through a 14-inch (36 cm) line into which a Y joint has been added so that the flow can be diverted from its normal route (to oily waste storage tanks) to the separator (Figure 3). Simultaneous actuation of automatic valves in the 14-inch (36 cm) line and in the separator influent line switches the flow routing. A duplex strainer in the influent line protects the separator system against any large solids entering with the wastewater. In the influent piping there are a flow meter, a manual valve for isolation, and a flow control valve to limit the influent flow rate to 3000 gpm (11,400 lpm).

3.3.2 First Section/Separation Process

Once through the influent piping, the flow enters the influent section of the separator tank where flow velocities decrease and any heavy solids, which might have entered with the influent, settle out (Figure 4).

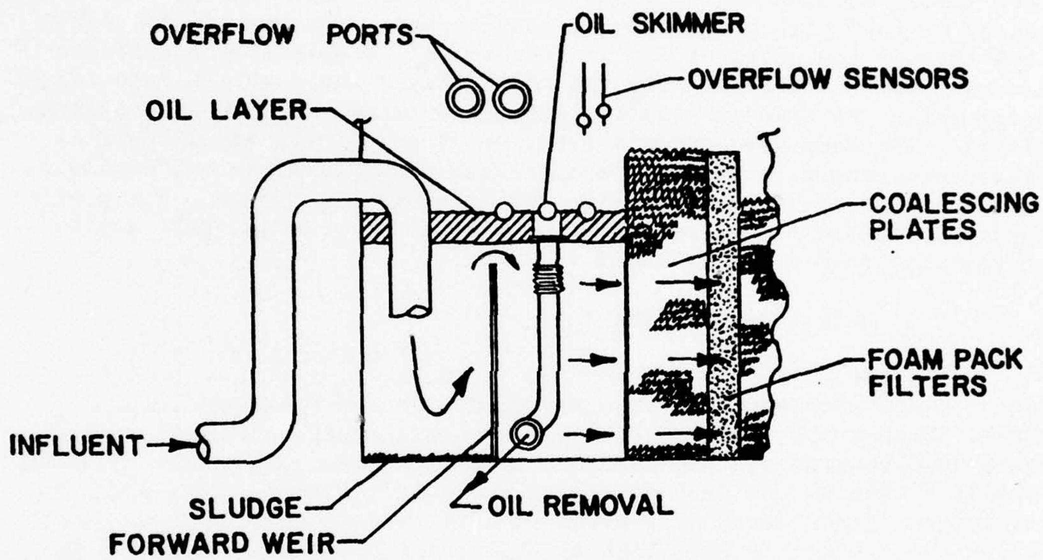

FIGURE 4. INFLUENT SECTION

The flow passes over the forward weir (dam) and into the first coalescing plate section. The forward weir holds back any heavy solids which might have entered with the influent and establishes a uniform flow distribution into the coalescing plates. Just forward of the plates there is a floating oil skimmer for removing the surface layer of oil which forms from free oil rising out of the mainstream. This section is also equipped with overflow warning sensors and overflow control pipes. The horizontal coalescing plates, made of corrugated oleophillic polypropylene, are closely spaced (¼ inch (6 mm) apart) and mounted in vertical stacks. Once the influent enters a coalescing plate stack, oil droplets coalesce into a film, which builds up and weeps larger drops of oil. The drops rise upward from one plate to the next as increasingly large buoyant drops. Therefore, the plate mechanism accelerates separation of the oil from the water by reducing to ¼ of an inch (6 mm) the maximum distance that oil droplets must rise in order to be removed from the water flow. The large buoyant drops, which form from the coalesced film, rise to the surface rapidly and form a layer of oil which is skimmed and piped by gravity flow to the oil holding tank. The wastewater, which still contains some oil in the form of small droplets, now enters into a foam coalescing filter.

3.3.3 Foam Pack/Filtration Process

The filtering mechanism consists of a bank of six polyurethane foam filter modules called foam packs. A foam pack contains five layers of foam with progressively larger pores. As the oil and water pass through the pores of the filter, the oil droplets come into contact with each other and with the foam fibers, and coalesce into larger drops which are removed from the flow by a second section of coalescing plates. The foam also screens out most of any finely divided solid particles present, which are often coated with miniscule oil droplets. Because these oil laden particles may be neutrally buoyant, the gravity separation process must be assisted by a filter or some other device to separate them from the flow.

3.3.4 Second Section/Effluent Flow

The flow, on emerging from the foam packs, enters a second coalescing plate section which consists of two adjacent banks of plate stacks (Figure 5). Here, again, oil droplets strike the plates, coalesce, weep upwards and are permanently removed from the flow. This oil finally floats to the tank's surface where it is removed by an oil skimmer and transferred by gravity flow to the oil holding tank. Free oil on the surface is held back at this point by an oil retention dam. In the surface area between the last plate stack and the oil dam there are interface sensors which give a warning should the oil layer become deep enough to be entrained with the water which passes under the dam. However, the oil layer in this section is normally very thin because any bulk oil in the flow is separated and removed earlier in the influent section of the separator.

Water, now substantially free of oil, passes under the oil retention dam and over the aft weir which controls the liquid level in the separator. The water then falls into a final segment of the tank, which has a raised bottom sloping toward the effluent outlet, and is discharged via the effluent pipe into the Elizabeth River.

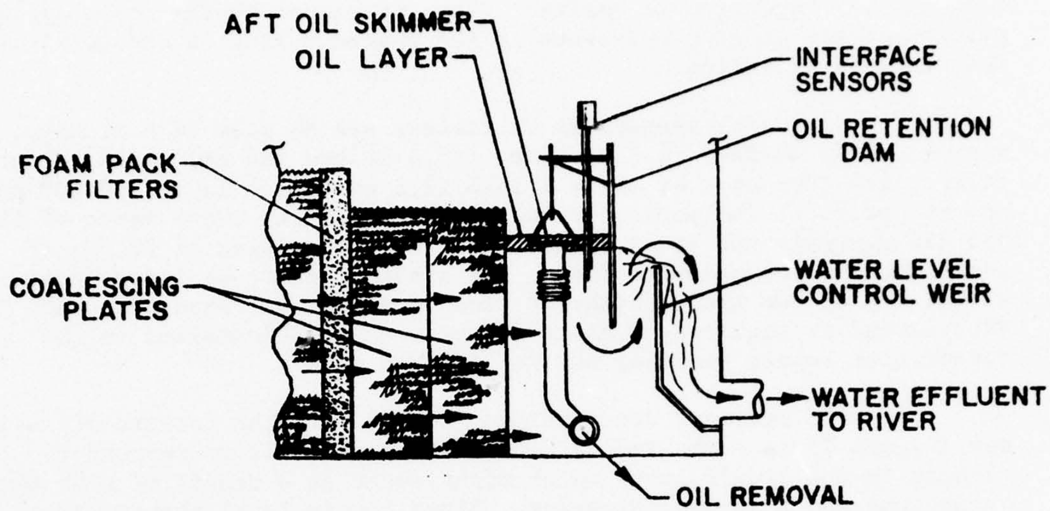

FIGURE 5. SECOND PLATE AND EFFLUENT SECTION

3.4 MECHANICAL COMPONENTS

3.4.1 Separator Tank

The separator tank is fabricated from cold rolled steel with a coal tar epoxy internal protective coating and a painted enamel exterior finish. A manhole through the side of the tank wall and ladders from the top of the tank provide access into the tank. Transparent viewing windows in the tank walls permit observation of fluid levels and the oil water interface. Personnel walkways are provided to allow inspection of the system's operation from the top of the tank, adjustment of oil skimmers, and access to the foam packs which require periodic replacement. The external ladders are coated with an anti-slip paint. Perforated metal screens are installed over the oil skimmers and the effluent pipe inlet to protect valves from jamming due to debris which might find its way into the separator tank.

The coalescing plate stacks (Figure 6), are assembled and installed as separate integral units to facilitate their removal should cleaning or inspection be desired. The individual plates are polypropylene and are mounted horizontally and spaced ¼ inch (6 mm) apart in the vertical direction.

The foam pack assemblies or filters are 8½ feet (2.6 m) high, approximately 3½ feet (1.1 m) wide, and 4 inches (10 cm) thick. Each filter is a composite of three 1 inch (2.5 cm) thick layers of 100 ppi (pores per inch) (40 pores per cm), ½ inch (1.3 cm) thick layer of 45 ppi (17 pores per cm) and a ½ inch (1.3 cm) thick layer of 20 ppi (8 pores per cm) polyurethane foam. The assemblies may be inserted in either one of two tandem banks as seen in Figure 6. When foam pack replacement is required, a spare filter module is installed in the vacant slot before removing the soiled foam pack.

Two oil skimmers are provided (Figure 2). The forward oil skimmer (Figure 7) is supported by floats which allow it to respond to changes in the liquid level which might occur as a result of flow rate variations and foam pack clogging. Since liquid level changes are small in the effluent section, the aft oil skimmer is a fixed standpipe whose height can be adjusted manually from the aft walkway.

3.4.2 Oil Holding Tank

The oil holding tank is fabricated from cold rolled steel with a zinc chromate protective internal coating and a painted enamel exterior finish. It is 8 feet (2.4 m) in diameter by 13 feet (4.0 m) long and holds approximately 5000 (19,000 liters) gallons. A 500 gpm (1900 lpm) pump, protected by a strainer, is provided to remove the oil on a batch basis from the holding tank to a central storage point or reclamation facility. Sensors at preset levels in the oil holding tank monitor the oil level and automatically control operation of the oil pump.

3.4.3 System Piping

To avoid problems, such as pipe strains associated with differential soil settling, the two tanks are supported by a piled concrete pad and expansion joints are used between the oil/water separator and existing pipes at the fuel depot. The fluid schematic shown in Figure 8 illustrates the piping of the system. The influent piping has a duplex strainer to protect downstream components from clogging or jamming and a flow meter for performance data acquisition. A flow control valve limits the flowrate to the separator to 3000 gpm (11,400 lpm) and manual valves serve as an alternate means of isolating the system. The large valves are all butterfly valves which use Viton as the seat material to prevent swelling. The effluent piping and piping to the oil holding tank have flow visualization tubes to permit the operator to check the status of the operation of the system.

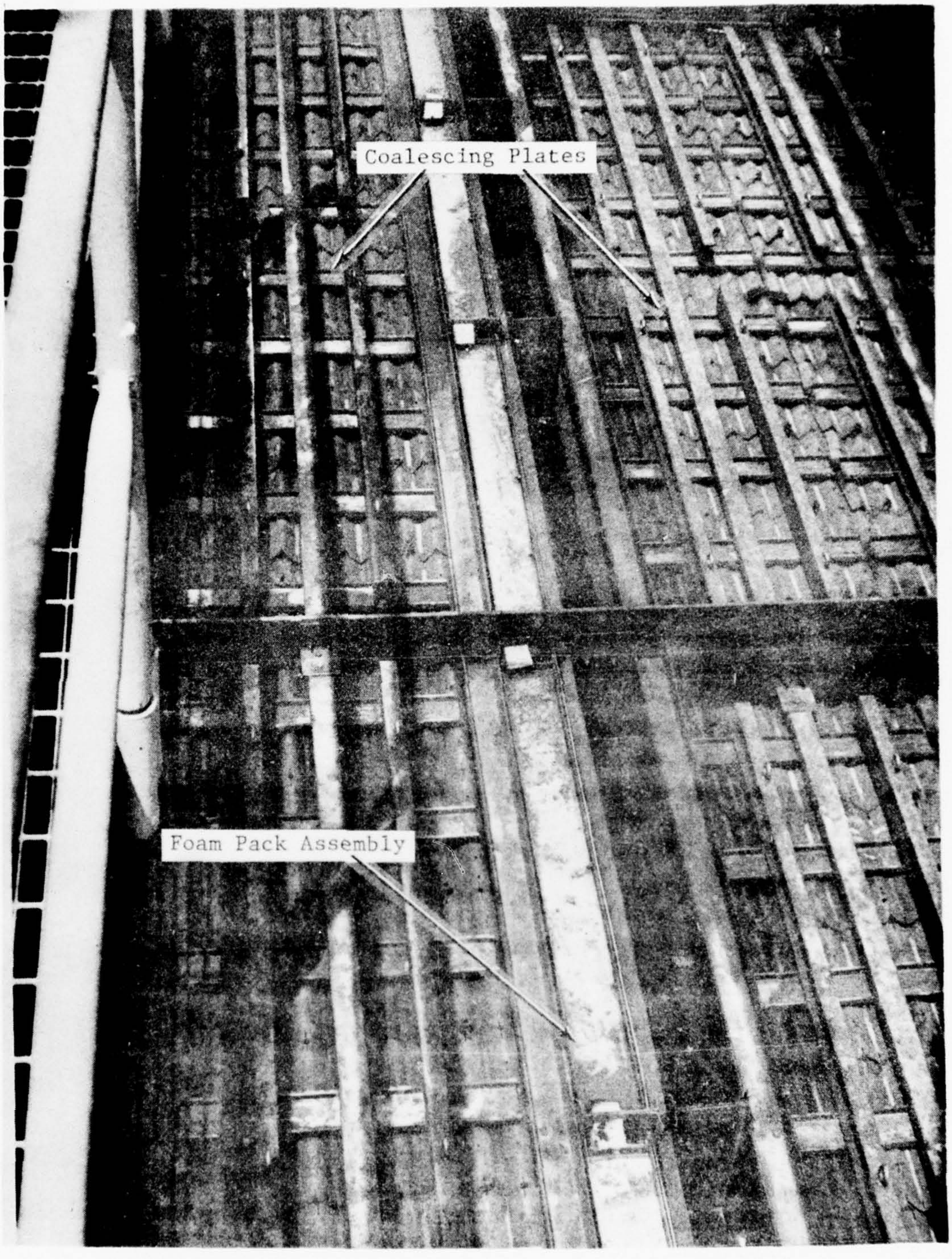

FIGURE 6. COALESCING PLATE INSTALLATION - OPC - 3000

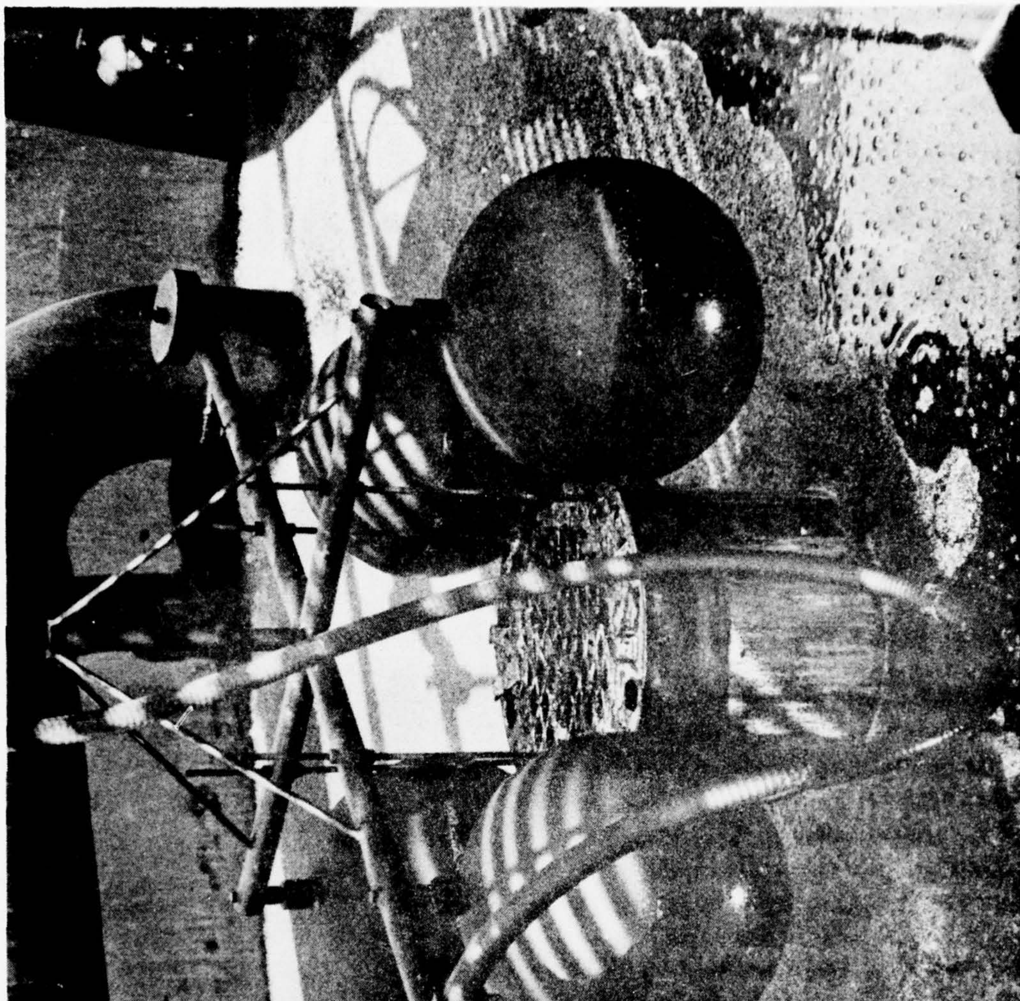

FIGURE 7. FORWARD OIL SKIMMER (RAISED FROM FLUID SURFACE)

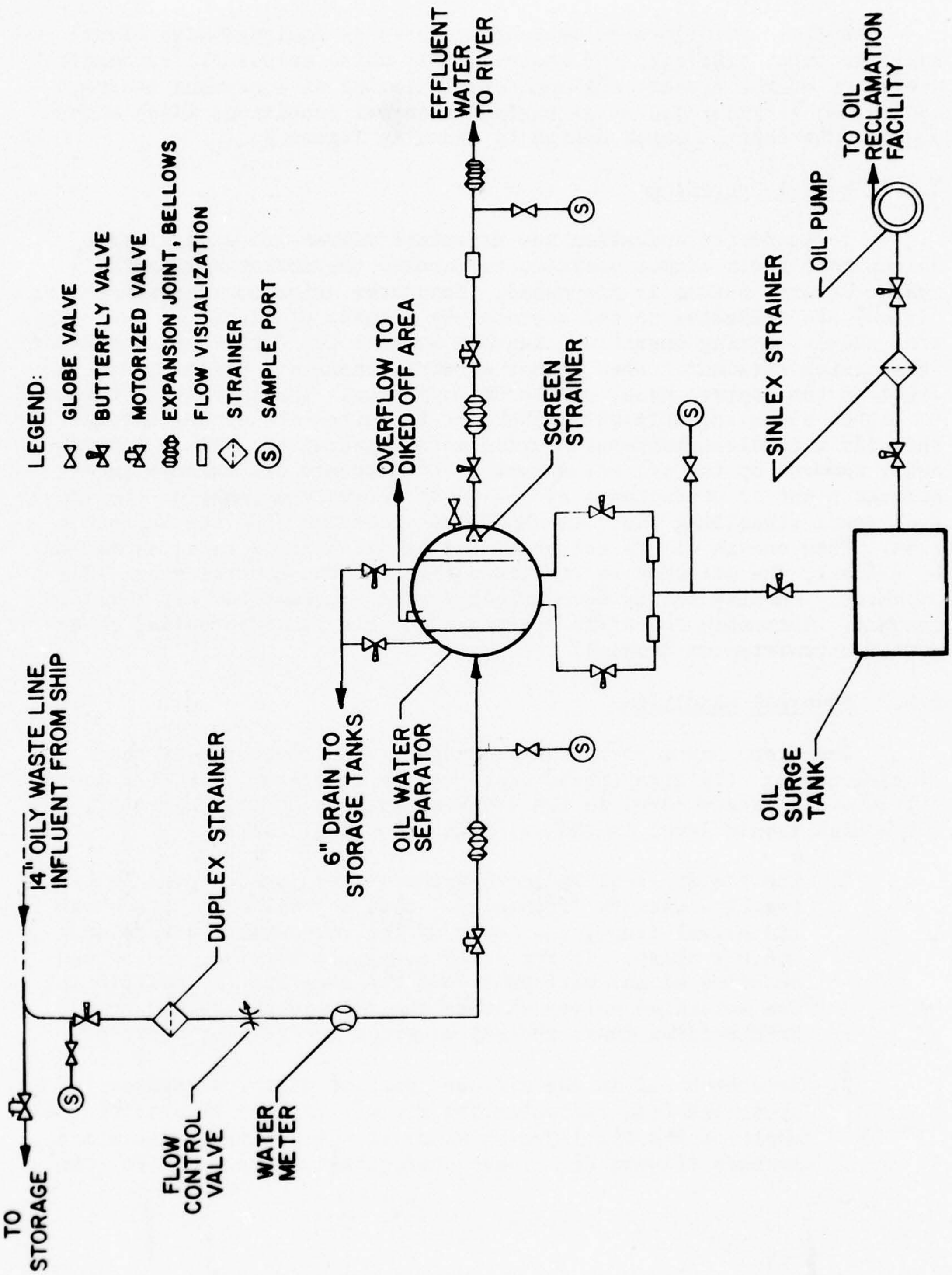

FIGURE 8. OPC-3000 SYSTEM FLUID SCHEMATIC

3.5 ELECTRICAL COMPONENTS

The OPC-3000 Oil/Water Separator system is equipped with electronic sensors, controls, and control panel which enable (1) automatic operation of the system, (2) monitoring/display of equipment status, and (3) monitoring/display of various abnormal conditions which might occur. The control panel design is shown in Figure 9.

3.5.1 Normal Operation

In automatic operation the motorized valves are electrically driven into their proper position to receive the influent when the system "start" button is depressed. Separator valve positions (open or closed) are indicated to the operator by display of lights on the control panel. During operation, sensors monitor the differential pressure across each strainer. When either strainer reaches a preset limit, a light on the control panel alerts the operator. This indicated the need to either clean the strainer baskets or to switch the duplex strainer to the side with clean baskets. During normal operation, oil is continuously removed by the aft oil skimmer. The forward oil skimmer incorporates a set of conductance probes which activate a light on the control panel signalling when oil should be withdrawn from the separator tank. When enough oil is collected in the oil holding tank, as sensed by a float, the oil pump starts and a light on the control panel illuminates. Pumping ceases automatically when a preset low oil level is reached. Automatic operation continues in this manner provided no abnormal circumstances develop.

3.5.2 Abnormal Conditions

There are three potential emergency modes monitored by the control panel: (1) high liquid level in the separator tank, (2) low oil/water interface level in the effluent section of the separator, and (3) a high liquid level in the oil surge (holding) tank.

1. The liquid level in the separator tank is monitored by two overflow sensors (Figure 2). Should the liquid rise above its normal level, the lower of the two sensors starts an audible alarm. If the level continues to rise, the second overflow sensor will shut down the separator by positioning the motorized valves so that the flow is redirected to a CIFD holding tank, thereby averting a separator overflow.

2. Recovered oil in the effluent section of the separator is prevented from contaminating the effluent by regulating the depth of the oil layer by means of the oil/water interface sensors (Figure 2). These conductance sensors monitor the

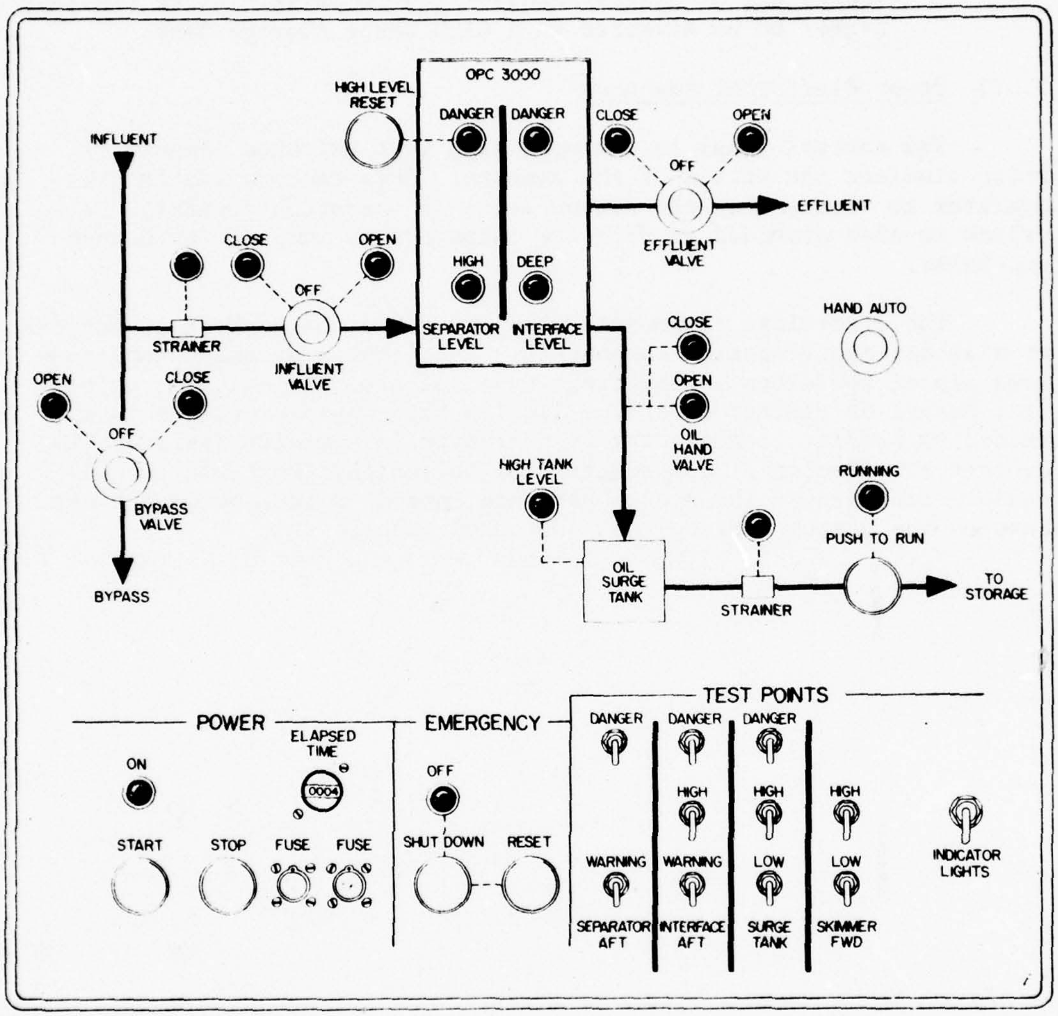

FIGURE 9. OPC-3000 ELECTRICAL CONTROL PANEL

depth of the oil layer and shut the separator down, redirecting the influent flow to a holding tank should the oil in the separator get too deep.

3. Float sensors monitor the liquid level in the oil surge tank. An indication is given on the control panel when the level reaches a danger point. If oil is not then removed from the oil surge tank, oil will build up in the separator, ultimately causing the incoming flow to the separator to be diverted to a CIFD waste storage tank.

3.5.3 Other Electrical Features

The control panel is equipped with test switches (Figure 9) which simulate the action of the sensors. This feature enables the operator to verify that the sensor logic is operating properly. A switch is also provided so that the operator can inspect for burned out bulbs.

The electrical components used are either high grade commerical or military specification components. The float and conductance sensors are of the ultra low amperage type and are intrinsically safe from hazard of explosion for the liquids the separator system is expected to handle. The electrical enclosure is humidity resistent to protect the electrical components from corrosion. Portable two-way radios, included in the system hardware, permit direct voice contact between the system operator and personnel onboard ship.

SECTION 4

DEVELOPMENT TESTING

4.1 GENERAL

Tests used during design, fabrication, and installation/checkout of the OPC-3000 separator system are described in this section. The results of performance tests conducted at Craney Island are reported in Section 5 of this report.

TEST PHASE	PURPOSE
1. *Concept testing*	Evaluate the ability of various system concepts, elements, and unit processes to meet the Navy's performance requirements.
2. Breadboard Testing	Verify performance of the chosen separator concept and electrical sensors.
3. Electrical Control Test	Verify logic and design of the electrical control panel.
4. Onsite Functional Test (Monitored by NCSL technical representative)	Verify system is operational and structurally sound after field installation at CIFD.

Figure 10 illustrates this test program and its relationship to the OPC-3000 design methodology. The development test program was conducted by the GE Re-entry and Environmental Systems Division in concert with NCSL personnel. The following discussion summarizes these tests.

A detailed account of the procedures and the results of the development tests are contained in Volume II of OPC-3000 Coalescing Plate Oil/Water Separator Final Report, dated 6 April 1977, prepared by General Electric Company for Navy Contract N00024-76-C-4334, Part B. Copies of this report are on file at Headquarters Naval Supply Systems Command (Code 0431), Washington, D.C., 20376 and at the Naval Coastal Systems Laboratory (Code 710), Panama City, Florida, 32407.

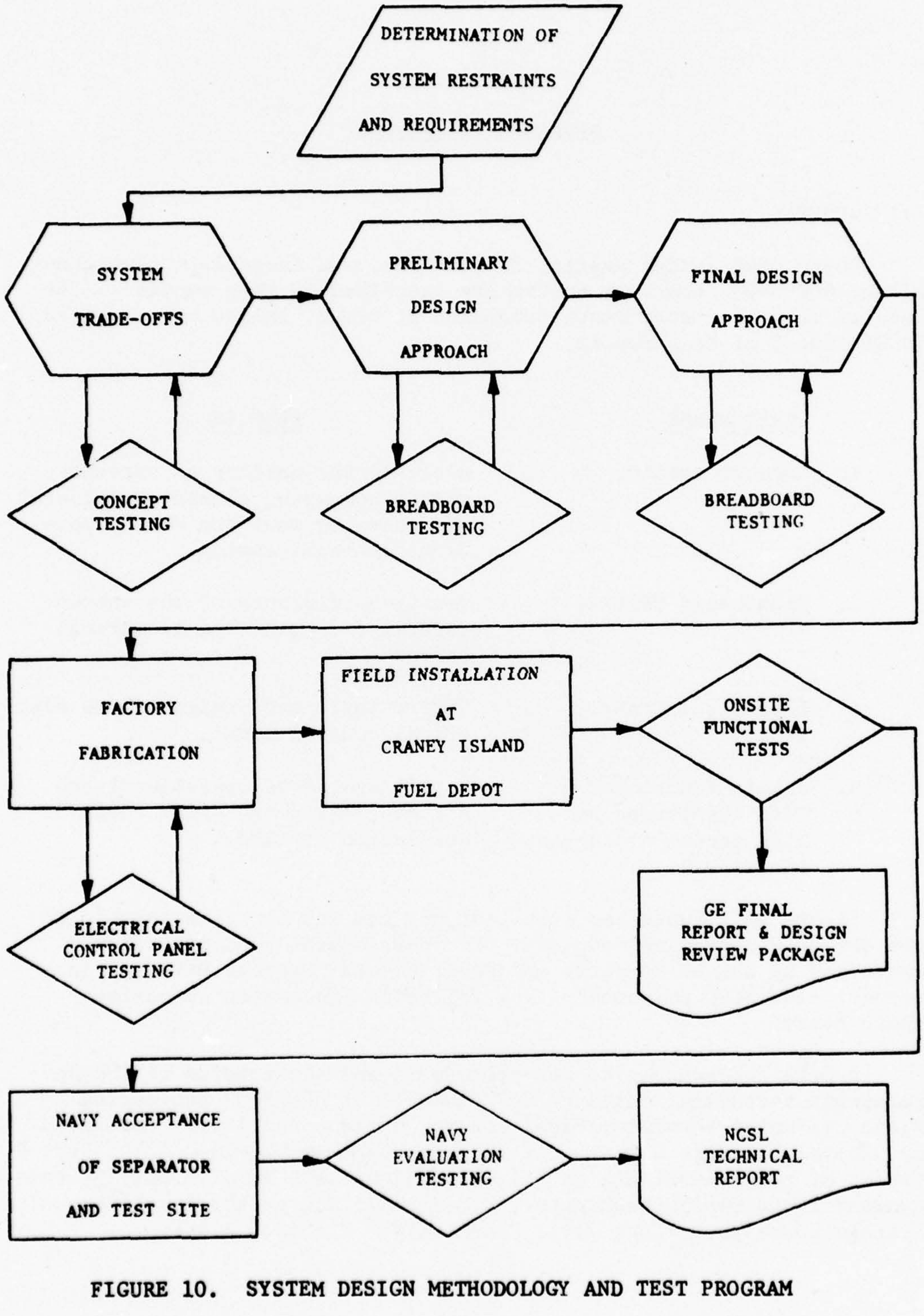

FIGURE 10. SYSTEM DESIGN METHODOLOGY AND TEST PROGRAM

4.2 CONCEPT TESTING

The purpose of this testing was to evaluate the ability of various system design concepts to meet the Navy's performance requirements and to provide guidelines for optimized sizing and interfacing of components for the final design. Each element of the separator system (including influent flow, various phases of the separation treatment, and the effluent process) was evaluated for performance using analytical models, GE laboratory testing, and/or field testing.

4.2.1 Advanced Separation Techniques

Some of the separator elements specifically tested for improvement of performance by design modification included: (1) interface sensor performance, (2) inlet section, and (3) coalescing plate configurations.

1. Interface conductance sensors were subjected to laboratory testing over a range of interface velocities, oil types, and influent contents to measure the probes' accuracy in detecting interface depth. The sensors were proven to be accurate within 1/2-inch (1.3cm) and capable of meeting the sensing requirements needed for automatic operation of the separator.

2. The functions of the inlet section are to dissipate the entrance velocity, distribute the flow, and to separate bulk oil and coarse solids. Experiments on the inlet section with 1/8-inch (3mm) polyethylene beads to simulate large oil droplets were performed over a range of velocities and inlet-section geometries. After analysis and correlation of results, the experiments adequately defined inlet performance and demonstrated that a submerged weir, located close to the inlet port, provides effective flow distribution.

3. Fluid mechanics between coalescing plates were tested to determine maximum flow velocities without turbulent instabilities, any oil entrainment due to fluid shear, and the ideal plate spacing for separator performance. A combination of laboratory experiments using variable flows and dye filaments with corrugated plates and computer program supported analysis resulted in the following conclusions: separation performance is degraded at flow velocities above 2.4 ft/min (73cm/min) due to turbulent instabilities and at plate spacings of 1/8-inch (3mm) or less because of blockage of the space between plates by oil.[16]

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[16]An in-depth description of concept testing of advanced coalescing techniques and configuration optimization is included in the GE 1975 Independent Research and Development Final Report entitled "*Oil Water Separator,*" Document No. 76SDR2158, Re-entry and Environmental Systems Division, Philadelphia, Pa. May 1976.

4.2.2 Coalescing Media Alternatives

In order to test the separator's flexibility in handling oily wastes other than ballast water, a series of field tests were run at Naval Station, Mayport, using the OPS-1000 oil/water separator in conjunction with several alternative media for handling the high solids content typical of many oily wastes. These alternatives included:

- Paper filters and diatomaceous earth leaf filters for removal of solids prior to coalescence.
- Foam and fiberglass coalescing media for use between stacks of coalescing plates.
- Fiber and stainless steel wool coalescing elements for tail end polishing.

The tests performed in Mayport along with results and conclusions are shown in Table 2. It was decided on the basis of these tests that laboratory tests of the foam and fiberglass packs should be scheduled to more fully define their interface requirements and maintenance characteristics. Figure 11 further details the experimental results obtained in Mayport with the coalescing pack configurations.[17]

4.3 BREADBOARD TESTING

The purpose of the breadboard testing was to evaluate and verify the separation performance of the proposed design concept using a hydraulically scaled laboratory model. The testing was performed in the laboratory of General Electric Reentry & Environmental Systems Division, King of Prussia, Pa., using simulated ballast water with varying influent oil and dirt concentrations. The concept was tested under anticipated influent characteristics which included the emulsification effects of the ship's pump and the piping at the Craney Island facility.

The development tests, which were undertaken to more fully define the performance of coalescing packs used in conjunction with the coalescing plates, were performed in a laboratory model separator with full size coalescing plates and full thickness foam packs. The model separator is approximately 1 foot ($30 cm^2$) square in cross section and 20 feet (6.1 m) long. The flow rate chosen for laboratory tests simu-

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[17]Detailed results of this phase of concept testing are contained in the GE final report entitled *Field Test Development and Evaluation Program for the Treatment of Sludge Barge Waste Water from Shipboard Sources* by J.B. Arnaiz and H.C. Hogue. The report, dated 30 August 1976, is on file at NCSL (Code 710), Panama City, Florida 32407.

TABLE 2

A SUMMARY OF MAYPORT TEST RESULTS

ALTERNATIVE	RESULTS	CONCLUSIONS
20 micron pleated paper filter followed by coalescing plates and 4-inch thick foam pack (10 cm)	46% solids removal; 25 psi drop across filter; poor overall (25 psi = 1.76 kg/cm^2)	No further consideration due to poor separation performance
Leaf filter (diatomaceous earth coated screen) followed by coalescing plates and 4-inch thick foam pack (10 cm)	99% solids removal; 30 psi drop across filter; excellent overall separation efficiency; short operational life between applications of diatomaceous earth	No further consideration due to excessive maintenance requirements and high supply pressure requirement (30 psi = 2.11 kg/cm^2)
Coalescing polyurethane foam filters between coalescing plate stacks	Separation efficiency (shown in Figure 11) varies with foam thickness; pressure drop and operational life acceptable	Further tests scheduled to determine interface and maintenance requirements and performance under ballast conditions
Fiberglass filter pack between coalescing plate stacks	Excellent separation efficiency shown in Figure 11; pressure drop higher than for foam	Further tests scheduled to determine interface requirements imposed by pressure drop
Woven fiber coalescer used with paper filter following coalescing plate section	Poor separation efficiency; short operational life;16% solids removal by woven fiber coalescer	No further consideration
Stainless steel woven coalescer following coalescing plate section	39% solids removal; poor separation efficiency	No further consideration

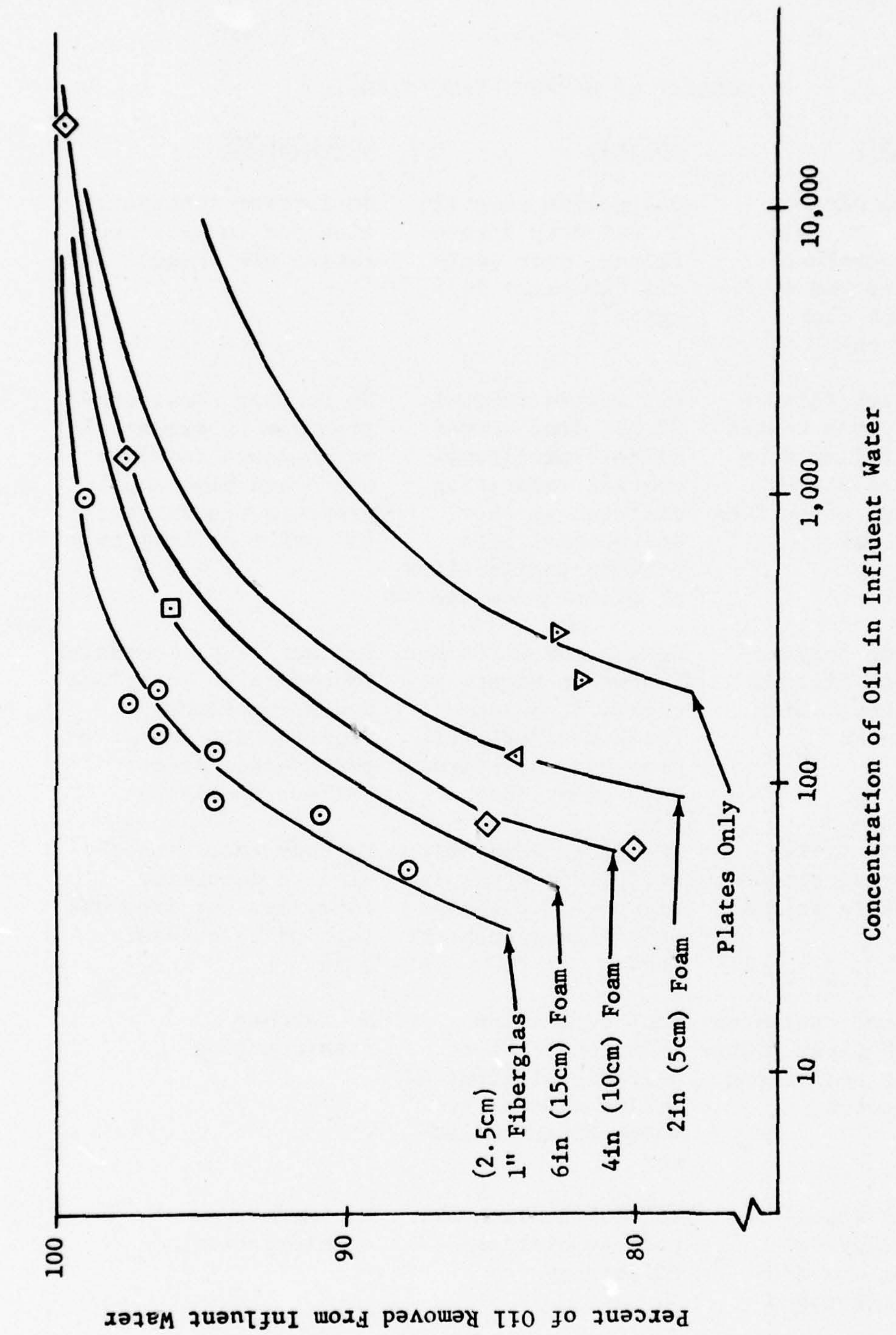

FIGURE 11. SEPARATION EFFICIENCY OF COALESCING MEDIA

lated the full 3000 gpm (11,400 lpm) flow rate through the proposed separator. The influent characteristics were made to approximately match expected ballast conditions by mixing oil with water in a centrifugal pump and passing this mixture through an appropriate length of pipe to simulate the effect of piping anticipated at Craney Island Fuel Depot. From these tests, it was confirmed that while the fiberglass exhibited a slightly superior separation efficiency, it clogged quickly, creating a large pressure drop across the fiberglass pack. Coalescing polyurethane foam packs, on the other hand, while slightly lower in separation efficiency, were less prone to clogging. In the final design, a 4-inch (10cm) layer of polyurethane foam was chosen to obtain satisfactory separation efficiency, reduce the structural problems associated with a pressure drop across the coalescing pack, and minimize the maintenance requirements imposed by clogged coalescing packs.

Breadboard tests of the chosen sensor hardware were also conducted during this time to verify the electrical control performance of the proposed design. They were conducted at modeled flow rates using appropriate fuels and emulsions.

The development tests indicated that the separator could be expected to produce an effluent which meets the goal of 10 ppm or less of oil for ballast water during the major portion of the deballasting operation.

4.4 *ON-SITE FUNCTIONAL TESTS*

4.4.1 Objective and Scope

During these tests, a GE engineer team verified the functional integrity of the OPC-3000 separator and the test facility/site at CIFD. The objective of the tests, which were monitored by an NCSL engineer, was to assure that the quality of hardware components and the operating characteristics met contractural requirements prior to the Navy's acceptence of the separator and its test facility. Detailed checks to verify proper functioning of electrical circuity, control logic, sensors, mechanical hardware, fluid flow characteristics, and emergency shutdown features were performed while circulating water through the system. The acceptance tests took place during two periods. From November 15 to 19, 1976, evaluations were performed at 2200 gpm (8300 lpm), and from January 31 to February 2, 1977, at 3000 gpm (11,400 lpm) The tests examined the system's performance both under normal operating and emergency conditions.

4.4.2 Results

The tests confirmed that the valves, strainer, flow meter, oil skimmers, electrical sensors, control panel, oil pump, etc. operated properly. Design calculations such as pressure drop across strainer, flow control valves, foam pack, weirs, etc. were also verified from measured data taken during the tests. Examination of the flow distribution in the separator tank assured that the total flow passed through the coalescing plates and foam packs.

After evaluation under normal conditions, the system was then cycled through various emergency conditions, such as excessively high liquid level, system overflow, and emergency shut down. In each case the tests verified the system's ability to cope automatically with the emergency situation. Finally, the system was drained and an examination for structural problems, plate movement of blockage, etc. was made. The overall results revealed a few minor deficiencies which have since been eliminated or resolved. The deficiencies included:

	ITEM	CORRECTION
1.	Separator level float switch (high level false indication)	Improved insulation of electrical connections
2.	Forward skimmer guide rods bent by ice	Repaired and modified to make less vulmerable to ice
3.	Minor leaks: aft skimmer flex hose, expansion joints (10 and 12 inch) (25 and 30 cm) and forward oil line viewing tube	Tightened bolts, replaced gaskets or replaced item
4.	Flow meter-calibration shift	repaired; replaced and re-calibrated read-out module

Based on the results of the development and preliminary performance tests, the following modifications were made to the OPC-3000:

1. Replaced guide rods of oil skimmers with a telescoping tube assembly to protect flexible hose from possible ice damage.

2. Raised oil/water interface sensors, which measure depth of oil layer in separator, approximately 6 inches (15cm) to prevent excessive oil accumulation and resulting contamination of effluent prior to emergency shutdown.

3. Revised oil removal pump circuitry so that the automatic emergency shut down process also stops the pump.

4. Added vacuum breaking vent to influent pipe to permit draining through duplex strainer drains so as to prevent ice damage.

Upon completion of the functional tests in February 1977, the OPC-3000 separator and its test site were accepted as successfully meeting Navy contractural requirements. The separator then began a series of NCSL conducted performance tests; the results are reported in Section 5.

Section 5

EVALUATION TEST PROGRAM

5.1 PRELIMINARY TRIALS

Performance evaluations of the OPC-3000 by NCSL personnel were begun immediately following the final onsite functional tests. However, it was discovered that neither the equipment nor the operational procedures were ready for full scale deballasting tests. Therefore, the first trial treatment of ballast resulted in abnormally high oil concentration levels in both the influent and effluent samples. During the separator design phase, records of deballasting had been analyzed and the design influent conditions (Table 1) showed high initial and final oil concentrations with a main cycle influent concentration of 50 parts per million. However, the average oil concentration of actual influent samples taken during the main cycle of the first deballasting was approximately 20,000 parts per million. The effluent, which was supposed to be less than 10 parts per million, ranged between 60 and 135 parts per million. The postoperational analysis of this ballast treatment test showed that the abnormally high influent concentrations were attributable to diesel oil standing in a section of the oily waste handling line, which was neither flushed nor isolated from the OPC-3000 separator. It was also found that the abnormally high effluent concentrations were attributable to damage by freezing of the oil removal system within the separator tank. Collapsed flexible skimmer hoses had allowed the oil layer in the separator tank to grow excessively deep. As the separated oil rapidly accumulated, the oil/water interface in the vicinity of the oil retention dam dropped to within about 4 inches (10 cm) of the lower edge of the dam. Hydrodynamic forces at the interface then stripped small droplets of oil from the oil layer and carried them into the effluent flow of water contaminating it.

5.2 PERFORMANCE TESTING

5.2.1 Scope

Repairs to the oil removal subsystems were made in April 1977. Since that time, tests have included two ship-loads of Butterworthings (tank cleaning wastewater similar in content to ballast water) and approximately 2 million gallons (7.6 million liters) of oily waste from tanks and barges at Craney Island. The data collected from these performance tests have been separated into two categories: (1) high flow rate processing of deballasting or tank cleanings, and (2) medium flow rate processing of influents from tanks and barges.

5.2.2 High Flow Rate Processing

The two offloadings of tank cleanings processed in April and June of 1977 produced far more realistic results than the preliminary trial deballasting. Although influent concentrations during the main pumping cycle were many times higher than the design level of 50 parts per million, the effluent purities still fell within acceptable limits. Table 3 gives specific information about these operations.

5.2.3 Medium Flow Rate Processing

Processing of mixed oily wastes from various sources, such as settler tank, cooker tank, and barges, can be accomplished by the OPC-3000 at flow rates from 600 to 900 gpm, (2300 - 3400 lpm). Gravity feeding or excessive oil content sometimes dictates an even lower flow rate. The salient characteristics of the three predominant sources are:

- Settler tanks, each of which holds approximately 2 million gallons (7.6 million liters) of oily waste, have historically been used to receive bilge water and ballast as well as wastes delivered by barges. In the past, their contents were slowly passed through API separators whenever waste handling operations would permit. Oily wastes in the settler tanks typically contain moderate amounts of finely divided solids and may have a pronounced sulphide odor. Waste from settler tanks was gravity fed into and effectively processed by the OPC-3000 at rates of up to 800 gallons per minute (3000 lpm). Sludge tanks at Craney Island are used to contain heavily contaminated oil prior to reclamation in the cooker tanks. The water bottoms from these tanks have been processed by the OPC-3000 at about 800 gpm (3000 lpm).

- Cooker tanks are used to heat reclaimed oil to reduce the water content of the oil. The water collected in the bottom of these tanks may be gravity fed into and processed by the OPC-3000 at approximately 400 gallons per minute (1500 lpm). The influent is usually about 120°F (50°C) and may contain a small amount of solids.

- Barges are used to collect oily wastes from nearby naval activities and to transport them to Craney Island for disposal. The older barges deliver an unpredictable mixture of oil, water, detergent, and solid debris at rates of up to 1500 gallons (5700 lpm). The newer SWOB (Ship Waste Offload Barge) delivers a somewhat cleaner cargo at less

TABLE 3

OPC-3000 PERFORMANCE: TANK CLEANINGS

SHIP	DATE	FLOW RATE (GPM)	INFLUENT CONCENTRATION (percent)* Average	High	Low	EFFLUENT CONCENTRATION (mg per liter)** Average	High	Low
AO-98 (CALOOSAHATCHEE)	6 Apr. 1977	1500-2000	3.7	70	2.5	4.3	15.1	3.8
AO-99 (CANISTEO)	9-10 Jun 1977	2000-2500	0.085	100	0.070	9.2	13.3	8.9

* 1% = 10,000 milligrams per liter
** 1 mg/1 = 0.0001%

than 500 gallons (1900 lpm). The OPC-3000 has received and processed wastewaters from the barges without a requirement for intermediate storage.

These three categories of waste, because of their solids content and the presence of small amounts of detergent-like compounds, pose a more difficult problem than do the relatively clean ballast and tank washing products. The separator's performance and other experience recorded in handling these oily wastes between May 1977 (after the oil skimmer repairs) and October 1977 are presented in Tables 4, 5, and 6.

TABLE 4

OILY WASTE SOURCES
(Craney Island Fuel Depot)

SOURCE	PERCENTAGE OF TOTAL THROUGHPUT	APPROXIMATE INFLUENT OIL CONTENT
Settler Tanks	79	500 mg/l
Cooker Tanks	7	500 mg/l
SWOB Barges	2	200 mg/l
Sludge Barges	9	1600 mg/l
Sludge Tanks	3	2000 mg/l

TABLE 5

FLOW RATES

FLOW RATE RANGE	PERCENTAGE OF TOTAL THROUGHPUT
0 - 300 gpm (0 - 1100 lpm)	12
300 - 600 gpm (1100 - 2300 lpm)	44
600 - 900 gpm (2300 - 3400 lpm)	44

TABLE 6

EFFLUENT PURITY LEVELS-CUMULATIVE DISTRIBUTION FOR TOTAL CARBON TETRACHLORIDE EXTRACTABLES[18]

25% of the effluent contained less than 5 mg/l.

72% of the effluent contained less than 10 mg/l.

87% of the effluent contained less than 15 mg/l.

89% of the effluent contained less than 20 mg/l.

92% of the effluent contained less than 25 mg/l.

97% of the effluent contained less than 30 mg/l.

100% of the effluent contained less than 35 mg/l.

The data presented in these tables do not include the tank cleanings described in Table 3. It is based on a total throughput of 1.2 million (4.5 million liters). A load containing a chemically stabilized emulsion discussed in Section 6 is also excluded from the statistics because it presents a radically different problem requiring a separate solution. Figure 12 shows the total system's separation efficiency when processing oily wastes from a settler tank at Craney Island. Because the influent was received at approximately 750 gallons per minute (2800 lpm), the separation efficiency shown in Figure 12 is somewhat better than the comparable curve (4" [10 cm] foam) derived from data taken in Mayport and shown in Figure 11 (Section 2).

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[18]Oil content analyses have been performed by infrared analysis of hydrocarbons extracted from the wastewater. Certain compounds, such as detergents may also be extracted, and contribute to the total reading. The contribution of these compounds have typically been between approximately 2 mg/l and 6 mg/l.

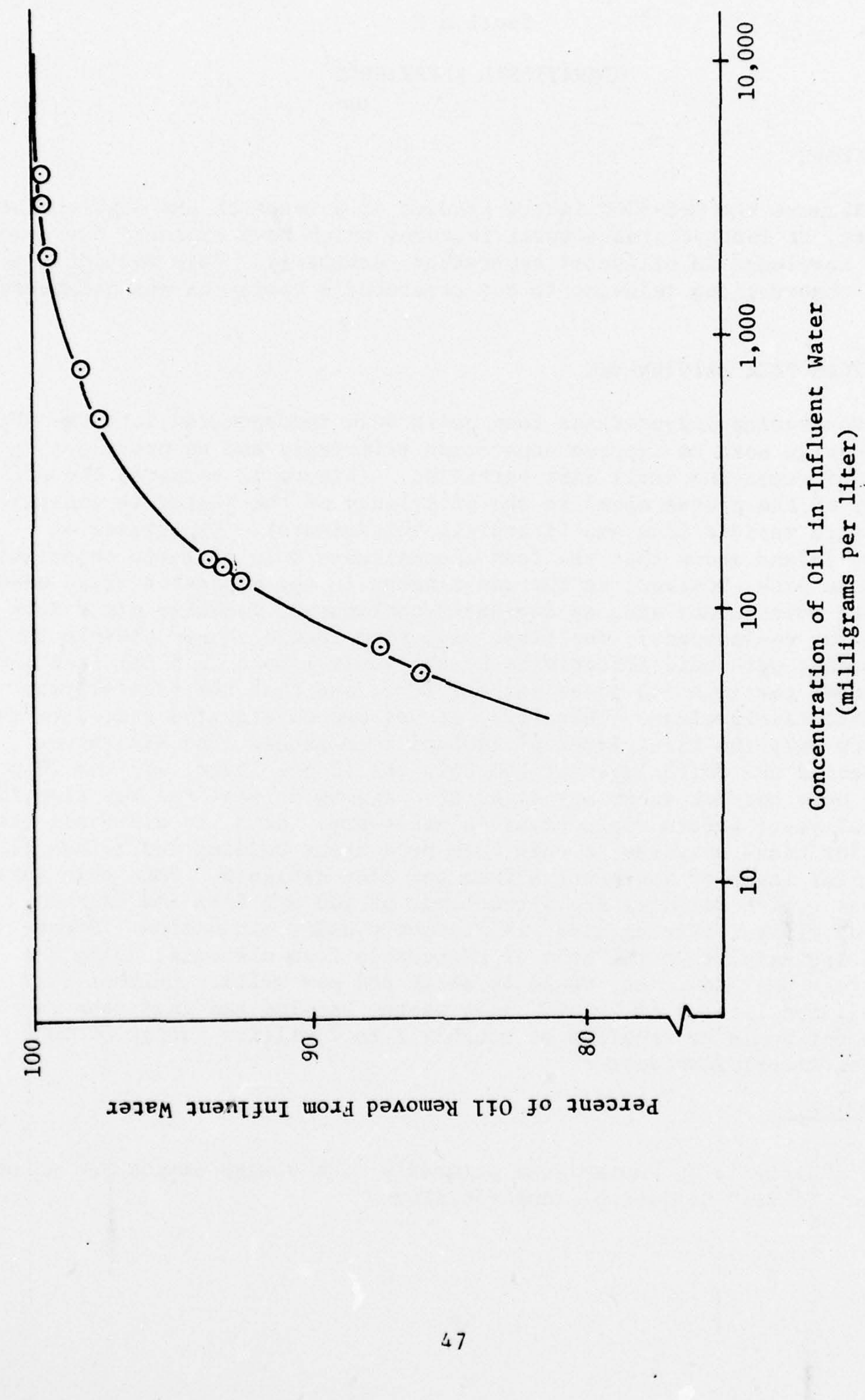

FIGURE 12. OPC-3000 SYSTEM SEPARATION EFFICIENCY

Section 6

OPERATIONAL EXPERIENCE

6.1 SCOPE

Because the OPC-3000 is the product of a research and development project, it incorporates several features which have expanded our practical knowledge in oil/water separation technology. This section presents observations relevant to the separator's operation and maintenance.

6.2 FOAM PACK MAINTENANCE

Coalescing polyurethane foam packs were incorporated into the OPC-3000 design both to improve separation efficiency and to provide a means of screening small dirt particles. (Figure 11 compares the efficiency of the plates alone to the efficiency of the plates in combination with various foam and fiberglass thicknesses). Experience at Craney Island shows that the foam accomplishes both of these objectives. The foam pack, however, is the one element in the separator which needs regular maintenance and, as currently configured, requires crane services for replacement. The first foam pack change showed clearly that the solids were held effectively by the first 1-inch (2.5 cm) layer of 100 pores per inch (40 pores per cm) foam, and that the other layers were relatively clean. Therefore, it has become standard procedure to replace only the first layer of 100 ppi foam rather than all three. The second and third layer of 100 ppi, the 45 ppi layer, and the 20 ppi layer have not yet shown any signs of clogging or wear and may last for several years before replacement is necessary. Also, to alleviate the need for crane services, a thin foam pack frame holding one ½-inch (1.3 cm) thick layer of inexpensive foam has been designed. This thin layer of foam which replaces the first layer of 100 ppi foam and can be changed without lifting aids, is currently under evaluation. Experience indicates that the cost of disposable foam elements, using the thin foam pack addition, would be about $64 per million gallons ($17 per million liters) of "dirty" oily wastes handled and that foam replacement would be required at roughly 1 to 2 million gallon (4 to 8 million liter) intervals.[19]

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[19]"Dirty" oily wastes come primarily from sludge barges and do not include "clean" ballast or tank cleanings.

6.3 FLOW ROUTING AND FLOW RATE CONTROL

The first and last few minutes of many offloading cycles contain significantly more oil than the main part of the cycle. Several methods have proven useful in handling these surges in oil concentration. It is the current practice at CIFD to flush the oily waste handling line to a separate storage tank before bringing the separator on line. Similarly, at the end of a cycle, when the influent contains excessive amounts of oil, the flow is again diverted to the CIFD oil reclamation facility. The OPC-3000 design, which is capable of oil removal at about 500 gpm, (1900 lpm) is normally kept on line when the influent contains less than about 20 percent; this relatively high concentration is usually a transient condition (at both ends of the offloading cycle) and is well within the capabilities of the separator.

No attempt has been made, so far, to throttle the influent flow rate, although the manual influent valve can be used for this purpose.

The water effluent purity is monitored by a Horiba OCMA-32 which indicates the effluent water's approximate oil content. The Horiba readings have typically been within 3 ppm of concentrations determined in the laboratory. If the effluent purity became unsatisfactory, the operator would divert the influent flow to storage tanks; provisions were not made at Craney Island to divert the effluent water flow to a storage tank although this capability would be valuable.

In fact, on only one occasion since May, 1977 was the separator exposed to an influent so difficult to treat that routing the water effluent to storage would have been expeditious. This influent contained a chemically stabilized emulsion which included a significant amount of oil in droplets less than five microns in diameter. This oily waste was processed at approximately 750 gpm (2800 lpm) and the separator reduced the influent concentration of 1 to 2 percent oil to about 160 milligrams per liter (0.016 percent). Because the emulsion was so stable, it met the "no sheen" criteria, but the high oil content was detected by the oil content monitor. When the high oil content was noted, the influent was bypassed to a storage tank. The need for additional treatment or preventive measures against chemically stabilized emulsions are discussed in the conclusions of this report.

6.4 OPERATOR TRAINING

Operation and control of the OPC-3000 is relatively uncomplicated; training of operators at CIFD has been accomplished on the job in periods of one to two weeks. The electrical control system designed for the OPC-3000 has proven to be easily understood by operators. Virtually all actions required of the operator are displayed on the control panel (Figure 9), leaving only a small number of procedures to be learned. The training basically involves:

- Orientation. System components and interfaces with the CIFD oil reclamation facility.
- Start-up and shut down. Valve positions, pipeline flushing and influent sampling.
- Foam pack maintenance.
- Effluent purity monitor operation.

Since the system was installed in November 1976, two operators have been trained. Each is capable of operating the OPC-3000 without assistance, although both prefer to have a worker help with such operations as cleaning the duplex strainer baskets.

6.5 MODIFICATIONS AND MISCELLANEOUS OBSERVATIONS

As mentioned in paragraph 4.4.2, several minor hardware modifications to the OPC-3000 have been made to take care of situations which were unforseen prior to operating the system. Those which may be of value to future designers are cited below.

Ice formation in the separator tank was not anticipated to the extent it actually occurred during the 1976-1977 winter. Ice which formed in the influent pipe section between the manual and automatic valves, both of which were closed, ruptured the pipe section in which the flow meter is located. This situation was remedied by adding a vacuum breaking vent at the hightest point of the influent pipe (where it enters the separator tank), and a procedure for draining the influent pipe section through the duplex strainer drains was developed. Also, the ice which formed in the separator tank under the oil layer crushed both flexible hoses which connect the oil skimmers to the oil removal pipes. These hoses were replaced and protected from further damage by the installation of telescoping rigid pipes around the flexible hoses.

The high concentration of oil that comes at the end of a ship's offloading cycle was anticipated and the OPC-3000 is automatically bypassed when excessive oil in the vicinity of the oil retention dam is detected. To gain confidence in the separator's logic sequence, the OPC-3000 has, on two occasions, been exposed to enough oil to trigger the automatic shut down. The first such experience resulted in a satisfactory shutdown followed by the unexpected migration of oil in the influent section through the foam packs and into the effluent section. Because this continued accumulation of oil in the effluent section could potentially lead to oil escaping under the retention dam, the interface sensors which initiate the shutdown were moved up about 6 inches (15 cm), providing a substantial margin of safety against oil flooding. On the second occasion, which occurred after the sensors were raised, the separator shut down in the proper manner. The subsequent migration of oil across the foam packs resulted in an oil depth (at the oil retaining dam) of only 6 inches (15 cm). This oil was later skimmed while operating in the manual mode. The water effluent quality remained excellent throughout this operation. Even so, in future coalescing plate separator designs the oil removal capabilities should be doubled or tripled.

Another modification that was tried was placing pillows of oil sorbent material in the space between the oil retention dam and the water level control weir. While the pillows appear to catch some oil (which may have traveled this far either as droplets attached to small solid particles or as clingage left over from a drain-down performed for skimmer repairs), they disintegrate fairly rapidly.

It is felt that a major source of problems, particularly with oily wastes from sludge barges and storage tanks, is still neutrally buoyant agglomerations of oil and solid particles. Therefore, although the foam packs have provided an effective measure of solids removal, further control may have to be sought through on-line chemical treatment or with improved foam packs especially if "dirty" oily wastes were to compose a significant part of the separator's wasteload.

Section 7

CONCLUSIONS AND RECOMMENDATIONS

7.1 CONCLUSIONS

The OPC-3000, now operational at Craney Island Fuel Depot, uses an improved technology that was not available at the time the Navy first laid plans to comply with the FWPCA water quality standards. The separator's success in treating the vast majority of oily wastes at Craney Island, however, should make this moderately sized coalescing plate/foam filter configuration an attractive, cost effective alternative to other oil/water separator designs for shore reception facilities.

Provisions must be made to allow for supplementary treatment of chemically stabilized emulsions to positively ensure that effluent water discharge to the environment will meet local purity criteria. The OPC-3000 is not designed to remove oil droplets of less than approximately five microns in diameter, nor is it designed to remove dissolved oils. Influent waste streams containing these dissolved or finely dispersed oils do occur from time to time at Craney Island and pose a problem which cannot be solved by the OPC-3000, or by any other treatment currently available at Craney Island. However, the OPC-3000 is capable of providing a first stage of separation that makes the subsequent use of supplementary treatment systems feasible. The effluent piping would have to be modified to permit the effluent stream to be pumped to a supplementary treatment facility to make use of the OPC-3000 in this mode.

Since April 1977 two loads of tank cleanings, which would otherwise have been stored at Craney Island, have been treated by the OPC-3000. Their on-line real time processing produced a legally dischargeable water effluent and eliminated the need for both large storage volumes and the manpower that would be required for subsequent treatment through the API separators at a greatly reduced flow rate. Similarly, sludge and SWOB barge deliveries have been treated without the need for intermediate storage. Oily wastes currently contained in settler tanks and cooker tanks have also been effectively processed by the OPC-3000. During the May to July 1977 period approximately 1.5 million gallons (5.7 million liters) of stored or barge-delivered oily wastes were treated by the OPC-3000. The effluent stream resulting from this treatment never contained more than 30 mg/l oil and contained less than 15 mg/l 95 percent of the time. The progressive evacuation of oily waste storage tanks has already led to the possibility of returning at least one 50,000 barrel (8 million liters) tank from waste to oil storage service.

Therefore, even though the separator has been operating in a limited test service mode for the relatively short period of 3 months, it has already produced some considerable savings in storage space and man-hours. All performance evaluations thus far point toward both versatile service and increased savings in the future.

7.2 RECOMMENDATIONS

The OPC-3000 has proven itself a useful system at the Craney Island Fuel Depot. Many navy fuel depots face the same problems as CIFD in handling ballast water, tank cleanings, and stored oily wastes; therefore, it is recommended that the coalescing plate/filter design be considered for inclusion in new facilities for handling oily waste.

To extend the range of influents treatable by the OPC-3000, it is recommended that chemical demulsification be studied at CIFD, using the OPC-3000 to process the chemically treated wastewater.

APPENDIX A

OIL/WATER SEPARATION TECHNOLOGY

A-1 SHORE RECEPTION PROCESSING

This appendix contains a brief survey of the major categories of oil-water separation technologies and devices adaptable to shore reception facilities. A comprehensive survey of separation technology and the shore reception industry is contained in the Burns and Roe Industrial Services Corporation report to the U.S. Environmental Protection Agency, *Effluent Limitations Guidelines and New Source Performance Standards* (scheduled for publication in late 1977).[A1] Various separation techniques and phased treatment systems have been developed by the industry as it attempts to process different types of wastewaters under divergent conditions and increasingly stringent purity standards for effluents. Forecasts by studies such as the Esso shore reception facility reports indicate that Navy bases will continue for the forseeable future to handle a spectrum of oily wastewaters.[A2] Influents may range from ballast and tank washings containing oil, grease, and very minute quantities of other extraneous matter to bilge water containing oil and a variety of additional concentrated contaminants such as detergent-like compounds, chemically stabilized emulsions, and dirt.

A-2 SHIPBOARD CONTROLS

Processing such an array of influents may require application of more than one separation technique supplemented by shipboard controls to reduce the volume and complexity of wastewaters handled.

[A1]Prepublication copies of the Burns and Roe report are on file in the offices of Water and Hazardous Materials, EPA, Washington, D.C. 20460 and at HQ NAVSUP (Code 0431), Washington, D.C. 20376.

[A2]Salvesen et al. *Research of Oily Wastes*, report by Esso Research and Engineering Company to NAVSUP (Code 0431).

Such controls, particularly those involved in tank cleaning, include stripping, air blowing, and recycling of cleaning water. Each of these processing steps minimizes the pollutant load to be treated and therefore the capacity required for the separation system. Segregation, another important control, precludes mixing by keeping each wastewater flow separate to be handled only to the extent required. (High flowrate, real-time processing of influent wastewater aids segregation controls by greatly reducing the need for storage and the potential for subsequent mixing with other contaminants.) Emulsion prevention is also vital and can be achieved by the avoidance or reduction of excessive pressures, cleaning chemicals and pumps which can cause emulsions. The separation technologies described below are divided into two categories, primary and secondary oil removal.

A-3 PRIMARY OIL REMOVAL AT SHORE RECEPTION FACILITIES

This technology includes gravity settling basins, holding tanks, and coalescent separators. The method consists of holding the oily wastewater and permitting the separation of oils and sludges from the water by virtue of their differences in density. The oil influent is contained long enough to allow the water to settle to the bottom where it is drained off separately and the oil to rise to the surface where it is skimmed. Another primary removal technique employs parallel coalescing plates which capture and coalesce oil droplets into large drops accelerating the oil's rise to the surface. An improvement in this technology is the primary subject of this report, and so the method is described in detail in the body of the report. It should be noted that, in general, primary gravity removal processes will not separate stable oil-in-water emulsions or substances in solution.

A-3.1 Gravity Separation Devices

There are two common gravity basin designs: the API and the circular. The API Separator is a gravity settling basin designed according to American Petroleum Institute standards. The basic design is a long rectangular basin in which wastewater is detained until the oil rises to the surface where it can be removed by skimming devices. Many API separators are divided into bays to maintain laminar flow and prevent recirculation or short circuiting of the oily wastewater. The separators are usually equipped with rotating scrapers that move the floating oil to the downstream end where it is collected. The scrapers also move the sludge settled on the bottom to the upstream end for collection.

Another gravity device employs a circular basin equipped with a rotating scraper, skimmers, and sludge collectors. The rotating collectors cause the water to move radially outward to a collection trough but the oil is prevented from exiting by means of a circular baffle on the surface. Both of the above separators are usually tied into a secondary treatment system to polish the effluent to meet legal standards.

A-3.2 Coalescing Separators

In addition to the corrugated, parallel plate type, (OPC-3000), the following coalescing separators are among the primary separation devices used in the shore reception facility industry. Manufacturer's literature on these systems generally claims effluent levels down to 10 ppm oil.

- Vertical Tube Coalescing (VTC). This recently developed separator uses a matrix of perforated polypropylene tubes with a filter module to separate oil from water. VTC separators are made in modular packages of 100 gpm units which, in a 74-foot long version, can handle up to 3600 gpm (13,600 lpm).

- Curved Plate Finger (CPF). These separators use a bank of curved, horizontally inclined, finger-like, steel plates which are closely spaced to coalesce the oil. The manufacturer builds CPF systems with capacities reaching 5000 gpm (19,000 lpm) and more.

- Porous Media. This device uses the principle of relative penetrability of oil and water when mixed together and flowing by gravity through a porous media. The influent flows through a basket of media consisting of lightweight plastic material. The media causes the oil to rise and separate from the flow, and permits the water to flow down through the basket. These separators are available in 120 gpm (454 lpm) modules.

A-4 SECONDARY OIL REMOVAL

This treatment category includes dissolved and dispersed air flotation, filtration, emulsion breaking, the use of heating tanks and evaporative basins, and combinations of these processes. Secondary separation techniques normally act as an auxiliary to a primary method to remove additional amounts of oil and suspended or dissolved substances by the use of various additives and other means.

A-4.1 Dissolved Air Flotation

In this process, the wastewater is saturated with compressed air and then instantaneously depressurized to permeate the water with microscopic air bubbles. The bubbles attach themselves to oil droplets and other suspended particles in the wastewater to form agglomerates which, due to entrained air, have greatly increased vertical rise rates. The agglomerates of oil and solid particles float quickly to the surface and form a froth which is then skimmed from the tank. If flocculating agents such as polyelectrolytes and alum are added, DAF has proved effective in separating suspended emulsions of oil and other particulate matter. A technique that is very similar to DAF is dispersed air flotation which employs mechanically injected air bubbles to achieve flotation of the oil.

A-4.2 Filtration

The two basic types of filtration techniques include screening and deep bed filtration. Screening consists of passing the oily wastewater through a layer of polyurethane foam or similar porous material. Oil droplets and other suspended matter will be retained for removal from the flow while the filtered water is discharged from the device. Deep bed filtration uses a granular media, usually sand mixed with anthracite coal (which is oleophillic) to remove the oil and suspended solids. Filters of both types are most frequently used in combination with other separation processes.

A-4.3 Emulsion Breaking

Emulsion breaking is the process of applying chemical or physical means to combine the finely dispersed particles of oild or other matter emulsified in water so that the enlarged particles of oil can be removed by other traditional methods. Emulsion breaking treatments include the following types of processes alone or in combination with each other: chemical additives, temperature adjustment, coalescence, and filtration. After the emulsion has been broken, the wastewater is passed through a conventional oil/water separator. The oil/water separator used in the system will normally be of the gravity separation type aided by oleophillic filters or coalescers to remove the small oil particles. The final step in the emulsion breaking process is chemical readjustment of the effluent's acidity to normal.

A-4.4 Heating

Separation through the application of heat is another secondary removal process. However, heating is primarily used to reduce the water content remaining in the recovered oil. The "cooker" or heating tanks are essentially gravity separators which use heat to lower oil viscosity and enhance its rise velocity. A disadvantage of heating the mixture of oil and water is that higher temperatures increase the solubility of oil in water. This oil would then have to be removed from the effluent water by some additional process.

A-4.5 Evaporation

In arid parts of the world, evaporation can be used to separate water from oil. This technique employs shallow holding basins or ponds from which the water vaporizes and surface oils can be skimmed. In times, grease and oil sludge will build up in the bottom of the basin and so the residue must be removed periodically. Experience has shown that water evaporation slows greatly when an oil layer is permitted to build up and completely cover the surface. Skimming or otherwise removing the oil before it reaches the ponds prevents this difficulty and reduces oily residue accumulation in the pond. Application of this process is limited in the industry because it requires the high evaporation and low precipitation rates of hot arid climates and extensive real estate for adequate evaporative holding areas.

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15 November 1977

CORRECTION REVISION

NCSL TM-212-77

OPC-3000 COALESCING PLATE OIL/WATER
SEPARATOR EVALUATION

November 1977

Corrections have been made on pages 1, 2, 46, 52, 53, and the Distribution List of this technical memorandum.

The area on the page in which the correction occurs is indicated.

SUMMARY

This memorandum documents the background, technology, and performance tests of the USN OPC-3000 Coalescing Plate Oil/Water Separator and evaluates the results of those tests. The Navy fostered the development of this separator as a part of its pollution abatement program for shore facilities. Federal legislation and local regulations have imposed stringent controls which fix point source effluent oil content limits at extremely low levels. Since ballast, tank washings, or other wastewaters containing oil must be handled and disposed of in large quantities by naval port facilities, the Navy needs a high-flow-rate separation system to supplement its oily waste treatment facilities.

A prototype model using a coalescing plate/foam filter design was selected by the Naval Supply Systems Command for a test and development program which resulted in the construction of the OPC-3000 at Craney Island Fuel Depot, Portsmouth, Va. After an onsite functional test verified that the system was operational, an evaluation test program of the separator began in February 1977.

The tests consisted of separation processing of deballastings and tank cleanings at high flow rates of 1500-2500 gpm (5700-9500 lpm) and processing of mixed oily wastes from settler tanks and barges at medium flow rates of up to 900 gpm (3400 lpm). These tests indicated that the OPC-3000 can treat ballast or tank cleanings within the EPA effluent concentration limits for oil of 10 mg/l daily average for a 30 day period and 15 mg/l daily maximum. The tests also showed that the separator can process the relatively dirty oily wastes from settler tanks and barges and meet the daily average requirement.

CONCLUSIONS

The separator's success in treating the vast majority of oily wastes at Craney Island should make this moderately sized coalescing plate/foam filter configuration an attractive, cost effective alternative to other oil/water separator designs for shore reception facilities. However, to positively ensure that effluent water discharge to the environment will meet local purity criteria, provisions must be made to allow for supplementary treatment of chemically stabilized emulsions.

During the May to October 1977 period of testing, approximately 1.8 million gallons (6.8 million liters) of stored or barge-delivered oily wastes were treated by the OPC-3000. The effluent stream resulting from this treatment never contained more than 35 mg/l oil and contained less than 15 mg/l 87 percent of the time.

Therefore, even though the separator has been operating in a limited test service mode for the relatively short period of six months, it has already produced some considerable savings in storage space and man-hours. All performance evaluations thus far point toward both versatile service and increased savings in the future.

RECOMMENDATIONS

The OPC-3000 has proven itself a useful system at the Craney Island Fuel Depot. Many navy fuel depots face the same problems as CIFD in handling ballast water, tank cleanings, and stored oily wastes; therefore, it is recommended that the coalescing plate/filter design be considered for inclusion in new facilities for handling oily waste.

To extend the range of influents treatable by the OPC-3000, it is recommended that chemical demulsification be studied at CIFD, using the OPC-3000 to process the chemically treated wastewater.

than 500 gallons (1900 lpm). The OPC-3000 has received and processed wastewaters from the barges without a requirement for intermediate storage.

These three categories of waste, because of their solids content and the presence of small amounts of detergent-like compounds, pose a more difficult problem than do the relatively clean ballast and tank washing products. The separator's performance and other experience recorded in handling these oily wastes between May 1977 (after the oil skimmer repairs) and October 1977 are presented in Tables 4, 5, and 6.

TABLE 4

OILY WASTE SOURCES
(Craney Island Fuel Depot)

SOURCE	PERCENTAGE OF TOTAL THROUGHPUT	APPROXIMATE INFLUENT OIL CONTENT
Settler Tanks	79	500 mg/l
Cooker Tanks	7	500 mg/l
SWOB Barges	2	200 mg/l
Sludge Barges	9	1600 mg/l
Sludge Tanks	3	2000 mg/l

TABLE 5

FLOW RATES

FLOW RATE RANGE	PERCENTAGE OF TOTAL THROUGHPUT
0 - 300 gpm (0 - 1100 lpm)	12
300 - 600 gpm (1100 - 2300 lpm)	44
600 - 900 gpm (2300 - 3400 lpm)	44

TABLE 6

EFFLUENT PURITY LEVELS-CUMULATIVE DISTRIBUTION
FOR TOTAL CARBON TETRACHLORIDE EXTRACTABLES[18]

25% of the effluent contained less than 5 mg/l.

72% of the effluent contained less than 10 mg/l.

87% of the effluent contained less than 15 mg/l.

89% of the effluent contained less than 20 mg/l.

92% of the effluent contained less than 25 mg/l.

97% of the effluent contained less than 30 mg/l.

100% of the effluent contained less than 35 mg/l.

The data presented in these tables do not include the tank cleanings described in Table 3. It is based on a total throughput of 1.8 million gallons (6.8 million liters). A load containing a chemically stabilized emulsion discussed in Section 6 is also excluded from the statistics because it presents a radically different problem requiring a separate solution. Figure 12 shows the total system's separation efficiency when processing oily wastes from a settler tank at Craney Island. Because the influent was received at approximately 750 gallons per minute (2800 lpm), the separation efficiency shown in Figure 12 is somewhat better than the comparable curve (4" [10 cm] foam) derived from data taken in Mayport and shown in Figure 11 (Section 2).

[18]Oil content analyses have been performed by infrared analysis of hydrocarbons extracted from the wastewater. Certain compounds, such as detergents may also be extracted, and contribute to the total reading. The contribution of these compounds have typically been between approximately 2 mg/l and 6 mg/l.

were moved up about 6 inches (15 cm), providing a substantial margin of safety against oil flooding. On the second occasion, which occurred after the sensors were raised, the separator shut down in the proper manner. The subsequent migration of oil across the foam packs resulted in an oil depth (at the oil retaining dam) of only 6 inches (15 cm). This oil was later skimmed while operating in the manual mode. The water effluent quality remained excellent throughout this operation. Even so, in future coalescing plate separator designs the oil removal capabilities should be doubled or tripled.

Another modification that was tried was placing pillows of oil sorbent material in the space between the oil retention dam and the water level control weir. While the pillows appear to catch some oil (which may have traveled this far either as droplets attached to small solid particles or as clingage left over from a drain-down performed for skimmer repairs), they disintegrate fairly rapidly.

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7.1 CONCLUSIONS

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Provisions must be made to allow for supplementary treatment of chemically stabilized emulsions to positively ensure that effluent water discharge to the environment will meet local purity criteria. The OPC-3000 is not designed to remove oil droplets of less than approximately five microns in diameter, nor is it designed to remove dissolved oils. Influent waste streams containing these dissolved or finely dispersed oils do occur from time to time at Craney Island and pose a problem which cannot be solved by the OPC-3000, or by any other treatment currently available at Craney Island. However, the OPC-3000 is capable of providing a first stage of separation that makes the subsequent use of supplementary treatment systems feasible. The effluent piping would have to be modified to permit the effluent stream to be pumped to a supplementary treatment facility to make use of the OPC-3000 in this mode.

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