AD NUMBER

AD881018

NEW LIMITATION CHANGE

TO

Approved for public release, distribution unlimited

FROM

Distribution authorized to U.S. Gov't. agencies only; Administrative/Operational Use; 01 JAN 1971. Other requests shall be referred to Naval Material Command, Attn: Code MAT-044P, Washington, DC 20390.

AUTHORITY

USNMC ltr dtd 14 May 1973

Report on

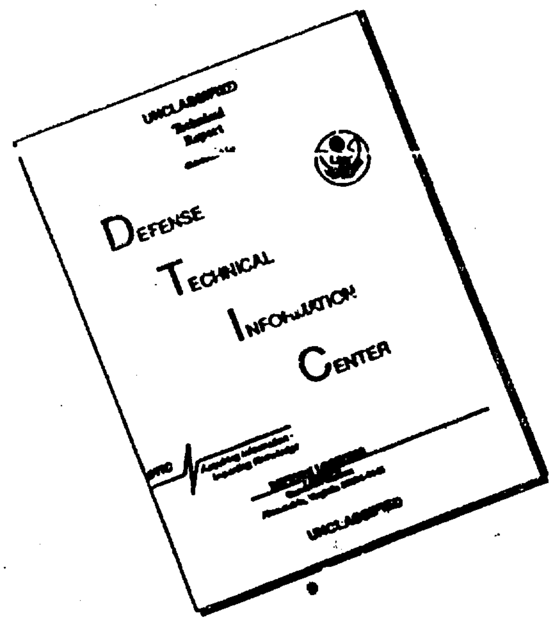
U.S. NAVY ENVIRONMENTAL PROTECTION PROGRAM

21 AUGUST 1970

J. L. Kalinsky
Navy Material Command Facilities and Industrial Resources Division

Prepared under the auspices of Deputy Chief of Naval Material (Logistics Support) and Deputy Chief of Naval Material (Development) by the Facilities and Industrial Resources Division

DISCLAIMER NOTICE



THIS DOCUMENT IS BEST QUALITY AVAILABLE. THE COPY FURNISHED TO DTIC CONTAINED A SIGNIFICANT NUMBER OF PAGES WHICH DO NOT REPRODUCE LEGIBLY.

SUMMARY RECOMMENDATIONS

The objective of this report is to define the Environmental Protection (EP) problems of the U.S. Navy ashore and afloat and to derive meaningful RDT&E requirements to be responded to by the various NAVMAT SYSCOMs.

The scope and responsibilities of the various federal agencies in the EP program are stated in official documents and are augmented, clarified, and updated for this presentation by personal discussions and visits with two groups of personnel – those responsible for research, development, and demonstration, and those for operations. In the establishment of requirements, care was taken to coordinate these areas with the cognizant agency to minimize duplication and where possible to reinforce and concentrate Navy resources in critical areas.

The principle of pollution prevention—treatment of waste (or surplus material) and by reprocess, purification, etc., where technically and economically feasible, to make available a reusable or salable product—was advanced.

Included with the RDT&E requirements for each pollution problem is a description of operational problems encountered and the existing state-of-the-art and technology in use or considered for use in the solution of the problem; where applicable, a technical appraisal is rendered. Thus the reader can be familiarized with the existing situation, the magnitude of the problem being faced, and the potential of some of the technical approaches to be investigated and tested. The major Navy R&D problem areas of concern are:

a. Sanitary Waste treatment and disposal systems for small boats, submarines, and large ships (AS/CVA) which spend considerable time in port—development of on-board holding or treatment systems with flexibility of performance to meet more rigorous water standards. Functional modules to be integrated into a shipboard system would include biological, biochemical, electrochemical, mechanical, membrane purification, filtration, and incineration.

b. Prevention of oil pollution of water resulting from pumping of bilges, deballasting of fuel or cargo oil tanks prior to refueling, pumping tank slop, accidental and deliberate fuel spillage from fuel replenishment (JP-5 contamination), fuel tank meter failure, etc. As a consequence, the R&D program consists of bilge and ballast oil/water separators, oil in water monitoring/measurement devices, oil slick containment and recovery systems for harbor use.

c. Reduction of smoke emission and noise of aircraft engines. A smoke problem is usually a corollary of carbon monoxide (CO) and unburned hydrocarbon exhaust. Operational (reliability) problems arise from use of fuel additives and combustion-can modifications when a reduction of "visible" smoke is attempted. Concern has been expressed that efforts to reduce smoke result in the increased emission of the more toxic air pollutant—the oxide of of nitrogen (NO_x).

d. Ordnance material reprocess and reclamation (explosives, propellants, pyrotechnics, and OTTO fuel). In addition, an attempt at improved reclamation of chemical silver from used photographic material will be made as well as recovery of the negative base without security compromise.

e. Other problem areas of distinct Navy application but of lower importance requiring solutions include: industrial (chemical) and galley wastes from ships, shore (and ship) destruction of classified material, ships antifouling paints, and aircraft cleaning and stripping.

f. Recommendations are made for the responsible system command project jurisdiction, and various administrative and procedural changes to promote greater effectiveness and coordination within the Navy. (Insufficient coordination within the Navy, and between the Navy and other federal agencies was clearly demonstrated in sanitary sewage and oil spillage problem areas.) Other recommendations include: formation of a Navy Environmental Protection Subcommittee consisting of all the SYSCOMS under CNM; greater role of CNM Laboratories in program planning and prosecution, and concentration of the RDT&E effort at the Naval Ship Research and Development Laboratory (NSRDL), Annapolis, and the Naval Civil Engineering Laboratory (NCEL), Port Hueneme, mainly but not exclusively for problems afloat and ashore respectively; and the establishment of an International Exchange Program (IEP) for Naval Environmental Protection with the United Kingdom.

U.S. NAVY ENVIRONMENTAL PROTECTION

TABLE OF CONTENTS

FIGURE

TABLES

APPENDICES

U.S. NAVY ENVIRONMENTAL PROTECTION PROGRAM

I. INTRODUCTION

A. The prime purpose of this report is to define the problems of the U.S. Navy ashore and afloat related to environmental protection (formerly titled Pollution Abatement and later Environmental Quality Control) and to derive, therefrom, meaningful research and development requirements/objectives. The various system commands (SYSCOM) under NAVMAT cognizance are expected to respond to these requirements by preparation and submission of updated DD 1634's Task Area Plans (TAPs) or where appropriate by Forms 3910 or 3920 (Semiannual Program Summaries–Task or Project Plans).

B. The statement of this objective was timely, in that new Presidential Executive Orders 11507 and 11514, and Public Laws -190 and 91-224 were being or about to be issued.

C. To develop realistic R&D requirements, the following approach was taken.

1. Review existing pertinent Department of Defense (DOD) and Navy official documents (instructions, memos, point papers, Exploratory Development Goals (EDG), General Operation Requirements (GOR) which set up responsibilities, organizational committees, requirements, objectives, etc. for on-going effort.

2. Review on-going, and planned programs (construction, operation and maintenance, research and development) of other federal agencies which would affect the scope or direction of Navy R&D.

3. Meetings and discussions with appropriate Navy SYSCOM, ONR, CNO, and MSTS representatives and personnel of other federal agencies were held to explain the CNM objective and to establish MAT 044 as the focal point for the Navy's Environmental Quality Control program as it applies to the NMC.

4. Meetings and discussions with British Navy Staff were held to obtain data on ship's sewage system development by United Kingdom (U.K.).

5. Meetings and discussions with Navy Laboratory representatives (Naval Civil Engineering Laboratory (NCEL), Naval Ships Research and Development Laboratory, Annapolis (NSRDL), Naval Weapons Center, and Naval Weapons Laboratory) were held to learn what pollution control and abatement programs are under investigation or being considered.

D. Discussions were also held with CNO Technical Analysis and Advisory Group representatives (Messrs A. W. Magnitzty (NOP-07T14) and T. L. Soo-Hoo (NOP-07T13)) regarding the advisability of preparing new GOR's (or by addendum, modifying existing ones) for the Navy Environmental Quality Control Program. These representatives indicated that four GOR's will be modified, the differential bases being land, air, sea surface, and sea subsurface, target date for approved versions was to be on or about 1 September 1970. Achievement of CNO approved GOR's would enhance the validity of the SYSCOM DD 1634 Task Area Plan submissions, and show response to a definite Navy operational requirement.

II. SCOPE OF NAVY ENVIRONMENTAL PROTECTION (EP) PROGRAM

A. EP PROBLEM AREAS

1. The Navy's policy is to play a leading role within DOD in the prevention, control, and abatement of the pollution of water, air, and land, and in the conservation of the nation's resources. In maintaining and furthering this policy, naval operations ashore and afloat are reviewed and analyzed periodically to determine and define problem areas, including anticipation of problems inherent in procurement of materials and systems. The solution is also dependent upon the nature, type, and severity of the problem. Some are considered more as safety or medical in nature (pest control and radiation), and some as combined pollution and combat effectiveness (aircraft smoke emission). Other EP problems are solved more adequately by military construction and installation and procedural modification projects. Examples of the latter projects are shore based incinerators and sewage disposal/treatment systems. In accordance with PL 91-224, Navy policy is to connect to municipal systems where practical rather than install Navy units. Additional examples of Navy EP problems by installation and procedural modifications are the Fire Fighting Schools where the emission of dense fumes of smoke were abated by modification and additions of ducts, fans and afterburners. Based on extent of expenditures, EP projects supported by RDT&E funds represent only a fraction of the total effort sustained by the Navy. Table 1 is a compilation of the major problem areas of the Navy Environmental Protection Program--(pollution prevention, control, and abatement, and resources conservation).

TABLE 1
NAVY ENVIRONMENTAL PROTECTION PROBLEM AREAS

a. Water Pollution

(1) Oil discharge or spillage (Harbor, Ships)
(2) Sanitary Sewage (Ships, Advanced Base)
(3) Industrial & chemical wastes
(4) Radiological wastes
(5) Miscellaneous--galley waste, garbage, trash, laundry
(6) C & B warfare agents
(7) Underwater explosion testing

b. Air Pollution

(1) Engine smoke & chemical emission (aircraft & vehicular)
(2) Coating solvents--(ship antifouling paints)
(3) Ships' stack exhaust (propulsion, industrial & sewage incineration)
(4) Ordnance material disposal (burning of explosives, propellants, etc.)
(5) Missile & Rocket Propellant Testing
(6) Smoke & chemical emission--(Fire Fighting Schools)

c. Radiation

(1) Ionizing--Nuclear, X-ray, UV (reactor propulsion, warheads)
(2) Nonionizing--Microwave, (radar) RF, ELF, & Lasers (communication, guidance control, navigation)
(3) Radiological wastes

d. Pesticides--Pest Control

(1) Persistent
(2) Nonpersistent

e. Noise Pollution

(1) Aircraft engines- onground service & test; flight operations
(2) Aircraft carrier noise environment
(3) Machinery, electronic equipment

f. Thermal Pollution of Water–Harbor area

(1) Ship Power/propulsion system–Nuclear reactor & fossil fuel–Not considered a Navy problem in Harbor

g. Land Fill–Solid Waste Disposal

B. DEFINED EP PROJECTS–RDT&E

1. Direct RDT&E--Water, Air and Noise Pollution. Table 2 is a list of projects planned or underway where the specific EP problem is definable and a major portion of the solution can be provided more suitably by RDT&E. To minimize duplication of effort among federal agencies, and among the Navy SYSCOMS/Bureaus, and to maximize the manpower, facilities, and funding resources within the Navy, an attempt was made to determine the cognizant or major responsible federal agency or Navy activity for each project.

TABLE 2
DEFINED DIRECT RDT&E EP PROJECTS

	Respondent Activity
a. Water Pollution	
(1) Oil Spill Countermeasures SHIPS	
(a) Bilge oil/water separation (Bilge pumping)	SHIPS
(b) Ballast oil/water separation (Deballasting)	SHIPS
(c) Oil in water monitoring & measurement	SHIPS
(d) Fuel tank filling alarm	SHIPS
(e) Fuel tank cleaning	SHIPS
(f) Slop oil containment & disposal	SHIPS
(g) Jet fuel (JP-5) Coalesceler/separator purification for Navy oilers	SHIPS
(h) JP-4 & AVGAS pumping/recovery system (nonexplosive)–in salvage operations	(SHIPS/SUPSALV)
(i) High speed oil pumping/recovery system in salvage operations	(SHIPS/SUPSALV)
(j) New design of Oilers (appl. to NAVSHIPS & MSC[1])	Depts. of Commerce & Transportation
(2) Oil Spill Countermeasures–HARBORS	
(a) Oil Slick Containment	
1 Booms, Pontoons, Air Bubble Formation	FAC
2 Chemical Monolayers	ONR

[1] Formerly Military Sea Transportation Service

	Respondent Activity
(b) Oil Slick Recovery	
1 Skimmers	FAC
2 Polymers	FAC
3 Oil/water separation	FAC
(c) Oil Slick Combat Technology Special Techniques	
1 Absorbents (being conducted at Navy Lab)	Dept. of Int. & Transportation
2 Sinking Agents	Dept. of Int. & Transportation
3 Combustion	Dept. of Int. & Transportation
4 Chemical Dispersants	Dept. of Int. & Transportation
5 Biological Degradation	Dept. of Int. ONR
(3) <u>Oil Deballast Facilites—ASHORE</u>	SUP/FAC/MSC
(4) <u>Sanitary Sewage Holding/Treatment & Disposal—AFLOAT</u>	SHIPS
(a) Boats and small ships (<40 men) primary treatment	
(b) Submarines—Holding Systems	
(c) Destroyers—On-board treatment	
(d) Large ships (AS, CVA)	
1 On-board holding system—pumping to shore sewage system or to barges	
2 On-board treatment system	
a Biodigestion	
b Chemical treatment—digestion, oxidation flocculation, antiseptic	
c Mechanical—Filtration	
d Electrochemical—coagulation, flotation, oxidation, antiseptic	
e Thermal—incineration, concentration, evaporation	
f Membrane technology—reverse osmosis etc.	
(5) <u>Sanitary Sewage Holding/Treatment & Disposal—ASHORE</u>	FAC
(a) Advanced base waste water treatment & disposal (same as d2a to d above)	FAC
(b) SHORE based-military construction projects	FAC
1 Navy—Better than primary treatment	
2 Connection to municipality systems	
(6) <u>Industrial & chemical wastes—AFLOAT & ASHORE</u>	
(a) Electroplating	ALL SYSCOMS
(b) Chemical cleaning	ALL SYSCOMS
(c) Submarine battery electrolyte [illegible]	ALL SYSCOMS
(d) Photographic chemicals	
1 Recovery of silver } conservation of resources	
2 Recovery of water }	
3 Recovery of chemicals process }	
(e) Aircraft anticorrosive rinse	AIR
(f) Aircraft cleaning & paint stripping-maintenance	AIR/FAC

	Respondent Activity
(7) Other Water Pollutants	
(a) Galley wastes	SHIPS/SUP
(b) Garbage	SHIPS
(c) Radiological wastes–radioisotopes	SHIPS/LABS
b. Air Pollution	
(1) Aircraft Engine Exhaust/Emission	AIR
(a) Visible smoke elimination	AIR
1 combustion chamber redesign	
2 chemical additives	
3 testing methods	
(b) Chemical emissions	
1 carbon monoxide	
2 hydrocarbons	
3 sulfur oxides	
4 oxides of nitrogen & their analytical instrumentation	AIR/FAC
(2) Ships Coatings	SHIPS
(a) antifouling paints–ketones & aromatic solvents	
(b) asbestos lagging	
(3) Stack exhaust	SHIPS/FAC
(a) smoke & chemical-emissions (incl. measurements)	
(b) destruction of classified material	SHIPS/FAC
(c) Electric motor overhaul–incineration	
(4) Ordnance material (normally disposed of by burning)	
(a) Pyrotechnics	
1 reclaim, salvage	
(b) Explosives	
1 reclaim, salvage	
2 biological degradation	
(c) Propellants	
1 Toxic propellant testing–beryllium, boranes, etc.	
(d) Otto Fuels (Torpedo)	
1 Purification/rework	

c. Noise Abatement. These problems are described in greater detail in other sections of this report, and where applicable, together with technical approaches that have been proposed for solution of the problem.

2. Indirect RDT&E EP Program. Problem areas which are being addressed by the Navy but are not a consequence or directly attributable to recent Navy EP policy per se or Presidential Executive orders, include:

RADIATION AND PESTICIDES

a. Radiation–(BUMED, SHIPS, FAC, ORD, ELEX, ONR)

(1) Ionizing–(Nuclear, X-ray, uv). This subject is adequately covered by instructional rules, and regulation documentation of the Atomic Energy Commission and with the policies and guidance of the Federal Radiation Council as published in the Federal Register. Pollution problems related to Naval Nuclear Propulsion and RDT&E conducted by NAVMAT Laboratories are further encompassed by "Radiological Controls," NAVSHIPS 389-0153 and pertinent National Bureau of Standards Handbooks.

(2) Nonionizing–(microwave, radiofrequency, extremely low frequency, IR & visible lasers). Problems related to electromagnetic radiation of Navy electronic systems are covered by the following:

(a) "Technical Manual for RF Radiation Hazards" SHIPS 0900.005-800.

(b) "Electronics Maintenance & Installation" SHIPS 0967-000-0100.

(c) "Technical Manual for Hazards to Ordnance, Personnel, & Fuel" OP 3565/NAVAIR 16–6-5-29.

(d) Although related to pollution control and abatement, a separate plan has been generated by the Research Division of the Bureau of Medicine and Surgery, supported by cognizant naval organizations, setting forth a general approach to the solution of Navy and Marine Corps personnel exposed to nonionizing radiation hazards. This proposed biomedical hazards RDT&E effort is a consequence of the safety concern of operating personnel in the environment of the more powerful aircraft guidance and fire control radars, satellite tracking and communication equipments utilizing devices which operate in the electromagnetic spectrum range, from 1 Hertz to the near ultraviolet, (extremely low frequency (ELF) radiofrequency (RF), microwave, IR lasers, etc.). Therefore no attempt was made to include this area in R&D requirements specifically for pollution control and abatement.

b. Pesticides–Pestcontrol

(1) For pesticide control, the following pertinent documents are cited:

(a) DOD Directive 5154.12 of 21 August 1968–establishment of Armed Forces Pest Control Board

(b) SECNAVINST 5430.54A (BUMED-7222) of 7 January 1970–outlines pest control responsibilities and functions of Navy offices, bureaus, and commands, "establishes policies to provide maximum effectiveness, efficiency, and safety in pest control operations"

(c) NAVFACINST 6250.12 of April 1970–establishes policy on the use of persistent pesticides at Navy activities.

(d) ASD (Manpower and Reserve Affair) Memo of 28 April 1970—curtails and specifies use of the persistent pesticide DDT, to be followed by disposition instructions for excess/surplus supplies.

(2) Conference was held with Mr. Hutton of NAVFAC (10133) who is presently chairman of the Armed Forces Pesticide Control Board and Capt. McWilliams of BUMED (7222) regarding pollution control of pesticides. A presidential cabinet subcommittee—Pesticide Working Group was established with three immediate objectives.

(a) Provide federal policy on hazardous pesticides.

(b) Establish a national training program and recognition procedures (training before procurement and dissemination practices).

(c) Establish state and/or federal standards/procedures for administering pesticide disposal.

(3) In this Group five working panels were established to deal with program review, monitoring, research, safety (disposal), and information. The safety/disposal panel has the greatest impact on environment quality control. On the basis of the above, it is not recommended that the Navy initiate any RDT&E project in this area.

3. Non-RDT&E EP Program. Examples of pollution problems which are either of no immediate concern to the Navy, or are being handled by procedural modifications or cooperative arrangements with local communities or regional districts are those of Thermal Pollution of Water and Land Fill Operations.

a. Thermal Pollution of Water is mainly concerned with the marine biological effects and adverse atmospheric conditions (fog, smog) produced by the increase in the temperature of rivers, lakes, etc., by water coolant effluents. The prime contributory cause of this pollution is the heat generated by power generators, especially those utilizing nuclear reactors which normally operate near peak capacity. For Navy purposes, this problem is related essentially to ships in port. Whether utilizing nuclear reactor or fossil fuel for power and steam generation, Navy ships in port utilize only a relatively small fraction of their own capacity and depend primarily on shore-based sources for electrical power and where practical, for steam. The thermal problem is not one applicable to open seas, where Navy ships operate at full power, and thus can be considered only as minor or nonexistent. It is conceivable though, that where many ships are berthed or nested in a port at one time, a survey could quantitatively determine the extent of the problem, if any. The problem of thermal pollution of water can thus be relegated to those private utility operations (in New England, Florida, and Long Island, N.Y.) using or building high power nuclear reactor facilities.

b. Land Pollution. Navy and Marine Corps dispose of their dry refuse and garbage in a variety of ways depending upon location, availability of municipal or contract disposal facilities, on-base sanitary landfill, and the type and volume of waste. Thus, because of California laws, garbage from Navy ships must be "cooked" to be buried raw in their sanitary landfills. As in the case of Naval Ordnance wood dunnage, the recovery, sale, and reuse of materials are common practices whenever practical and economical. NAVFAC has been involved in most landfill operations with minimal or no RDT&E required for compliance with existing local or federal regulations.

III. WATER POLLUTION

A. OIL SPILLAGE/DISCHARGE

1. Problem Definition—Phases. Cleaning up an oil contaminated area . e consuming, difficult, and costly. To cleanup costs must be added the costs of the oil invasion itself; destruction of fish, and other wildlife; damage to property; contamination of public water supplies; and a number of material and aesthetic losses. Whether due to mechanical failures or human carelessness, corrective attitudes, procedures, and equipments must be acquired. The oil pollution problem can be subdivided into six (6) phases:

a. preventive measures

b. containment of oil at source when accident occurs

c. removal or recovery of oil from within the containment area

d. treatment of the oil that spreads beyond the containment area

e. efficient and rapid separation of oil from water (recovery process)

f. ecological and meteorological factors

The last item is in reality an ancillary problem—related to the selection and effectiveness of the corrective measures adopted. Ecology determines the acceptable materials/chemicals/procedures that may be used without significant damage to biota and marine life. Meteorology can be used to predict the direction and speed of movement of oil slicks, the wave turbulence which affects the integrity (and dispersion) of the oil slick, the thickness of oil film, etc.

2. Scope and Responsibilities—Federal Agencies. As stated in OPNAVINST 3120.27 (18 Sep 1968) "the primary responsibility for mobilizing personnel and material resources against major oil pollution hazard rests with federal departments and agencies other than the Navy Department." This OPNAV Instruction, based on Public Law 80-513, specifies the responsibilities of the Ship Salvage authority of the Naval Ship Systems Command in coping with a potential pollution problem involving a U.S. Navy vessel, "and a public or private vessel at the request of competent authority."

The federal agencies with defined responsibilities for oil pollution prevention, control, and abatement are listed as follows:

EPA—Environmental Protection Agency, formerly FWQA (Federal Water Quality Administration)—Dept. of Interior
GS—(Geological Survey)—Dept. of Interior
CG—(Coast Guard)—Dept. of Transportation
Office of Emergency Planning
Corps of Engineers—Dept. of the Army
Maritime Administration—Dept. of Commerce

The basic responsibility for surveillance, prevention, and cleanup of oil spills is vested in the CG and EPA.

a. Public Law 91-224. Consistent with the National Contingency Plan required by Public Law 91-224, "The President shall issue regulations consistent with maritime safety and with marine and navigation laws.

"(1) Establishing methods and procedures for removal of discharged oil.

"(2) Establishing criteria for the development and implementation of local and regional oil removal contingency plans.

"(3) Establishing procedures, methods, and requirements for equipment to prevent discharges of oil from vessels and from onshore facilities and offshore facilities.

"(4) Governing the inspection of vessels carrying cargoes of oil, it is further stated that 'each such department, agency, and instrumentality in order to avoid duplication of effort shall whenever appropriate, utilize the personnel, services, and facilities of other Federal departments, agencies, and instrumentalities.' "

b. EPA

(1) There is also established an Interagency Oil and Hazardous Material Research and Development Task Group as an ad hoc group of the National Contingency Plan and an Interagency Agreement between the EPA and the Department of Defense. Certain responsibilities emerge clearly as predominant from various agencies; some appear quite hazy, and in others, duplication is evident. Thus, EPA as the czar of water pollution, has the major responsibility—supporting R&D in chemical treatment (oil refineries, etc.), setting standards for water pollution, approval of dispersants, RDT&E of technology and equipments for confinement and recovery of oil spills especially in inland waters, an oil source-identification system, and treatment of contaminated beaches (shoreline-restoration technology).

(2) It is also the major responsibility of EPA to provide financial assistance (grants, etc.) to local and state agencies to assist them in meeting their own responsibilities, and to negotiate R&D contracts with industry for assistance in technology and systems for the prevention, control, and abatement of water pollution.

c. Department of Transportation—Coast Guard

(1) The Coast Guard's major responsibility appears in the major oil spills. It covers control and cleanup systems, and law enforcement; the development of lightweight and heavy-duty booms for confinement of spills at open sea; an air (helicopter) portable oil-recovery system for use with stricken tankers which includes power supply, high capacity pumps, and plastic/elastomeric inflatable bag-tanks which float on the sea surface to receive the oil. It also covers airborne detection and surveillance of oil spills, remote slick thickness measurement, and a collective term—"oil spill combatant technology" involving the following components or special techniques:

(a) Mechanical Containment—booms, pontoons, etc.

(b) Mechanical removal or recovery—skimmers, suction devices.

(c) Physical Sinking methods—surface-chemically (hydrophobic) treated sand.

(d) Chemical Dispersion—toxicity of dispersants (mainly surfactants) especially to intertidal fauna and flora provides a basis for controversy for use.

(e) Physical Absorption—inorganic (solid and porous) and organic (natural, synthetic polymers) materials which can absorb oil up to 40 times the weight of absorbent—also an aid in mechanical removal—considered more efficient for harbor areas or calm waters, and for thin to moderately thick oil slicks.

(f) Combustion—burning more effective on fresh and higher vapor pressure oil slicks in calm waters—not very effective for open or turbulent sea—possibly augmented by wicking and/or oxidizing agents.

(g) Biological Degradation—use of natural marine environment microorganisms and/or biological seeding with selective bacteria which are capable of metabolizing oil—a slow process that may be accelerated by nutrients and catalysts.

(2) With the Maritime Administration (see subpar. d): Design tankers to minimize spillage.

d. Department of Commerce—MARAD

(1) MARAD with the Coast Guard is involved in new design of and methodology for use with tankers to prevent or minimize oil spillage. Thus, the purpose of MARAD's Ship Containment Systems Support Plan is to "investigate and develop ship systems for containing spillage of pollutant cargoes in the event of ship grounding, collision or other disaster, submerged or surfaced." Among the alternatives, the following were listed:

(a) double hulled ships.

(b) elastic tank liners.

(c) explosively operative rail-mounted booms. (It is of interest to note that Military Sealift Command (formerly Military Sea Transportation Service (MSTS)) tanker division considers it impractical for tankers to carry booms.)

(d) gelling agents to be added to oil when spillage is threatened.

(2) Oil pollution abatement R&D: the Maritime Administration has a major responsibility for the following two projects related to bilge pumping and deballasting:

(a) Research, development, and evaluation of oil/water separators (deballast flow rate up to 600 gal/min).

(b) Research, development, and evaluation of monitor and measurement systems of oil-in-the-water effluents of oily water separators.

(3) An outline of MARAD's planned marine pollution abatement R&D program includes the following:

(a) Determine equipment requirements and develop necessary hardware for existing trade route ship designs (other than special purpose).

(b) Determine environmental problems associated with waste disposal in the arctic environment and develop pollution control systems for processing or disposing of such waste.

(c) Collect and analyze ocean environmental-quality data.

(d) Analyze requirements and develop specifications for converting reserve fleet ships into community waste processing plants and oil-spill cleanup facilities.

e. Department of the Army—Corps of Engineers. One of the earliest examples of federal legislation concerned with pollution of navigable waters, especially by dumping of wastes (sewage, oil, chemicals), is the Rivers and Harbors Act of 1899. The responsibility for rules, regulations, and enforcement was part of the charter of the U.S. Army Corps of Engineers. To date, this activity is involved in various harbors throughout CONUS, even in the largest ports as in New York, providing permits for dumping of sludge, exacting penalties (fines) from industrial concerns for oil and other chemical dumping into rivers. The Corps operates many dredges for navigable water maintenance and modification. Its role in pollution and resources conservation is a very important one.

f. Department of Housing and Urban Development (HUD)—A basic water and sewer grant program with its $500 million 1971 budget. This program is considered an integral part of its urban development program.

g. Department of Agriculture—$100 million water and waste disposal grant program.

h. Department of Commerce—Its Economic Development Administration sewer program.

3. Naval Responsibilities and Requirements—Harbor Oil Spills. Naval Sea Frontier Commanders and Naval District Commandants have been directed to maintain adequate facilities, equipments, and capabilities for coping with limited oil spills incident to routine Navy ship, shipyard, base, and facility operations. NAVSHIPS through Superintendent of Salvage (SUPSAL) is tasked with the same responsibilities incident to ship salvage operations; NAVFAC (Naval Facilities Engineering Command) is responsible for providing up-to-date technical information on procedures, chemicals (especially where and when permitted for use) and equipment for limited oil spill incidents.

The NAVFAC responsibilities for oil spills stated in NAVMATINST 6240.1 of 29 July 1969 are quite vague, with their scope not intended to be restricted to providing technical information. Such indeterminate task might be misconstrued as a technical data information "retrieval and dissemination" responsibility. A more realistic interpretation of NAVFAC responsibility is to support appropriate RDT&E related to the main phases or problems of oil pollution control (subpars. 1b, 1c, 1d, and 1e above) conducted in close coordination and cooperation with the other responsible federal agencies and private industry (petroleum products, oil equipment manufacturers, etc.) so that naval shore activities will achieve and maintain, as rapidly and economically as possible, the most adequate capability in personnel, equipment, timely countermeasures, and procedures for coping with any potential or existing oil spill in the shore areas (not open sea).

a. State-of-the-Art and RDT&E Requirement Surveys. Several important studies have been made recently to determine the magnitude of the oil-spill problem and to survey existing capability and state-of-the-art, followed by a cost effectiveness analysis of equipment, materials, and techniques for control, confinement, and removal of the spilled oil.

(1) Under NAVFAC administration an in-house, on-site survey of East and West Coast Navy harbors was made in 1968, followed by a cost effectiveness study under contract to Battelle Northwest Laboratories completed in August 1969. This study emphasized the need to develop oil containment and removal equipment, chemicals for oil-pollution control (dispersant use must be approved by EPA), and oceanographic factors affecting oil pollution in harbors.

(2) A. D. Little, Inc., under contract to the Coast Guard, prepared a fairly comprehensive two volume report in June 1969 on "Combating Pollution Created by Oil Spills." Volume 1 provided information on the state-of-the-art and available methods and their basic technology with effectiveness rating of each method. However, as the report indicates, the evaluations of the different techniques were not based on definitive empirical evidence, with little or no laboratory and/or field testing. Volume 2 proposed an R&D plan to achieve near-term objectives and to work toward long term solutions. This R&D plan considered the following:

(a) Optimization of existing methods.

(b) Development of equipment and procedures for implementation of available technology.

(c) Basic research into the physics and chemistry of oil pollution to provide needed design information.

(d) Research on the operational and system aspects of the combatant technology.

The R&D plan addressed itself in large part to the seven (7) special techniques or components described earlier in this section (III A 2c(1)) of the report (mechanical containment, mechanical removal, chemical dispersion, physical absorption, physical sinking, combustion, and biological degradation.)

(3) In addition to these studies, several field experiments were recently conducted with oil spills (Santa Barbara, Calif., Chevron oil well fire, blowout in the Gulf of Mexico, and a deliberate spill near Boston, Mass.). These experiments provided realistic evaluations of containment and recovery equipments and devices, demonstrating the deficiencies of candidate oil booms, skimmers, and pumps while operating in three foot plus seas. One item clearly emerges: manufacturer's claims of performance cannot be relied upon. For example, the Kain Filtration Boom (Kain Division of Starcross Oklahoma, Inc.) is selectively permeable to water, with one of the highest weight per foot ratios of the available booms. The manufacturer claims its product to be strong enough for open sea use (Litton report page

18), yet it failed in the Chevron spill operation (Memo fo. CNM by COMNAVFACENGCOM of 30 Mar 1970).

(4) All of the above programs, plans, and concepts demonstrate that an extensive amount of studies, programs definition, etc., have been collated. Additional studies in depth do not appear warranted. These facts also show that the federal agencies with major responsibilities are investigating practically all aspects of the problem, anticipating that results of on-going research, development, and demonstration in the latest state-of-the-art technology and equipment can provide at least short term solutions to the problems. Additional information provided by U.S. and U.K. laboratories regarding satisfactory natural degradation (microbiological, etc.) of oil slicks in the open sea (Torrey Canyon Disaster) will decrease the importance of certain special techniques (absorption, combustion) where shore pollution is not a hazard.

b. Navy Requirements—NAVSHIPSYSCOM—SUPSAL

(1) SUPSAL of NAVSHIPS (Code OOC) has the following capability of dealing with oil spills incident to ship salvage operations:

	Diameter (")	Flow Rate (gal/min)	HP
Submersible pumps	4	500	25
Surface pumps	3	140	—
Surface pumps	6	740	40
Surface pumps	10	1150	70

The surface pumps are diesel engine driven and are not considered satisfactory for heavy crudes in cold water, nor because of explosion hazards for AV-Gas or JP-4.

(2) SUPSAL requires the development of procedures to permit defueling of ships at sea with minimum hazard—to effect gas-free tanks without explosion hazard, submersible pumps of high flow rate capability (say utilizing a 10" line) are also required. A state-of-the-art survey would most likely be performed regarding the development requirements for impeller blades and seals that can be used for all petroleum products (heavy crudes, distillate fuels, JP-5, etc.), water-free or entrained water. Present pumps usually require changing of impeller blades for the particular petroleum product. SUPSAL also utilizes booms to contain oil spills. However, it is recommended that R&D efforts of the Coast Guard (open sea), and NAVFAC (harbor) be utilized for boom and other containment development and effective coordination be encouraged to permit timely and effective test and evaluation of the developmental items in SUPSAL operations. (Here again SUPSAL participation in National Multi-Agency Oil and Hazardous Materials Pollution Contingency Plan, at least as Deputy to CNO (OPNAV-03) is recommended.)

c. NAVFAC SYSCOM

(1) NAVFAC is in a unique position in environment protection (air, liquid and solid waste discharges) for Navy shore activities, including naval bases, shipyards, etc., where fueling, and normal shipboard operations produce limited spills and accidental discharges. NAVFAC, through LANTDIVNAVFACENGCOM, observed and participated in the

Chevron oil incident. NAVFAC, directly through their regional divisions, and indirectly through the Navy activity Public Works Departments, can operate effectively with the Naval Sea Frontier Commanders and Naval District Commandants in maintaining adequate facilities and capabilities for dealing with limited oil spills incident to routine Navy ship, shipyard, base, and facility operations.

(2) In coordination with the Coast Guard, EPA, and SUPSAL, NAVFAC should be responsive to the following requirements for coping with limited oil spills in harbors:

(a) Establishment of valid design criteria and performance characteristics of candidate oil containment systems such as: volume, slick thickness, sea state, wind velocity and direction, wt/ft of boom, physical strength of members, etc.

(b) Containment system concept: barge, towing, boom, bubble air curtain; modification of NAVFAC pontoons, etc.

(c) Techniques for mechanical concentration and removal of the oil from the water surface.

1. Mechanical surface skimmers usually are self-propelled special duty barges (efficiency depends upon thickness of oil film on the surface) which removes the top layer of oil by suction pumps, overflow dams, or scoops. NCEL Report CR 70.001 "Study of Equipment and Methods for Removing Oil from Harbor Waters" by Battelle Northwest Laboratories, August 1969, recommended the use of suction devices as most cost effective for mechanical removal of oil from water surface.

2. Included in this requirement is the important project proposed by Mr. Garrett of the Naval Research Laboratory (NRL) and sponsored previously as ONR 6.1 effort. Using a chemical monolayer spread on the sea surface and displacing the oil/water interface, contributes to greater confinement and film thickness properties of the oil slick, facilitating the containment and recovery processes. It is recommended that this ONR/NRL effort be included and sponsored as part of the NAVFAC solution to the oil spillage problem.

(d) Oil/Water Separators—These concept and performance requirements are significantly different from the bilge and ballast oil/water separation system development (under cognizance of NAVSHIPS). This can be separate or part of the skimmer-separator system. The later combination type uses hydrophobic (oil-absorbent, water-repellant) elastomeric material with mechanical devices to recover oil/water mixture and drive off excess water. Requirements for this o/w separator would not necessarily be as stringent as that for bilge and ballast o/w separation.

(e) Absorbents—R&D effort should be restricted to following the output of EPA and Coast Guard programs. CG is presently sponsoring such R&D work at NSRDL. Minor effort should be employed in evaluation of such selected absorbents in combination with NAVFAC and SUPSAL oil containment/recovery systems in use and under development.

(f) Dispersants and Sinking Agents, as described earlier, this is a very controversial subject due to toxicity of the dispersants, especially in intertidal and shore waters, with EPA deciding which chemicals can or cannot be used. For critical harbor or pier areas, if a great danger of the oil being driven on shore by a prevailing wind exists, and no mechanical means can be effectively employed, the use of EPA approved dispersants or sinking agents may be employed. Oil would then move with water currents rather than downwind.

(g) Combustion—Not recommended in harbor areas.

(h) Biodegradation—A major R&D effort is being sponsored by EPA, especially at Florida State University in the microbiological seeding and accelerated degradation of hydrocarbons. A much smaller 6.1 effort is being sponsored and highly regarded by ONR at Rutgers University, N. J.

4. Oil Discharge From Ships (Limited Spills)—Problems & Requirements

a. Bilge and Ballast Pumping

(1) Oil discharge from ships can occur from several sources; viz., pumping of bilges, deballasting fuel- or cargo-oil tanks, pumping tank slop, overflow from filling of tanks due to equipment (unreliable tank capacity indicators) or personnel failures, and those from more drastic action resulting from grounding, hull leakage, salvage operations, etc. Information provided by NAVSEC also indicates that it is not unusual for ships, prior to entering a naval base or shipyard for dockside overhaul, to clean their oil tanks at sea with MILSPEC emulsifier/detergent followed by sea water flush, and the combined discharged at sea. This operation is performed at sea to reduce the ship down-time in port, resulting in lower cost, etc. Thus, aside from the accidental oil spillage, pollution of water from shipboard oil sources is the result of more or less deliberate acts, contrary to the existing (national—50/100 miles from coast) and the proposed IMCO (50/100 miles) regulations. Directly related is the problem of inadequate deballast facilities at government terminals, worldwide, to receive the contaminated oils from the ships (presently being addressed by DFSC and Military Sealift Command). (The problem of oil spillage in harbor areas, aside from salvage operations, under cognizance of NAVFAC, Naval Sea Frontier Commanders and Naval District Commandants is described in section IIIA3c of this report.)

(2) Problem Definition, Objectives and Requirements. The above problem is thus resolved into the following aspects:

(a) Development and shipboard evaluation of oil/water separators with specific performance criteria or standards related to bilge, ballast, and tank cleaning discharges.

(b) Development and shipboard evaluation of oil-in-water measurement/monitoring systems for the differential 100 ppm effluent rate and/or the integral 60 liters per mile discharge.

(c) The systems to be developed should be relatively simple, compact, and reliable, to be applied to any mixture of oil and water. It should be able to handle a variety of oil characteristics, i.e., specific gravity, water-oil interfacial tension, viscosity, additive composition (extreme pressure, antirust, antioxidant, antifoam, etc.) which would affect its separability from water. In addition, the systems to be developed must be capable of sustained operation irrespective of the nature and extent of oil/water contaminants—which would also significantly affect both the separation and monitoring per rmance.

(d) The problems of bilge and ballast oil/water separation are in a fashion of equivalent difficulty. The main problem in deballasting (mostly fuels), is the high flow rates to be encountered. Design criteria for Navy applications include 600 gal/min and 3000 gal/min for small and large ships respectively. It is important to point out here that the lower requirement (600 gal/min) is identical to that of the Maritime Administration and the hardware or systems to be evolved would be satisfactory to both; parallel development is underway in the Navy and MARAD. Recent discussions with the U.S. Coast Guard has indicated the latter's independent entry into this area of development.

(3) Bilge oil/water separation flow rates usually are below 25 gal/min. While the flow rates are very small compared to deballasting, bilge oils contain a considerable amount, and wide range of the viscous, additive-loaded lubricating oils with suspended-particulate contaminants—all of which would increase the burden of separation and monitoring. While it is true that we have shipboard oil/water separators as with operation of steam turbine lubrication systems, the situation is reversed (compared to bilge and ballast) in that the amount of water in the oil is small, and to the best of my knowledge, no quantitative measurement is made to determine the amount of oil in the heated effluent water. One item has been demonstrated—the water treatment does leach out an extensive amount of the oil additives, causing mandatory additive of make-up oil.

(4) Literature surveys conducted by the Permutit Co., in 1962, and more recently (1969) by NSRDL, Annapolis, on the subject of oil/water separation—reveal that practically all marine and industrial separators depend upon gravity difference for separation. No available technology, alone, was deemed practicable for shipboard reduction of the oil content to points below the required limit. A combination of at least two distinct operations—mechanical filtration followed by physicochemical treatment devices along with some [illegible]process module may be required to reduce the oil content of the water discharge be[illegible] the required limit.

(5) The RDT&E program of oil/water separation, and monit[illegible] [illegible]asurement must address itself to the problems listed above—a variety of petroleum products with different compositions and formulations, many types of liquid and solid contaminants, oil/water flow rates and surges, reliability and simplicity under shipboard environmental conditions, etc. For the oil in water measurement/monitoring device, additional requirements include rapid, accurate, and precise detection, within close tolerances, at extremely low oil concentrations. Although MARAD has been developing these two items for several years—and shipboard tests of one candidate system for each (separation and monitoring) are scheduled within the next few months with NSRDL support—too much is at stake to rely solely on this agency development (this opinion is also shared by Coast Guard, EPA and Military Sealift Command). It is recommended that NAVSHIPS undertake this dual role utilizing where practicable the resources of NSRDL. It is also likely that CG and EPA would provide additional support for a Navy sponsored program.

b. Fuel Replenishment—Tank Filling. In fuel replenishment operations, new pressure-responsive probes have significantly reduced fuel spillage. Although newer Navy oilers are being fitted with tank alarms, most of those in use do not have such operational systems, relying instead on unreliable tank-fill indicators. It is recommended that this situation be investigated by NAVSHIPS, with full coordination and assistance of NAVSEC and NAVFUELSUP, and define the problem in fueling, the magnitude of fuel spills, the state-of-the art of tank-fill (electronic and remote) indicators and alarms feasible for automated fueling procedures to minimize human error under various sea states or meteorological conditions with sufficient safety factors to prevent or drastically minimize tank overflow or other fueling difficulties encountered.

c. Sloptank and Deballast Facilities. To further reduce the problem of oil pollution of water related to ballast oil/water separation, the following items are recommended:

(1) Requirements for slop tanks.

(2) Requirements for deballast facilities at government terminals world-wide. Information on commercial facilities in the United States has been made available by DFSC and MSC. DFSC is attempting to require suppliers to maintain shore-based deballast facilities in order to bid on new oil procurements.

d. Jet Fuel (JP-5) Spillage at Sea (NAVSHIPS in conjunction with NAVSEC, NAVSUP, and NAVAIR)

(1) Background. In the process of fuel replenishment at sea involving AO "oilers" and aircraft carriers, existing practices result in dumping of millions of gallons of the fuel into the open sea. This was discussed with and confirmed by many codes—NAVSHIPS (PMS-383, 422, 427), NAVFUELSUP (40), NAVSEC (6101F, 6154D) and NAVAIR (535). It was estimated that $6 million of JP-5 fuel is lost annually in this manner. According to records of NAVFUELSUP (41), one oiler dumped 20,000 barrels (840,000 gallons) overboard in one month alone. It should be borne in mind that the fuel cost does not include Navy transportation costs, handling, storage, etc., involved in logistics.

(2) The problem of water in jet fuel and its catastrophic effect on jet engine performance at higher altitudes (where lower temperatures cause dissolved water to separate and free water to freeze) has been investigated by NAVSHIPS and NAVAIR for the past fifteen or sixteen years. The development and installation of coalescer/filter components for aircraft carrier purifier systems to ensure specifications and test methods for quality of the fuel. Present specs call for "clear and bright fluid," a subjective appraisal, and an AEL detector on the carrier to determine free water content. Free water maximum is thus set at 30 ppm and suspended solids or particulates at 10 mg per liter. The water content of the fuel can vary from 0-100 or more ppm (depending on fuel temperature and composition variations) while turbidity would depend on size and number of dispersed water droplets.

(3) There are insufficient containment tanks aboard oilers for water-contaminated fuels—(allow for adequate water separation and use of supernatant fuel).

(4) Prior to the 19 May 1970 meeting at Norfolk held under auspices of COMAIRLANT and COMSERVLANT, the potential of the problem of fuel dumping was increased by AIR's arbitrary setting of 15 ppm free water (which can be more reliably monitored by the AEL detector). However, it appears that this new position was reversed and the older concept of "clear and bright" fuel will still be acceptable.

(5) Although JP-5 fuel has a considerably higher vapor pressure than crudes or NSDF, it is still a fuel oil and is a pollutant covered by the IMCO agreement of October 1969, which President Nixon recently requested the U.S. Senate to ratify. This would prohibit the dumping of the fuel within the 50 mile limit.

(6) Problem Definition and Requirements. It is conceivable that the following problems ought to be defined, requirements established and responded to with an appropriate RDT&E project established to ameliorate simultaneously the technical and supply aspects of the problem—a combination of pollution prevention and economy measures.

(a) State-of-the-art of coalescer/filters for separation of JP-5 from water (fresh and sea).

(b) Quantitative and qualitative criteria that are realistic and scientifically meaningful (rather than arbitrary) regarding free-water content of the fuel—(clear and bright concept, limitation of free in accordance with temperature, etc.).

(c) In defining the problem, to answer the following:

1. Is the free water "salt" in nature?

2. Identify sources of water contamination—condensation (in fuel lines, etc.) accidental leakage in tanks, shipboard fueling practices.

3. Requirements for design and capacity for containment tanks for contaminated fuel. How much fuel must be disposed of before acceptable quality fuel can be delivered to the carrier.

4. What is the "condition" of JP-5 stored in the carriers' tanks? Is its fuel equal to or better than the fuel it refuses to accept from the oiler? (Especially when its own tanks are ballasted.)

NOTE: Because the JP-5 fuel problem aboard the carrier is presently seriously aggravated by the Cu/Ni piping system, gum formation, etc., its solution is beyond the scope of this investigation.

e. Used Lubricant Disposal (Reclamation)

(1) The Navy, as with other DOD services, utilizes an extensive amount and variety of lubricants. For jet aircraft, the expensive synthetic ester (nonpetroleum) lubricants are used, and steam turbine oils and diesel engine lubricants are used for ships. Gasoline powered vehicles and generators have other petroleum lubricants. Each system requires makeup, frequently followed by regular maintenance and drainage of the lubricant. Previous practices involved dumping, burning, spraying on earth or sandy roads, etc. In view of the pollution control program, most of these practices are forbidden.

(2) Requirement. It is recommended that a survey be initiated (NAVSUP, NAVFAC) regarding existing practices at naval bases, stations, etc., and investigate the feasibility (technical and economical) of refinement, reclamation, reuse, for the original purpose, or by chemical treatment to convert the lubricant into a useful product for other than lubrication purposes. The requirement in essence is threefold:

(a) to define the problems quantitatively,

(b) to develop methods for reclamation, reuse or resale, and if not feasible

(c) to develop means for disposal of lubricants without or with minimal pollution problems.

B. SANITARY WASTE TREATMENT AND DISPOSAL SYSTEMS (FOR SHIPS)

1. NAVSHIPS On-Going Effort

a. The development of a candidate shipboard sanitary waste treatment and disposal system for U.S. Navy has been underway for several years. The RDT&E effort has been conducted by NAVSHIPS and NAVSEC with laboratory assist from NSRDL, Annapolis, for three applications, viz., boats or small ships (40 man unit), submarine (study only), and larger ships (destroyer and tender) for 175 and 500 man units to meet existing U.S. Public Health Standards. Prior to proceeding with a description of the processes and technical problems related to shipboard sanitary waste treatment and disposal, a brief description of NAVSHIPS on-going effort and its impact would be beneficial.

b. For Small Ships, three approaches were studied:

(1) Chlorinator-macerator—a combination of maceration for dispersion of the solids followed by hypochlorite injection for biological decontamination—described in MIL-S-24201B, March 1970.

(2) "Incinolet"—electrically evaporates waste water and incinerates residue.

(3) "Jet-o-matic"—a portable recirculation and flush system whose operation principles consist of disinfection of waste, and treatment with deodorizer and coloration chemicals. None of the above approaches was deemed satisfactory.

c. For Larger Ships, two on-board treatment approaches have been investigated and evaluated:

(1) The Fairbanks-Morse (FM) System is a compact mechanical-electrochemical treatment system designed for 175 and 500 man units. This system consists of the following modules or processes:

(a) Interceptor for separation of larger or coarse solids from the flush fluid at entry into the unit.

(b) Froth-flotator (also called chloroflotator)—electrolysis of sea water produces two gaseous products—chlorine for disinfection and oxidation of suspended solids, and hydrogen that enhances flotation of solids.

(c) Incinerator—froth flotation fines are joined with interceptor solids and incinerated. The liquid effluent from the chloro-florator and sump tank is dumped overboard.

This system, designed for U.S. Public Health Service (USPHS) standards, may not meet the anticipated (January 1971) more rigorous Department of Interior standards. Units have been installed on USS FISKE (DD 842) and a submarine tender—USS CANOPUS (AS 33). Although limited evaluation indicated meeting of the PHS standards, the system to date has proved to be mechanically and electrically unreliable. In addition, restrictions on discarding paper towels into the commodes are necessary, and long and tortuous piping paths that produce slurries or comminution, reduce the solid separation capability of the interceptor. Negotiations are currently underway between NAVSHIPS and the contractor regarding redesign, establishment of performance criteria (reliability, maintainability, and supportability), and modification of system components. Poor reliability precluded the production of significant data to determine efficiency of sanitary waste treatment and effluent quality.

(2) The FRAM System is an adaptation of the well known biological-digestion, activated-sludge method of sewage treatment. The system consists of the following components or processes:

(a) Activated carbon filtration.

(b) Extended aeration, biological digestion.

(c) Biochemical waste solubilization.

(d) Chlorination of effluent and pumping overboard.

While the principle is valid, the system has demonstrated a tendency to clog in the activated carbon beds. No further significant effort will be pursued by the Navy.

d. For submarines—a NAVSEC study contract with the Electric Boat Company resulted in the recommendation of a holding system on board followed by discharge of the waste to shore sewage systems or by barge.

e. A NAVSHIPS contract with Booz-Allen Research Corporation resulted in the recommendation of an on-board holding system to be followed by periodical removal by barging or pumping to shore treatment plant. Efficiency of a holding system can be enhanced by increased holding capacity (or duration of the holding period) by incorporation of one or more of the following concepts:

(1) Reduced flushes with nonstandard commodes.

(2) Recirculation of flush (as in aircraft systems) where the fluid is masked by a dye and a deodorant.

(3) Reduced-volume holding system where concentration of the fluid can be attained by distillation, ultrafiltration, etc.

2. Other Federal Agency Efforts

a. Departments of Army and Interior—While the U.S. Navy has been the first agency involved and responsible for development of shipboard sanitary sewage treatment and disposal systems, other agencies have since entered the picture with separate development programs. Thus, the U.S. Army (Corps of Engineers), in cooperation with Environmental

Protection Agency has an extensive research, development and demonstration program (eight projects simultaneously) currently underway. These are listed briefly as follows:

(1) Fiferator Unit--extended aerobic digestion system for 30-40 personnel.

(2) American Ship--"Biogest"--also an extended aerobic digestion system for 85-105 personnel. (Both units above use settling or holding tanks with chlorination.)

(3) General American Transport--GATX--Similar to aircraft systems recirculation of flush, evaporation of fluid from sludge, chemical antiseptic and deodorant, for 30 personnel.

(4) Micro-Floc--filtration system using multiple tubes with activated charcoal filtration of solids and transport to sewage disposal system.

(5) FRAM--biodigestion system with charcoal filter beds described in NAVSHIPS section 1.c.(2) above.

(6) General Electric Company--Electro-coagulator--a novel approach installed (August 1970) aboard the 370 foot U.S. Army Dredge--GERIG--accommodating 40 personnel. The system consists of a grinder or macerator producing a thick slurry. The slurry is fed to an electrocoagulation cell where accelerated flocculation reduces settling time to one hour. The sludge is evaporated and can be incinerated (like the FM unit). The water effluent is chlorinated. This unit claims removal of most phosphate and some nitrates (undesirable marine nutrients).

(7) Chlorinator-Macerator--described under NAVSHIPS 1.b.(1).

(8) Pall Corporation--Biodigestion system--a heating system was introduced which is claimed to accelerate the biological digestion process. It is important to note here that Litton Systems, contractors for the new U.S. Navy LHA acquisition, has subcontracted for installation of the Pall sanitary sewage treatment system on the LHA's under a fixed price agreement. Approximately ten modifications or recommendations were made by Corps of Engineers/EPA to improve the Pall system.

b. Department of Transportation--U.S. Coast Guard has had under investigation for a considerable period of time a version of the FRAM System. Thus, this system, with various component modifications, was being simultaneously investigated and independently funded by three federal agencies. The Coast Guard has not been satisfied with the FRAM performance and it is doubtful if further work is warranted. However, at the time of this writing, the Coast Guard has prepared a RFP (request for proposal) for two alternate approaches--RD&D contracts, more or less independent of other federal agency on-going or planned projects. Another project being conducted jointly between the Coast Guard and a contractor, VALDESPINO, involves an aerobic digestion system. Although the system to date with several generations of modifications, does not possess adequate reliability, its performance in other areas appears satisfactory. The main function--ability to provide the equivalent of secondary sewage treatment--appears attainable.

3. United Kingdom—Ship's Sanitary Sewage

a. For many years the U.K. has placed restrictions on the discharge of raw sewage into the waters of the Port of London in England. Information obtained from the British Navy Staff, Washington, D.C. indicates that a biological digestion sewage treatment/disposal system is in operation aboard an Australian frigate. Another biological system called "Defecamat" is presently being installed (recirculation—flush and chemical treatment—Holding System) on the British frigate HMS BRISTOL; ship's completion or launch is scheduled for November 1970. This same system was proposed by its British contractors, for installation on the DX/DXG ships in 1967. The 300-man unit, manufactured by Porter & Co. Ltd., was guaranteed to produce an effluent which was equal or better than the USPHS standards (same as for FM unit). The loading for USN ships is considered by U.K. to be double the loading for HMS ships.

b. Specifications of the Defecamat include the following:

300-man unit
Hydraulic load (W.C. and urinals only) 3100 gal/day
BOD load—45 lb/day (or 0.15 lb/man/day)
Discharge Rate—2 pumps—70 gal/min
Weight of Plant (lbs)— 31,000 dry
136,000 wet-max
101,000 wet-min
Electrical Power—14.5 KW
Air Requirement—320 cu. ft. at pressure of 7.5 lb/sq. in. for aeration of sludge
Steam—not required
Space—
Effluent Quality—BOD—50 ppm; suspended solids—150 ppm, coliform—<1000/100 mL

c. For commercial ships, several systems are available. One of the more prominent is "ELSAN YARROW" a biological digestion system which uses chemicals for assistance in digestive and micro-organism sterilization. Installation of a small version of this system is being contemplated or negotiated by EPA for a special aluminum boat. Actual shipboard performance data of U.K.-manufactured sewage treatment/disposal systems were not available at the time of this writing.

4. Responsibilities of Federal Agencies (PL-91-224)

a. Department of Interior. The EPA in consultation with the Coast Guard, U.S. Army Corps of Engineers and U.S. Navy Ships System Command "will promulgate Federal standards of performance for marine sanitation devices to prevent the discharge of untreated or inadequately treated sewage (human body wastes) into or upon the navigable waters of the U.S. from new vessels and existing vessels except vessels not equipped with installed toilet facilities." The research, development, and demonstration program to receive, retain, treat or discharge sanitary sewage from toilets aboard vessels is directed essentially to "equipment to be installed on small recreation vessels."

b. Department of Transportation. The U.S. Coast Guard "shall promulgate regulations," consistent with standards evolved by EPA "governing the design, construction, installation, and operation of any marine sanitation device on-board such vessels." The Coast Guard will issue certifications that the marine sanitation device performs in accordance with the appropriate standards and regulations. For vessels owned and operated by DOD however, the regulation and certification authority will remain with DOD, and not the Coast Guard.

5. Brief Description of Processes/Technology

a. Biological Processes.

(1) Micro-organisms have the capability of continuously metabolizing and removing dissolved organic matter from wastes. The rate of metabolism is governed by temperature, pH, and nutrient concentration. Aerobic organisms require dissolved oxygen for metabolism; oxidation is complete and carbon dioxide and water are the final products. Anaerobic organisms do not require dissolved oxygen, and can substitute "chemically bound" oxygen for their metabolism. Anaerobic processes are much slower, require larger equipment, and are less efficient than aerobic organisms for waste removal. In the "log-growth phase," organisms grow exponentially and remove dissolved nutrient at a maximum rate.

(2) Fixed bed units (trickling filters), fluid bed systems (activated sludge) and various modifications of these are utilized in biological digestion of dissolved waste and are described briefly as follows:

(a) In trickling filters, organic wastes are continuously passed over packed media; micro-organisms grow into a gelatinous mass adhering to these media. Filters and settling units remove unoxidized organic matter, inert materials, and micro-organism masses which slough off the filter.

(b) In the activated sludge process, the flocculated biological growths are continuously recirculated and contacted with organic waste in the presence of oxygen which is fed into the sludge-liquid mass under turbulent aeration conditions. The aeration step is followed by solid-liquid separation. Part of the separated sludge containing the organism growth mass is recycled and the remainder is disposed of by suitable means.

(3) Whether by contact stabilization or completely mixed activated sludge, the biological digestion system consists generally of the following modules or subsystems:

Contact tank, clarifier, reaeration tank, sludge or aerobic digester, chlorinator, and drying bed.

(4) The contact stabilization systems are most compact, but operational flexibility is limited and requires close control of sludge aeration to produce good sludge-settling characteristics. Completely mixed activated sludge systems provide a homogeneous mixing of the waste with the micro-organism seed sludge during aeration. Thus, raw sewage is brought into immediate contact with the organism masses and shock loads are more easily handled because the waste load is dispersed throughout the system rather than confined to a segment of the system. Ultrafiltration consists of a modified activated sludge process coupled with a pressurized, reinforced organic polymeric membrane to provide ultrafiltration. The membrane loop is claimed to filter out all residual suspended solids, a substantial fraction of the residual BOD, and practically all the coliform (E. Coli) bacteria from the effluent, thus obviating the effluent chlorination prior to discharge. Various new systems modifications

have been introduced. These include: the modified trickling filter where the bacterial growth is suspended in the recycled effluent rather than attached to the filter media; the mechanically rotating biological contactor where microbial films developed on the surface of the rotating discs.

(5) Biological digestion systems can be made very efficient for sanitary waste treatment. The major drawbacks cited are: relatively larger space and weight requirements compared to chemical and electrochemical/mechanical systems; and the longer lead time for initiation of action. Recent efforts are claimed by a contractor to reduce the time of biological digestion by optimization of the temperature of the reaction. In spite of these shortcomings, the United Kingdom utilizes biological digestion systems for both commercial and military shipboard use.

b. Chemical Processes

(1) Chemical treatment of waste water involves the addition of chemicals (either directly, or indirectly by electrolysis) which will effect one or more of the following:

(a) Produce a flocculant precipitate and accelerate sedimentation of settling of the suspended solids.

(b) Release of ions to oxidize the organic matter and reduce the BOD.

(c) Disinfect the water effluent by killing (reduction of viability by 10^4 to 10^6) micro-organisms mainly, but not limited to bacteria.

(d) Colorize and deodorize flush water recirculation systems.

Chemical treatment systems are receiving considerable interest, attributable to: more efficient chemicals at lower cost, better knowledge of chemical reactions involved, and in conjunction with recent innovations in electrolytic and electro-mechanical approaches can provide improved and compact methods of handling the sludge.

(2) Examples of the electrochemical and electromechanical modules in candidate sanitary sewage treatment systems are the Fairbanks-Morse system presently being evaluated on the USS CANOPUS, and the General Electric Electrocoagulator intended for the U.S. Army dredge, the GERIG.

(3) An example of chemical treatment without electrolysis is the Ultradynamics Corporation system. This system employs a mixture of 5 or 6 water-soluble ingredients called "Ultrad-Ion-Mix" and claims to provide the following:

(a) Solution of chemical compounds produces an ionizable coagulating effect upon organic colloids in the wastewater.

(b) Porous minerals process absorbent and adsorbent properties.

(c) Oxygen is liberated to partially oxidize the organic matter and maintain a relatively high dissolved oxygen content of the water.

(d) Bacteriocidal or antiseptic effect (which would be less effective than chlorination).

(4) In the ultradynamic chemical treatment system, the wastewater is screened, comminuted, and mixed with the proprietory chemicals "Ultrad-Ion-Mix." The flocculent mass is separated in a settling or precipitation tank and the sludge is vacuum filtered and dried. Ultraviolet light is used to disinfect the effluent.

(5) In the chemical processes described above, the sludge is relatively easily disposed of; the vacuum dried sludge and/or the incinerated ash by land fill if desired.

c. Criteria for Performance–Analytical Tests. In estimating the efficiency of a sewage treatment process, certain terms are quantitatively defined. The principle terms and their significance are described as follows:

(1) Biochemical Oxygen Demand (BOD) of a liquid is defined as the quantity of oxygen required for the biochemical oxidation of the decomposable matter--usually performed as a test for 5 days at 20°C. This measure or index of oxidizable (soluble and colloidally dispersed) organic substances (including proteins) which deplete the amount of oxygen dissolved in the water and required to sustain animal life. The BOD has proved to be the best single test for measurement of sewage treatment processes. For U.S. Navy applications, a BOD loading of 0.20 pounds per man per day which is considerably higher than the analogous U.K. loading estimate is assumed. Presumably this is due to the type and quantity of the U.S. diet.

(2) Suspended Solids–There are various classifications and human sanitary sewage solids–suspended or dissolved, fixed or volatile (at 600°C). Suspended solids are both settleable and nonsettleable (a very fine dispersion). As with BOD, this item varies with the type and amount of food consumed and indicates the loading and efficiency of treatment.

(3) Coliform Units or Coliform Density–Sewage contains a vast amount of micro-organisms–bacteria, protozoa, viruses, etc. Most of these are harmless to man and also to fish life. However sewage can contain harmful or pathogenic organisms, discharged by victims or carriers of infectious diseases–as typhoid, amoebic and other dysenteries. Contaminated shell fish harvested in polluted water can cause typhoid and other intestinal disease out-breaks because of coastal pollution. Coliforms (Escherichia Coli) are mammalian intestinal bacteria whose presence in the water indicates mammalia (and human) excreta or fecal matter. Thus while Escherichia Coli are more or less nonpathogens to humans, their presence is used as an index of the presence of pathoghus. Coliforms are usually reported as the MPN (most probable number) by one incubation method or measured by a relative new bacterial membrane filter. Chlorination is normally used to destroy all forms of micro-organisms.

(4) Hydraulic Loading is a measure of the water consumption which empties through the piping-draining system. For U.S. Navy shipboard W. C. use, 25 gallons per man per day is assumed. This does not include showers and other use. For shore or advanced-base use which includes showers, 65 g/m/d is assumed.

(5) USPHS (U.S. Public Health Service) Standards. The USPHS standards used as criteria for the first candidate USN shipboard system performance based on effluent quality consisted of the following:

BOD– ≤50 mg/liter or ppm
Suspended Solids– ≤150 mg/liter or ppm
Coliform (MPN)– ≤1000/100 ml

Thus, as criteria for the anticipated next-generation shipboard sewage treatment/disposal system, the following specifications were formulated:

Criteria	Loading	Effluent
BOD (mg/l)	600	≤50
Suspended Solids (mg/l)	800	≤80
Coliform (MPN)		≤240/100 ml

6. Conclusions of Present Developments. The following conclusions may be derived for U.S. Navy shipboard sanitary sewage system developments to date:

a. Many approaches have either been investigated and evaluated or proposed to solve the problem.

b. Several basic principles have been developed and tested in shore facilities that appear capable of providing or exceeding secondary sewage treatment. The principles include aerobic biological digestion and chemical treatment, with various modifications and auxiliary components--electrochemical, mechanical, etc.

c. Software studies indicate development of on-board holding systems and methods have advanced to increased effectiveness.

d. Up to the present, no system has been satisfactorily developed and demonstrated on an American ship with favorable reliability, maintainability, and functional performance (effluent quality) measurements.

7. Problem Definition--In defining the problem, one must take into account the diversity of circumstances that exist in Navy ships--construction and operations which affect the choice and design of a potential sewage system. These variables include:

a. Number of decks--4 for DD, 8 for AS, 12 for CVA.

b. Location of WCs--in newer ships they are superimposed, in older ships, no definite vertical alignment.

(For a. and b.--the longer and more tortuous the lines of sewage drainage, the greater is the tendency for dispersion of the solids.)

c. Shipberthing--nesting, dockside, at buoy.

d. Salinity and pollution levels of port sea water.

e. Temperature extremes of ports of call—arctic, temperate and tropical.

f. Size of crew complement—units constructed for 40, 175 and 500 men.

g. Types of ships—auxiliary, combat, etc. with variations of permissible space, weight and power.

h. New construction vs modification and installation into existing ships—hydraulic loading on new ships can be substantially reduced by separation of showers, wash basins, etc., from commode drains. Because of such variations, it is difficult to conceive the evaluation of a single ship sewage system which can be both system and cost effective.

i. Variations of amount and homogeneity of loading (BOD, hydraulic, etc.).

8. Requirements, Objectives, Technical Approaches. The establishment of requirements, development of quantitative objectives, and recommendation of suitable technical approaches must be now applied to a program whose projects are being conducted on both parallel and sequential stages of development.

a. Performance Parameters (also see Section IIIB5c). The installation and utilization of any Environment Protection System should not place any unreasonable burden on ships' personnel nor degrade the mission effectiveness of fleet units. In deriving quantitative objectives, an in-house study should provide meaningful reliability, maintainability and supportability criteria which may have flexibility according to the type of ship involved or time spent in port. Regarding functional performance criteria which affect the effluent quality and determine the systems' compliance with existing standards, the same three essential ingredients evolve:

(1) Biological Oxygen Demand.

(2) Suspended Solids.

(3) Coliform Forming Units.

In determination of a candidate system's efficiency the following parameters must be included:

(1) Hydraulic loading—gallons of water consumed per man per day (g/m/d)—this could vary from 25 to 65 g/m/d.

(2) Total waste loading—weight of BOD and solids per man per day (ca.0.2lb/m/d) with provision for peak loading. Difference exists between U.K. and U.S. Navy on this figure, U.K. being ½ that of U.S. In a. and b. above, the concentration of the load can vary without any variances of load charge due to hydraulic variations. In determination of efficiency as governed by percent reduction, classification must be made and resolution to distinguish between averaging, integration (loading change integrated over a period of time), or dynamic, so as to respond to peak loading phenomena.

(3) Controls—Statistically valid measurements of equipment performance must take into account pre-existent pollution. For example, aboard the USS CANOPUS, controls

must be run in the polluted Holy Loch sea water alone before the performance of the F-M units can be quantitatively determined.

b. Short Range—Existing Ship-System Modifications

(1) For the short range problem—making available as rapidly as possible a shipboard sewage disposal system of meeting or exceeding the USPHS standards—of course refers to the F-M system presently installed on several Navy ships. Negotiations between NAVSHIPS and the contractor have been held pursuant to redesign of the system and establishment of reliability goals. As explained previously, this project is a high risk area—utilizing components of a system which can never provide optimum performance (interceptor separation of solids from flush water is poor when the entering fluid is a slurry) regardless of enhanced reliability development. A trade-off analysis would indicate the feasibility of substitution of another module for the interceptor stage—a module which depends on comminution of the solids for proper performance—as an alternate or simultaneous investigation for the FM system fix. Modules dependent upon improved flocculation and coagulation and accelerated settling of solids, even under ship's motion, should be considered. Examples are chemical ("Utrad-Ion-Mix") and electrochemical (GE Electrocoagulator or use of Al of Fe anodes). It would appear that the explosions experienced by the FM system, most likely due to hydrogen entrapped in the froth from the chloroflotator must be eliminated. The potential of a partial vacuum over the chloroflotator, to assist the escape of hydrogen bubbles together with an explosimeter probe into the air duct should be investigated. The partial vacuum may further improve the chloroflotator by enhancing the buoyancy of the hydrogen bubbles. Another alternative would be the addition of a module to the final stage of the liquid effluent to improve its quality and provide a degree of flexibility in performance—which is not one of the FM unit's virtues. This added module could include available membrane technology for water purification—reverse or electro-osmosis, ultrafiltration, etc.

(2) Regardless of short or long range solutions of the sanitary sewage disposal problem the establishment of realistic and meaningful criteria and standards in cooperation with the regulatory agencies should be based in large measure on the present state-of-the-art, equipment, and available technology for existing ships.

(3) In attempting to define the Exploratory Development (6.2) and Advanced Development (6.3) portions of NAVSHIPS' sanitary sewage program, within the constraints of funding, time, and resources (facility and personnel) availability, the following points are salient.

c. Exploratory Development (6.2) Long Range

(1) A concept for long range solution of ship's overall waste problem—integrate other wastes (food, industrial, etc.) with sanitary waste. This principle, proposed by NAVSHIPS, must consider priorities and compatibility of prospective modules and not be restricted to Biological Digestion.

(2) The 6.2 program should be limited to laboratory studies and investigations of basic concepts or principles and determination of this feasibility of being incorporated into a ships' system. Relatively new principles made available to sanitary engineering could be literature searched and investigated under controlled and simplified conditions. These include:

(a) Membrane technology—electro-osmosis, reverse-osmosis, using cellulose acetate and other suitable polymers.

(b) Chemical and electrochemical coagulation and flocculation; investigation of parameters affecting size, charge density, and concentration of the flocculants; choice of electrodes (Al, Fe, etc.) which have a profound influence on the coagulation and settling rates of the suspended solids. In close coordination with and perhaps sponsored by EPA to investigate the fundamental process parameters involved in using synthetic polymers, polyelectrolytes, and other novel surface-active chemicals to improve flocculation, sedimentation, and conditioning of sludges.

(c) Enhancement of aerobic biological digestion using modified trickling filters or mixed activated sludge treatments. Effects of temperature and pH, and nutrient concentration should be optimized. Feasibility of addition of recoverable enzymes (such as cellulase and proteolytic enzymes for cellulose and proteins respectively) could be included in the 6.2 program. In dealing with the biological digestion process module, the following items may be investigated to eliminate or minimize its inherent deficiency (longer lead time required to start the process):

1. Feasibility of culturing the aerobic micro-organisms (brackish and sea water bases), store as refrigerated slurry when not required, and with 1 or 2 days notice, incubate to "log-growth" phase. When starting the biological digestion module, approximately 1 day's travel from port of entry, the incubated micro-organism mass can be added to the module under favorable conditions and proceed almost as if the digestion process has been continuous.

2. In lieu of the enzyme addition, consider the feasibility of the addition of thermophilic cellulose—digesting bacteria. In order to be practical, the mixed colonies should both digest the cellulose and reproduce rapidly. It has been estimated that a conversion rate of 10 grams per liter of fluid per hour is a desirable goal.

(d) Determination of feasibility of development of realistic simulants in lieu of human wastes for laboratory and small mockup investigations.

(e) Investigation of certain commercially available modules (not systems) preferentially of a single process.

(3) In the submission of the Form 3920's from NSRDL to NAVSHIPS and the latter's DD 1634's Task Area Plans, the objectives should quantitatively stipulate the goals to be achieved in a five (5) year time frame with a realistic funding estimate. The goal should specify effluent quality of module concept based on dynamic or differential rate of loading, integration, hydraulic load limits, and any other functional parameters required to properly evaluate its feasibility.

d. Advanced Development (6.3)—Intermediate Range

(1) For the 6.3 of Advanced Development Program, at least 75 percent of the scope of effort should have advanced beyond the exploratory or applied science stage. The 6.3 program of necessity is addressed to the military, technical, and financial feasibility of the concept being incorporated into a reliable shipboard system. This program would thus include:

(a) Evaluation of modules which have been refined or engineered toward operational conditions.

(b) Coupling of individual modules in laboratory testing where each module represents a distinct and important process segment of the system concept. Compatibility and interface complications of each module are determined and solved at this stage.

(c) Scaling-up of laboratory module subsequent evaluation to simulate shipboard conditions.

(d) Under unusual circumstances where definite and dependable data of performance are available, a candidate commercial system, whose principles of operation and concept appear compatible and suitable for marine service, can be included in the 6.3 program. Full laboratory and shore testing must be complete to consider feasibility and testing in the shipboard environment.

(e) Design, fabrication, and testing of demonstrated modules, geared toward shipboard environmental conditions.

(2) The final phase of a 6.3 effort would normally include a realistic trade-off analysis (and a concept formulation) of the competitive systems or module integration and the decision as to which effort based on cost and system effectiveness, time, priority, etc., can properly advance to Engineering Development (6.4).

(3) The candidate systems to be critically analyzed might fortuitously be a complete system conceived, designed and fabricated by a contractor (of either on-board holding or on-board treatment) or a hybridization—an integration of optimum functional modules. It is very unlikely that a single system concept would be appropriate for all ship types. On this basis, there would be a requirement for development, evaluation and conceptual validity of sewage systems optimized for each ship type, with additional R&D effort slanted toward standardization and interchangeability of these modules as in electronic systems [illegible]ted-circuit functional modules. The resultant system concept should have a good measure of flexibility of performance criteria inherent within its design to prevent obsolescence, and have the ability to meet new and upgraded effluent quality standards. This flexibility could conceivably include a "polishing unit" module developed under 6.2 program or commercially available. <u>Technical areas of high risk</u> should be so addressed and identified by the SYSCOM.

e. <u>Coordination</u>. As expressed earlier, it is strongly recommended that more extensive coordination be effected between the Navy and other federal agencies and departments, with a more thorough investigation of existing technology and state-of-the-art of both domestic and international efforts especially of the United Kingdom. Special attention should be directed to the Department of Interior—Office of Saline Water for membrane technology applied to water purification, to EPA in Washington, D.C. and to the regional laboratory at Taft Engineering Center, Cincinnati, Ohio. Additional effort should also be made to incorporate the basic science, technology, and engineering efforts of NASA for human waste treatment and water reclamation.

C. SHORE BASED WATER AND SANITARY SEWAGE DISPOSAL/TREATMENT

1. Advanced Base Integrated Water and Waste Management System

a. Background. Naval Advanced bases are often located in remote and underdeveloped areas of the world where water supplies are minimal and of poor quality. Even in remote areas where adequate water supplies are available, development of the necessary waterworks facilities is often very difficult and expensive due to adverse climatic, topographic, or geologic conditions. Contamination of groundwater supply sources is also a common problem at advanced bases. An integrated water- and waste-management system is a potentially attractive solution to many of the problems associated with water supply development and waste water treatment/disposal at naval advanced bases in areas of minimum water supply or high contamination potential. With an integrated water- and waste-management system, the highly polluted waste streams containing mixed urine and feces are segregated from the lesser polluted waste streams from the galley, showers, laundry, etc. The concentrated waste streams are generally combined with the refuse for ultimate disposal, and the lesser polluted waste streams are treated to potable water quality and recycled for re-use. It has only been in the last few years that direct recycle of reclaimed waste waters has developed from concept to practice. Preliminary efforts to develop waste water reclamation systems for military application have been advanced by the Army under the Medical Unit, Self-contained-Transportable (MUST) program. Although very effective for producing potable water, the MUST waste water reclamation system is too costly and complex for routine use at advanced bases. The development of a highly cost-effective system and integrated water and waste-management system for advanced base application would essentially alleviate the water supply and water pollution problems simultaneously.

b. Requirement. To develop and demonstrate an integrated water and waste management system, capable of providing a practical means for waste water treatment, reclamation, and reuse at naval advanced bases and capable of effective operation under various environmental conditions.

c. Approach. A study will be made to develop technical requirements and design criteria for a total water- and waste-management system for advanced base application. In this study, current and projected field input data will be used to define water usage, storage and distribution requirements, waste water generation sources, collection system alternatives, and ultimate disposal techniques. Alternate subsystems for waste water collection and treatment/disposal, refuse collection and collection/disposal, water treatment/reclamation, and water distribution systems which are within the state-of-the-art will be investigated. The compatibility of alternative subsystems will be established and the technical and economic merits will be analyzed. Total water- and waste-management systems, including hypothetical systems, will then be formulated and all concepts will be subjected to cost-effectiveness analysis in order to develop the most effective and overall economical technical requirements and design criteria for the system.

2. Advanced Base Waste Water Treatment and Disposal System

a. Recent military experience has demonstrated that safe and efficient sanitary waste treatment and disposal systems for advanced bases are desirable in the interest of overall combat effectiveness. NCEL's "Advanced Base Sewage Treatment Study" delineated technical requirements and design criteria. Battelle Memorial Institute under contract to NCEL made an analyses of the problem together with a cost and systems-effectiveness study of 21 commercially available systems of sanitary sewage. It was concluded that three possibilities exist to improve overall effectiveness by integrating selected components or modules of existing systems into a single unit tailored to the specific requirements of advanced bases.

b. The ultimate approach to effective environmental protection will be the integration of this sewage treatment disposal subsystem into a comprehensive water- and waste-management system where the water can be reused. The recommendations for technical modifications of existing systems and expansion of the RD&D program as submitted by the BMI report appear very realistic.

c. The recommended RD&D program consists of the following three sequential steps:

(1) Adoption of a highly cost effective, commercially available waste water treatment and disposal system for incorporation into the Advanced Base Functional Component list.

(2) Development of improved waste water treatment and disposal systems.

(3) Development of an overall water- and waste-management system for Advanced Bases.

D. WATER POLLUTION BY INDUSTRIAL & CHEMICAL WASTES

1. Problem Definition. An extensive amount and variety of various industrial and chemical wastes are emptied from Naval shore facilities and ships into inland waterways and harbor areas, with either minimal or no treatment. In the absence of a suitable survey to quantitatively identify the magnitude of the problem and sources thereof, the following items are reported:

a. Photographic Chemicals. The Naval Photographic Center (under NAVAIR jurisdiction) discharges approximately ten tons of chemicals into the building's storm and sanitary sewer lines each month. These sewer lines lead either to the Anacostia River or D.C. Treatment Plant at Blue Plains. The chemicals which do not undergo treatment, include silver (Ag) salts, formaldehyde, borane compounds, and ferricyanides which are particularly harmful to marine life even in low concentrations, thus polluting the river and degrading the sewage plant treatment process. Aircraft carriers and submarine tenders also have photographic shops. For the tenders, two photographic and one X-ray shop dispose of their photo chemicals through regular waste, also without treatment. Mobile field photo-processing units now deposit used process chemicals and wash water directly in local streams.

b. Electroplating. As with photography, Naval forces ashore and afloat possess extensive electroplating facilities. Cadmium (Cd), Chromium (Cr), Silver (Ag), copper (Cu), and Zinc (Zn-galvanize coating) operations are quite common, with Cu and Ag having the lowest level permissible criteria. For anions, cyanides represent the most toxic variety of water pollutant.

c. Acids. In submarine battery overhaul and repair operations, the tenders are fitted with special lead lined pipes and sinks; the sulfuric acid electrolyte however, is discharged overboard without any treatment. Although seawater has buffering action characteristics, the extent and nature of this acid damage to the water environment must be quantitatively assayed. In Bull Pup missile, and the AQM(37) Aerial Target Drone, hypergolic liquid propellants are used, one of which is the strong oxidizing red fuming nitric acid (RFNA). In the event of leakage aboard ship, the unit is dumped overboard for safety reasons. In this case, safety to ship and personnel is much higher priority than the water pollution problem.

d. At various Naval Air Repair Facilities (NARF) there is an extensive amount of aircraft cleaning, stripping, etc., involving chemical treatment of aluminum and its alloys (MIL-C-5541A) and cleaning materials for Naval Air Systems Maintenance and Overhaul Operations (NAVAIR 07-1-503). These chemical treatments involve the use of chromic and phosphoric acids which are difficult to treat for removal in sewage treatment plants. Neutralization only counteracts the acidity but does not eliminate the anions from the effluent. Chromates must first be reduced by a chemical compound, followed by precipitation, typically with lime. NAVAIR (R&D) has attempted to find a suitable replacement for strontium chromate which is 20% of the composition of their standard Navy aircraft anticorrosive primer (MIL-P-23377). However, to date no substitute even approaches the efficacy of chromate as a cathodic inhibitor. Although not in acidic form, a considerable amount of chromate is also used as corrosion inhibitor in various ship tanks that hold seawater, such as ballast tanks.

e. Laundry. The chemicals used for laundry purposes consist of an eighty percent (80%) minimum biodegradable detergent with a twenty three percent (23%) polyphosphate minimum. The main problem at present appears to be the phosphate (nutrient for algae); the effects of biodegradable detergents on marine ecological systems have not been clearly established. Edison (N.J.) lab of EPA is investigating the effects of chemical dispersants (as oil-water emulsifiers) prior to granting approval for use of same. According to CDR W. Lehr of the Coast Guard (R&D) in his recent trip to Europe, the French reportedly have demonstrated various degrees of toxicity of biodegradable detergents to marine life. At the present time, this area is not recommended as a Navy problem. EPA is awaiting industrial developments in this field prior to issuing any standards. Some soap-makers have marketed a detergent without phosphate and another firm was substituting a chemical, nitroloacetic acid (NTA), for 25% of the phosphate. Until such time as technology has sufficiently advanced to make suitable detergents available and in commercial quantities, and EPA as well as the FTC have issued criteria, guidelines, and appropriate standards, laundry chemical usage should not be a recognized and defined water pollution problem for the Navy.

f. Miscellaneous. NAVAIR has developed a taxi-through, fresh water, aircraft rinse system to wash off the corrosive salts adhering to the aircraft as a consequence of flight operations in the marine environment. The present formulation for rinse includes a corrosion inhibitor at a relatively high concentration of 500 ppm, which is considered toxic to marine life. Under project WF-2.461.406, NAVAIR is attempting to develop a water effluent purification which would reduce the corrosion inhibitor concentration to a safe level and if possible, reclaim and reuse the rinse water.

2. Requirements, Objectives, Technical Approaches

a. A survey is required to quantitatively define the problems stated above, and to delineate the respective priority to best utilize limited available resources. It is doubtful also, that a comprehensive investigation of all potential pollution problems could be attained in the relatively short time of this assignment. Thus, the survey would also help to identify problems not included above, but of significant importance to be addressed in future RDT&E projects.

b. The basic and most advantageous policy in Environmental Protection is one of pollution prevention to be enhanced by resources conservation. As expressed in the NAV-ORD submission and in some of NAVAIR's projects, the prime requirement is the R&D of materials, procedures, and equipments for pollution prevention, reclamation, and reuse or resale of the items.

c. In photographic processing, EPA is sponsoring a major RD&D project at Rochester, N.Y., for chemical recovery. The Air Force Weapons Laboratory (KIRKLAND AFB) is also investigating liquid photographic waste treatment. Membrane technology and ion exchange resin availability could provide the basic approach of purification and reclamation for a majority of the chemicals employed in both photography and electroplating. Techniques initially developed by the Navy and subsequently by Interior (reverse osmosis, electro-osmosis, electrodialysis, ionic membranes, etc.) for water purification are very well applicable and feasible toward solutions of the above problems. Electrolytic recovery system for the valuable silver would also appear promising. Modules may be required (based on the particular SYSCOM application and investigation) for treatment of contaminants, removal of contaminants, reclamation of contaminants, or reuse of water where the level of contaminants is reduced without affecting efficiency of the particular process—all dependent upon economics of purification and reclamation vs importance of pollution prevention.

d. For shipboard applications where space requirements are more critical, the feasibility of continuous ion exchange, a comparatively recent development, appears to have considerable merit. In addition to the lower space requirement, additional advantages claimed are reduced capitol investment and reduced regenerant chemical consumption. Ion exchange resins can be selective–to remove toxic products such as cyanides, copper, and chromates; for recovery of precious metals and in regeneration of metal surface treatment and electroplating baths.

e. Requirement also exists for the R&D of new chemicals and processes for cathodic protection of metals, and less toxic or easily recoverable corrosion inhibitors, whether organic or inorganic, effective in low concentrations, which would not be harmful to fish or to marine biota.

IV. AIR POLLUTION

A. INTRODUCTION

1. Although several aspects of the Environmental Protection problem are related to preservation of aesthetic beauty and resource conservation, air pollution in the main is concerned directly with the health of man and his environment. These effects, together with those affecting combat effectiveness, will be referred to in the listing and source of air pollutants. In the description of atmospheric pollution, the troposphere, ranging in altitude from sea level to 30 km (avg), is the region of interest. This region has the greatest turbulence and atmospheric pressure and the highest concentration of pollutants.

2. Air pollutant emissions are usually categorized either by mobile or stationary sources. Mobile sources include aircraft, automobiles, trucks, and various materials-handling systems utilizing fossil-fuel combustion engines. Stationary sources include incinerators, power plants (ship and shore), chemical and industrial plants (where combustion products, reaction products, or volatile ingredients are the principal effluents), trash, refuse, and ordnance burning, painting, etc. Table 3, Nationwide Air Emission Estimates, demonstrates the nature and extent of air pollutant contributed by the more common mobile and stationary sources.

TABLE 3
1968 NATIONWIDE AIR EMISSION ESTIMATES
(10^6 tons/year)

Category	HC	CO	NO_x
Transportation			
Motor vehicles			
Gasoline	15.2	59.0	6.6
Diesel	0.4	0.2	0.6
Aircraft	0.3	2.4	n
Railroad	0.3	0.1	0.4
Vessels	0.1	0.3	0.3
Nonhighway use of motor fuels	0.3	1.8	0.3
Fuel combustion in stationary sources			
Coal	0.2	0.8	4.0
Fuel oil[a]	0.1	0.1	1.1
Natural gas[b]	n	n	4.7
Wood	0.4	1.0	0.2
Solid waste disposal	1.6	7.8	0.6
Industrial processes	4.6	9.7	0.2
Miscellaneous	8.5[c,d]	16.9[c]	1.7[c]
Total	32.0	100.1	20.7

[a] Includes kerosene.
[b] Includes natural gas processing plants and transmission facilities, and liquefied petroleum gas (LPG).
[c] Includes emissions from agricultural burning, forest fires, structural fires, and coal refuse fires.
[d] Includes organic-solvent evaporation and gasoline marketing.
n—negligible.

3. For Naval application to mobile sources, the prime contributors to air pollution are aircraft and vehicular engines. These consist of exhaust emissions, fuel evaporative emission, and smoke emissions. For further clarification, the chemical classification of air pollutants is included as Table 4. The concentration of combustion product emissions are strongly affected by type of operation (idle, take-off) and by air to fuel mixture ratio.

TABLE 4
CHEMICAL CLASSIFICATION OF AIR POLLUTANTS*

	Major Classes	Subclasses	Typical Members
1	Inorganic gases	Oxides of nitrogen	Nitrogen dioxide, nitric oxide
2		Oxides of Sulfur	Sulfur dioxide, sulfuric acid ($SO_3.H_2O$)
3		Other inorganics	Ammonia, carbon monoxide, chlorine, hydrogen sulfide, ozone
4	Organic gases	Hydrocarbons	Benzene, methane, butadiene, isooctane
5		Aldehydes, Ketones	Acetone, formaldehyde
6		Other organics	Acids, alcohols, chlorinated hydrocarbons, polynuclear aromatics
7	Aerosols	Solid particulates	Dusts, smoke
		Liquid particulates	Fumes, oilmists, polymeric reaction-products

*U.S.P.H. Serv Publ 937.

B. FEDERAL AGENCIES–RESPONSIBILITIES AND PROGRAMS

1. Federal air pollution legislation has consistently pointed out the primary responsibility of state and local governments for preventing and controlling air pollution at its source. With the Department of Health, Education and Welfare (and its National Air Pollution Control Administration) as the federal agency of prime responsibility, the federal government provides "technical and financial assistance to state and local governments so that they can undertake their responsibilities." Under the Air Quality Act of 1967, HEW publishes technical information on control techniques, air quality criteria, and finally, standards for the pollutants that HEW considers harmful to health or welfare. The Clean Air Act, as amended, is the legislative basis for the Federal air pollution control program for new motor vehicles. It should be pointed out, however, that because of unique environmental situations and keen anticipation and appraisal of the potential air pollution problem, California first provided air pollution legislation, as early as 1947. This state has taken the lead role in the nation for most stringent and vigorous air pollutant standards–most visibly demonstrated in gasoline-powered vehicle emissions, and reactive organic compounds used in industrial processes, etc. Another case in point–Federal standards apply to new vehicles only–California's standards are applicable to all vehicles, new or used, dependent upon year of manufacture.

2. As an example of the scope and responsibilities of federal agencies involved in mobile source air pollution—Appendices A and B (taken from NAPCA PUBL #AP-66), list the programs to reduce emissions sponsored by federal agencies and NAPCA respectively.

3. The Air Force has expanded the scope of their Aircraft Engine Emissions Research program in FY 1971—funding estimate of 6.1 and 6.2 is $2.0 million. Their problem areas, and the areas of interest are listed as follows:

a. Chemistry

(1) High altitude photochemical processes and aerosol production of aircraft engine exhaust.

(2) Detectors and diagnostic instrumentation for determining exhaust species.

(3) Chemistry of flames.

(4) Reactives formed by oxidations of hydrocarbons.

(5) Catalysis for reducing undesirable exhaust species.

(6) Surface chemistry involving jet engine produced aerosol, surface coatings and propellant degradation.

(7) Investigation of the inhibition and promotion of hydrocarbon combustion by additives.

b. Energy Conversion—Problem areas and areas of interest.

(1) Lean combustion operation of turbojet engines.

(2) Chemical kinetics of combustion.

(3) Fluid dynamic energy transfer.

(4) Combustion of metal fuels, Boron, Aluminum.

(5) Combustion dynamics of homogeneous and heterogeneous systems.

(6) Jet engine exhaust studies (determining exhaust species).

(7) New diagnostic tools such as electrostatic probes.

4. Aircraft emissions meetings are held in the offices of the DOD Environmental Pollution Control Committee. A typical example is the 27 March 1970 meeting attended by NAPCA (federal facilities, Off. of Stds.), DOD (Surgeon Gen., DDR&E), Army (ACFT Prop. R&D; ACSFOR), Navy (NAVFAC, NAVAIR), and the AIR FORCE (AFOLE, AFMSP, AFSMGMS and AFRDG).

C. MOBILE SOURCES--ENGINE EXHAUST EMISSIONS

1. Aircraft Problems and Requirements. High performance aircraft used by the military have unique problems of noise and combustion product emissions. Military operations often require higher jet velocities, speed, engine temperatures, and altitude in addition to use of exotic fuels, and afterburners. Like their civilian counterpart, military jet aircraft are also being subjected to fuel additive R&D to reduce visible smoke exhaust. The emissions, aside from the aesthetic sense, have a deleterious and degradative effect on flight crews and support personnel in terms of health, welfare, and their combat effectiveness. Many R&D programs are either underway or planned among federal agencies, including DOD, to understand, characterize, and identify the emission phenomena, and the interaction of the emission with the atmosphere; attempting to find ways and means to control such emissions; and ultimately funding the wherewithal in research and technology to abate them below the level of pollution index (standard) and extended safety environment. All these objectives must be achieved without any decrease in mission-keeping effectiveness or significant increase of cost.

a. Particulates (Smokes)

(1) Problems and Requirements

(a) The main portion of the solid particulates emitted by combustion engines consists primarily of smoke or carbon particles. For aircraft turbine engines the size of the particles varies from 0.01 to 0.1 micrometers. For aircraft piston engines the emission particle sizes are about equivalent to automotive engines, in the range of 0.02 to over 1.0 micrometers. Gasoline fuels contain tetraethyl lead with acidic scavenger compounds. The compression-ignition diesel engines produce a significantly higher concentration of smoke. The smoke particles are a consequence of incomplete combustion and oxidation of the fos[illegible] fuel.

(b) Problems associated with particulates are concerned with aesthetics (public annoyance), reduced visibility for aircraft operations, and a minor health problem. Since the particles are small, their facility of entrance and absorption in the respiratory tract of man is nearly optimum. Because the carbon particles have high sorption capacity for nuisance vapors (SO_2), the medical hazards cannot be ignored. The toxicity of lead and lead compounds is fairly well established. Operationally speaking, the visible exhaust emission from turbine engines presents an obvious tactical problem to the Navy and Air Force.

(c) Requirement. A basic requirement for naval aircraft is an engine performance with no visible smoke exhaust without sacrifice of operational capability for both combat effectiveness and environmental protection purposes. This requirement is implemented into specifications for the new F14 aircraft and the proposed heavy-lift helicopter. The requirement includes the development of reliable and quantitative methods and equipments for testing under various operational conditions.

(2) Approaches and Technical Problems. Three approaches are being undertaken towards the smokeless aircraft engine--(a) use of chemical additives to the fuel, (b) modification of combustion chambers of existing engines for retrofit, and (c) new designs of engines (included in new aircraft procurement).

(a) Fuel Additive Development. With a significant lead taken by the Navy, and augmented by efforts of GE, Rolls Royce, Standard Oil of N.J., etc., a program of evaluating the effects of various chemical additives for smoke abatement of turbine engine exhaust has been underway. No completely acceptable additive has as yet been found. Ethyl Corp.'s "CI 2" additive, considered (by USAF) as the best of current additives is not fully acceptable since it causes formation of oxide deposits in the engine hot section with consequent engine performance loss as a function. The CI-2 additive will be used as a standard by USAF for comparison with 28 candidate additives to be evaluated in their RDT&E program. On-going R&D at USAF indicates promise of 9 out of 28 additives to eliminate visible smoke based on the T-56 engine single combustor rig to be followed by the small Williams WR 24-6 engine to determine extent of engine performance loss, if any. In addition, to be completely acceptable, any new additive must be completely compatible with existing additives, elastomers, and other materials that are used in aircraft fuels and fuel systems.

(b) Engine Modification. Smoke reduction programs based on modification of the combustion chambers of several existing engines are currently underway, both military and civilian, such as JT8D, J52, TF30, and TF39. The Navy's program of incorporating smokeless combustion liners in service engines applies only to the J52 engine on a firm basis; extension to other engines will depend upon reliability and engine performance measurements.

(c) New Engine Design. As part of the joint procurement for GE's J79 engine, by USN and USAF, the contractor is including new design requirements for the smokeless engine. No Navy R&D funds are involved in this operation.

(d) Smoke Measurement & Standard. According to NAVAIR (AIR-536) "the R&D effort in smoke reduction will be principally concerned with methods of testing and defining values of smoke emission under various flight conditions." Several methods were previously employed with differences in specification of important procedures; viz., location of sample probe, choice of reflectometer background shade, and conducting leak and cleanliness checks of the systems. A Ringelmann method is used for smoke plumes as from incinerator stacks, and the Van Brand Smoke Index for engine exhausts. The SAE (Ad Hoc) Technical Committee E-31 on Aircraft Exhaust Emission Measurement, whose membership includes government, engine manufacturers, airframe manufacturers and commercial airlines, has evolved a new, indirect, filtration-type reflectance-measurement system. Identified as SAE Aerospace Recommended Practice (ARP) 1179 "Aircraft Gas Turbine Engine Exhaust Smoke Measurement," the System is defined broadly enough to allow use of the hardware of most existing systems. Claims for the SAE System include higher precision, reasonable simplicity and universal acceptance. The same SAE Committee is to develop a sound relationship between SN (the quantitative, dimensionless measurement of smoke) and the actual smoke visibility. Since the Navy played a role in the SAE Committee's evaluation of the data and adoption of the method, it would be logical to assume that the Navy R&D work will incorporate this method and coordinate closely with results obtained by the other participants, especially the Air Force, which has committed itself to full implementation of the SAE method.

(3) Problem Complication. It is important to note that practically all R&D efforts to reduce visible exhaust smoke have resulted in a significant increase in the invisible chemical pollutant—oxides of nitrogen (NO_x)—which is considered by many authorities as a

toxic contaminant (e.g., the threshold limit of NO_2 = 5 ppm). This is exemplified by JT8D engine test data below:

JT8D Engine w/JP-5 Fuel	NO$_x$ Conc. (ppm)		
	Idle	Take-Off	Smoke Index (Von Brand)*
BM Burner	2.8	70	0.6
Smokeless Burner	7.4	98	0.25

*Threshold of smoke visibility using Von Brand rating index is 0.2 to 0.25 on a 0-1.0 scale.

b. Carbon Monoxide (CO)

(1) CO is a product of combustion either of poor efficiency or lack of sufficient oxygen for complete oxidation to CO_2. CO has a threshold level value of 50 ppm (8 hr/day, 5 day/wk). CO concentrations of turbine engine exhausts are extremely high during idle power settings and very much reduced in takeoff. Thus, either at an air station for service, or aboard the aircraft carrier in preparation for take-off, higher concentrations of CO are encountered. In addition to the normal medical problems associated with CO, this pollutant "has a deleterious effect on night vision and there is some concern that CO, even at low concentrations, has an adverse effect on a pilot's capability in high-order problem solving such as instrument flying." Although improved combustion efficiency and increased operating temperature reduces the CO effluent concentration, smokeless burner cans have only a slight beneficial effect.

(2) Problem Complications. As in the case of smoke emission, reducing the engine exhaust pollutant, CO, by increasing the air-to-fuel ratio, produced a simultaneous significant increase in the NO$_x$ emission. Also increase in operating temperature requires special heat exchange modifications to avoid increasing the susceptibility of the aircraft jet/ exhaust to infrared-(IR) seeking missiles.

c. Hydrocarbons (HC)

(1) Hydrocarbons (HC) are a class of organic chemicals of carbon and hydrogen with an extensive range of vapor pressure depending upon its molecular weight and structure—such that some are gases at room temperature (75°F) (such as methane), some are liquid with high concentration of vapor (as isooctane), and some are liquid with extremely low equilibrium vapor content (as lubricating oils). Flash points of these hydrocarbons are essentially a function of their vapor pressure. Hydrocarbon fuels are essentially aliphatic (gasoline and jet fuel) while some gasoline additives (subst. for tetraethyl lead) are aromatic (benzene). Hydrocarbon compounds in engine exhausts are a consequence of incomplete and inefficient combustion of the fuels. At very low concentrations, hydrocarbons are considered very harmful. At about 0.5 ppm, the fuel causes irritation of pilot's eyes in the cockpit. In addition, hydrocarbons, under proper conversion conditions and photochemical reactions, produce smog.

(2) Problems of elimination or minimizing hydrocarbon emission are common to smoke and CO, especially the latter. At idle conditions, hydrocarbon and CO emissions

are very high; on take-off, when combustion efficiency and temperature are higher, the hydrocarbon concentration is reduced several orders of magnitude. Requirement for hydrocarbons emission reduction would be the same as for CO.

d. Sulfur Oxides (SO_x). When sulfur (elemental or compound) in jet fuel is burned, sulfur dioxide (SO_2) is formed. As an exhaust, this gas has adverse effects on health (bronchitis, cardiovascular problems, etc.). In the atmosphere under suitable conditions it is further oxidized to SO_3 which combines with water to form sulfuric acid droplets–a strong irritant and very deleterious to plants and property. Fortunately, sulfur in aviation fuel is kept at a relatively low level–nominally 0.4%; average level is about 0.05%. The sulfur content of residual type fuels is much higher. With the Navy switch to a lighter distillate fuel for ship use, and within limits of region jurisdictional areas, sulfur oxides from fuels do not appear to present any problem of significance.

e. Nitrogen Oxides

(1) Oxides of nitrogen are formed in the engine combustion process when oxygen (O_2) and nitrogen (N_2) combine to form nitric oxide (NO) at high temperatures; at lower temperatures, the NO combines with O_2 to nitrogen dioxide (NO_2) or as the dimer N_2O_4. The latter oxides combine with water to form the strong nitric acid, HNO_3. As mentioned previously NO_2 which is formed from NO is toxic and produces photochemical smog. NO, NO_2, and N_2O_4 as a class are called oxides of nitrogen (NO_x). Aviation personnel have pointed out that aircraft engines produce only a small fraction of the NO_x found in the atmosphere–the predominant source being lightning discharges (100 x 10^6 tons/yr) compared to motor vehicles (6.6 x 10^6 tons/yr) vs aircraft (0.4 x 10^6 tons/yr). In areas where atmospheric diffusion and turbulence is absent (such as occurs in the Los Angeles area), the NO_x dispersion in the air can be relatively high and produce the effects described earlier.

(2) Problem. At sea, flight operations do not appear to be strongly affected by NO_x emission–idle engine operation on the flight deck and good wind conditions favor low NO_x concentrations in the environment of operating personnel. However in flight with higher temperatures, and improved combustion efficiency, NO_x emission contributes to the general atmospheric pollution. If compared to the total amount present, aircraft engines cannot be a major problem. At air stations, in hangars, and on test stands, NO_x emission is a problem. Nitric oxide is the most difficult of the exhaust emissions to measure. No new instrumentation has been developed for rapid quantitative measurement, with high sensitivity, of the NO_x effluent. For reliable interpretation, a dynamically reading device is required (rather than integration) for measurement, with probes placed in difficult positions of the exhaust for a composite assay.

(3) Recommendation. In addition to the need for improved methodology and measurement instrumentation (a burden more appropriate for NASA and DOT), a survey should be performed by NAVAIR in conjunction with BUMED (utilizing services of NAVFAC's SET (source emission team)) to determine the severity of the pollution problem at the more obvious critical locations and situations. In view of the extensive effort by the other federal agencies, technical difficulties of the problem, and funding constraints by the Navy, it is recommended that the Navy maintain close coordination with the developing agencies and apply results of such development to Navy engines when corroborative evidence and reliable test data determine feasibility of such implementation.

2. Vehicular Engines

a. Problem

(1) As the greatest single contributor to production of HC, CO, and NO_x from mobile sources, the gasoline engine is receiving the greatest attention. For the Navy, the problem of vehicular combustion engine contribution to atmospheric pollution must be slight compared to civilian sources. For this reason it will be treated briefly, rather than excluded.

(2) Air pollutants from motor vehicles without emission control originate from four major sources. The sources and approximate distribution of emissions are listed as follows:

(a) Carburetor (b) Fuel tank	Evaporation of fuel—HC 20%
(c) Crankcase	Blowby past the piston rings—HC 20%
(d) Engine exhaust	Combustion products—HC 60% CO 100% NO_2 100%

(3) Because of the similarity of automotive engine to aircraft engine exhaust, Figure 1 is included to demonstrate the basic problem involved in attempting to control these emissions by variations in the air-fuel ratio. As pointed out previously, at rich or oxygen-deficient conditions, complete combustion cannot take place, and circumstances do not favor full oxidation of the reactants. Thus HC and CO emissions are high and NO_x is small. As the air-to-fuel mixture ratio increases, combustion is more complete, and temperature increases, thus decreasing CO and HC, with simultaneous increase in the toxic NO_x. All three emissions could theoretically be reduced at high air to fuel ratios, but operating difficulties (misfire, stalling, poor idling, etc.) would be encountered. Recent developmental claims (applicable to aircraft and vehicles) point to methods of jet vaporization and injection of fuels under lean conditions to reduce the pollutants and simultaneously alleviate operating difficulties of poor idling and stalling. As with other contractor claims, skepticism of significant improvement by this method would be a normal reaction.

(4) Extensive R&D is being performed on engine modifications (positive crankcase ventilation, exhaust emission control systems, air injection systems, fuel modification, and fuel substitution. For the latter, liquefied natural gas (LNG) and compressed natural gas (CNG) in spark-ignition engines have shown a tremendous reduction of CO, HC and NO_x to the point where the emissions are below any present or soon-to-be schedule standards—federal or statewide. However, the logistical and economical aspects must be investigated and evaluated in determining feasibility of this approach.

b. Requirements. No special Navy requirements are included. Navy vehicles are normally procured via the Army, and all new vehicles will possess standard pollution control devices. For existing vehicles, the feasibility of modification to reduce the magnitude of air

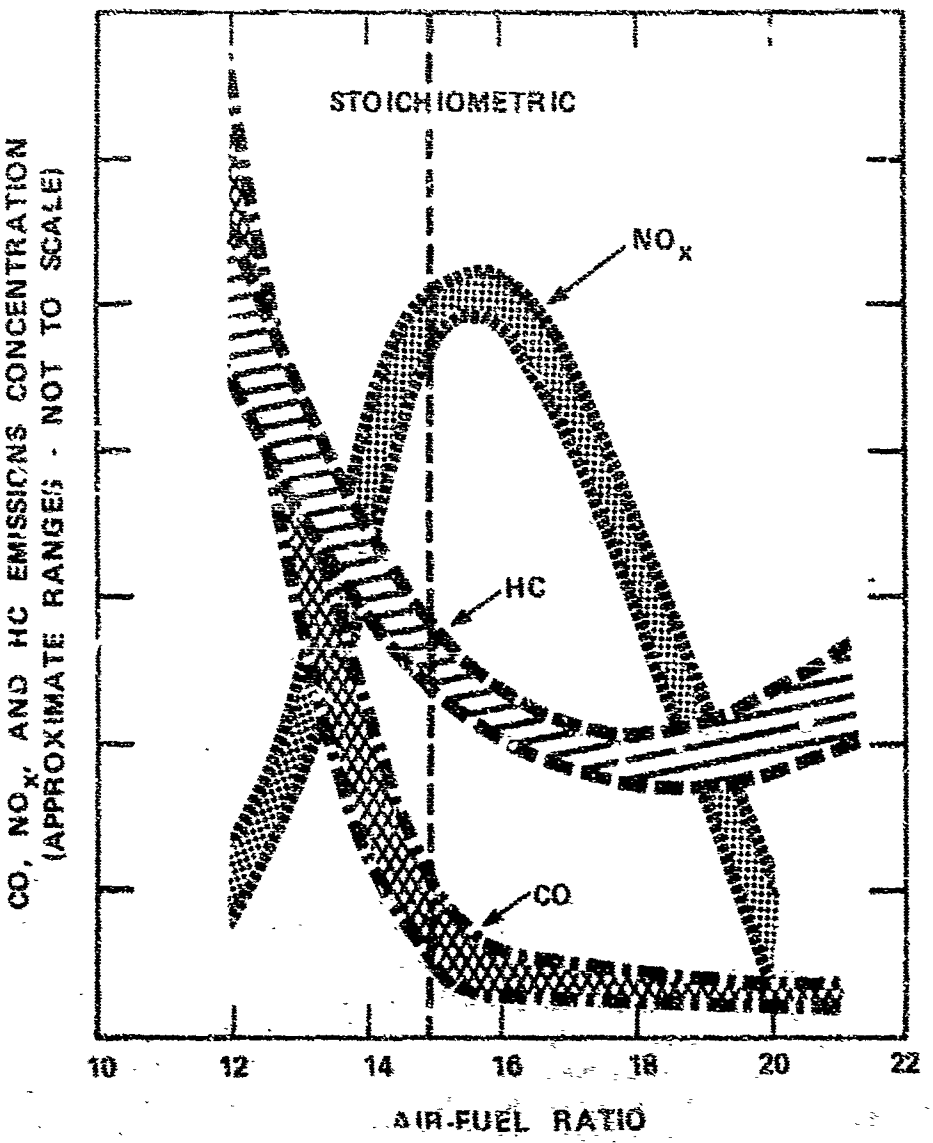


Figure 1. Effects of air-fuel ratio on exhaust composition.[1]

polluting emissions should be investigated by the cognizant Naval SYSCOM (NAVFAC). A survey of the magnitude of the problem would be included.

D. STATIONARY SOURCES

1. Pollution Sources and Emissions

a. In considering stationary sources, one normally includes fixed shore installations. Ships moored in harbor areas can be categorized as stationary sources, especially when on-shore winds prevail, carrying the pollutant emission to the population ashore. When considering ship's emissions, it is also important to measure the contribution of the ship relative to shore-source emissions, especially those not derived from Naval Operations.

[1] From BMI (OHIO) Report.

b. Table 3 provided a crude listing of pollution sources and the approximate emissions. Among stationary sources, utility plants (especially those using coal) and outside fires appear to be the worst offenders. Aircraft engine test stand operation is a special category. (The problem of open burning of ordnance items (explosives, propellants, etc.) together with requirements and technical approaches are addressed in a separate section of this report.)

2. Incinerators--General Purpose--Requirements. Fossil fuel for incinerators will have sulfur content maxima in accordance with local criteria and standards (same would apply to fuel for ships in port); other emissions--smoke, HC, CO, & NO_x - would require NAVFAC assays to assure compliance. In view of the recent policy and tendency of more stringent regulations and standards, it would appear that new designs for incinerators for military construction contain some module flexibility for further cleansing of the air effluen.. Within funding and time constraints, feasibility of modification of existing incinerators for the same purpose should be determined. Thus in N.Y.C. which has taken a lead role in this area, incinerators are fitted with either electrostatic precipitators (to remove particulates) or water scrubbers (to remove particulates, SO_2 and NO_x) as polishing modules on the smoke stack exhaust system. A water scrubber is presently being used in a Navy experimental model rotary drum classified material incinerator. A nucleation scrubber was recommended by a FAC/AIR contractor-consultant as the most efficient made for purification of aircraft engine test cell exhaust emission. The EFD's of NAVFAC would play a major role in determining the extent of compliance of shore based incinerators with existing standards.

3. Incinerators--Special Requirements

a. Disposal/Destruction of Classified Naval Materials Ashore.

(1) Long Range. More adequate and efficient means are required for destruction of classified materials ashore. Currently available incinerators are not satisfactory to meet the increased volume (500 lb/hr) and variety of materials used to convey classified information--viz., papers, bound volumes, IBM cards, photographic films (movies, slides), Mylar Tapes, oil based teletypewriter tape, and miscellaneous items of glass, metal, etc. Present incinerator deficiencies include high costs of operation and maintenance, possibility of security compromise, and excessive stack emission and consequent air pollutant burden. The RDT&E project should provide a clearer definition of the problem; investigate improved methodology, processes, and equipment; conduct a system and cost effectiveness study; design, fabrication and testing of prototype; prepare approved military specifications for installation and use. This Problem is related to Naval Communications Command and Naval Security Group Command Headquarters requirements.

(2) Short Range. The rotary drum incinerator concept adopted by NAVFAC/contractor appears to be capable of meeting air pollution restrictions and simplified feed requirements. Prototype unit procured and evaluated by NAVFAC contained a number of design flaws and did not meet all the design goals. However, NAVFAC considers that new engineering design can correct these deficiencies. One major drawback of this prototype, however, is the very high power requirement which in use at some installations causes a power drain and voltage drop. Additional requirement or goal is the ability to destroy the classified material w/o security compromise in load feeds in excess of 500 lb/hr.

b. Disposal/Destruction of Classified Materials--Ships. A deliberate attempt is being made here to avoid potentially classified items from being incorporated into this report.

Therefore, R&D's new methods of destruction and self-destruction of classified material will not be described herein. The problem of destruction of classified film using existing shipboard incinerators involves the extensive evolution of toxic and obnoxious fumes—so much that some practices involve "deep-sixing"—overboard/sinking for disposal rather than burning. Dependent upon time and loading constraints, RDT&E is required for optimum disposal/destruction of shipboard photographic classified material. The practicality of incinerator modification vs. rapid chemical stripping w/o security compromise should be investigated. It would also be beneficial to further investigate this problem to define its scope and extent.

4. Shipboard Industrial Sources (other than SO_x from fuel)

a. As mentioned earlier, ship industrial operations in port (tenders, aircraft carriers) contribute a certain degree of pollution to the atmosphere. The intensity of the problem depends upon the point source concentration, and its relationship in magnitude to that from the surrounding community. In this context, the following potential shipboard air pollution problems are cited, using submarine tender activities as an example. The new tenders contain 67 industrial shops, each with its own contributory cause:

(1) Rubber & plastic shop. Mold, heat, and burn plastics elastomers; exhaust directly thru stack.

(2) Asbestos lagging, etc. At present, asbestos particles are viewed as one of the most hazardous particulates—effects on ingestion in lungs have been recently and alarmingly presented by the medical profession. Operations involving shredded asbestos aboard the tenders have special exhaust accommodations—but this exhaust into the air is not filtered.

(3) Foundry. Although perhaps small in capacity relative to municipal industrial plants, each tender has two 600 lb and one 800 lb charge-capacity furnaces—for both ferrous and non-ferrous alloys—including zinc (Zn), and lead (Pb), which are vented to the atmosphere without any collection devices. As with other sources, this area must be quantitatively and qualitatively analyzed to determine the nature and extent of the potential atmospheric pollution.

(4) Resin encapsulation. In electrical repair shops of tenders and carriers, motors of various sizes or capacities are overhauled. This operation requires the removal of the resin encapsulation (epoxies, silicones, etc.) by careful incineration. Aside from the safety features (some have exploded), the noxious fumes emanating from the stacks have not been known to have been analyzed to determine if they meet federal, local, or regional air standards.

5. Ships' Coatings

a. Problem. In considering air pollution problems, the state of California has taken the lead nationwide for rules and regulations for control and abatement. Because of the high pollution (people, vehicles, etc.) in Los Angeles county and the stagnation of wind currents in that area, atmospheric smog is a common occurrence. Thus LA initiated vehicular controls long before the federal government. To further reduce the smog formation, low limits were placed on sulfur in fuels, and to certain solvents used in industrial operations—the emission of which under photochemical reactions contributes significantly to smog. The San Francisco Bay area and LA county have issued regulation 3 and rule 66, respectively, restricting the types and amount of reactive organic compounds from industrial sources. For

Navy purposes, these restrictions are most applicable to surface coating solvents, such as ketones and aromatic hydrocarbons used mainly in paints adhesives, etc. For shore applications, solvent emissions can be controlled by various means and processes. For ship applications and open environment, controls are practically impossible. The bulk of the coatings involved in this problem use synthetic resin formulations; viz., epoxies, polyurethanes, and vinyls (alkyds pose very little problem comparatively). For aircraft coatings, NAVAIR has almost completed the investigation and evaluation of the epoxy and polyurethane coatings which use methyl isobutyl ketone and toluene as the problematical solvents. Results to date indicate successful modification of formulation and conformance to air pollution rules and regulations. A problem does exist in the use of Navy antifouling paints--a vinyl composition (vinyl A/F) which uses xylene as the aromatic solvent. A maximum of 8% of this solvent is permitted, posing several difficulties in its use.

b. Requirements. RDT&E is required to formulate an effective antifouling coating for ships' bottoms in conformance with the California rules and regulations, without any loss of effectiveness, and with minimal increase of cost compared to existing specification formulation. The problem is subdivided into three potential avenues of approach:

(1) Substitution for the xylene (8 carbon aromatic) solvent with less reactive organic solvents.

(2) Substitution of other resinous materials for the vinyl.

(3) Development of new coating with water-based formulation, to practically eliminate all organic solvents.

c. Vinyl A/F Related Water Pollution Problem. An adjunct, really related to water pollution, the Navy vinyl A/F contains copper oxide (as the barnacle deterrent) which depends upon chemical leaching by the water for its biochemical action. The Navy is investigating organometallics (tributyltin oxide, triphenyl lead acetate) as contact rather than leaching out poisons. These compounds are also used in lower concentrations than the copper compounds. The organic metallics are more localized (rather than ion diffused) for coating protection, and used in less amounts, thus they may prove to be less toxic to other marine biota and thus less of a water pollutant.

d. Aircraft Deck Coatings. A/C deck coatings are based on alkyd, epoxy, and urethane formulations. Approximately 100,000 feet of coating per deck are used for flight and hangar decks, and areas of heavy traffic. Although the solvent concentration would be less than the vinyl A/F or vinyl A/C coatings, assessment of the nature and extent of this problem should be made to determine compliance with California rules and regulations.

V. POLLUTION PROBLEMS ASSOCIATED WITH NAVAL ORDNANCE SYSTEMS COMMAND

A. **INTRODUCTION.** The situation existing at several Naval Ordnance Stations (NOS) indicated non-compliance with existing local or federal regulations for Air or Water Quality Control. Several NOSs reported open burning of excess or surplus explosives, wood from crates, etc. Basically, one can initiate military construction requests for incinerators and sewage treatments at the various installations. Rather than convert one severe pollution problem to a milder one, it would appear that some consideration be given to the concept of pollution prevention—where reclamation and salvage of some ordnance materials can be economically and technically feasible, and other material disposed of without additional pollution of air, water, or land. This is in essence the approach to be taken by NAVORDSYSCOM in solutions to its Environmental Protection and resources conservation problems.

B. **EXAMPLES OF ON-GOING EP WORK.** Examples of NAVORD on-going effort related directly or indirectly to environmental quality, prior to this survey and the issuance of the Executive Order which demonstrate the above theme, are listed as follows:

1. Surplus wood from ordnance crates (dunnage) is conveyed to a specially designed shredder. Ferrous metal fragments are magnetically separated from the wood chips and the resultant chips are sold to commercial buyers.

2. In lieu of open burning of the organic explosive TNT, a small R&D project is currently underway, investigating the feasibility of biological (microbial) degradation or metabolism of the chemical to a non-hazardous, non-toxic product.

3. NAVORD is the DOD coordinator for the silver reclamation program. Silver, because of its high cost, is salvaged from used photographic, and X-ray negatives. In a majority of the cases, the film is carefully burned in a commercially available reduced-atmosphere incinerator. When the temperature control fails, the silver is lost with the rest of the ash up the stack. Some chemical stripping process is also performed; but the negative base must be incinerated to assure non-compromise of military security items. As explained in one of the attached project proposals, an attempt will be made to chemically etch the negative base stock to completely erase any silver deposit, so that reuse or reprocess of the base can be economically and technically possible. NAVORD R&D of smokeless binary explosives is predicated on military tactical reasons and not related to or a consequence of pollution control.

C. **NAVORD APPROACH.** Extensive discussions were held with CAPT Z. C. Trzyna (ORD-0461), Mr. H. Roylance (ORD-048), who is the NAVORD pollution control project coordinator, and Dr. A. Amster (ORD-033) with the theme hopefully being reclaim, reuse, resale, and pollution prevention. It is recognized that in this short period of time, NAVORD's pollution problems cannot be methodically identified and quantitatively analyzed. In addition, there is very little information available from other services regarding existing state-of-the-art in treatment and control technology to the ordnance items. The U.S. Army has the responsibility for manufacture of the explosives and has, in fact, sponsored R&D effort in new methods of synthesis of TNT with minimal pollution of the air and water (Picatinny Arsenal contract with Stanford Research Institute). Information obtained from U.S. Army OCRD (Office of Chemical Research and Development) revealed their sponsored effort in investigating chemical methods for elimination or disposal of a large amount of stored lead azide. NAVORD's proposed pollution control program appears to be original and novel, not duplicating any existing or planned program of any other federal agency or commercial activity and warrants full Navy support.

D. AIRFORCE AND NAVAIR PROPELLANT POLLUTION PROBLEMS. The Air Force with responsibility for the development and deployment of the Minuteman missile system, has investigated air pollution problems related to combustion of the propellants. Toxicity and other hazards involved in the exotic fuels (Beryllium, boranes, etc.) while reflected in Navy documents (NAVMATINST 6240.1 of 27 Sep 1967) is being further evaluated by the Air Force (SAMSO, LAF Station). There is a potential air pollution problem related to the Navy FBM system and NAVAIR's air-to-air and air-to-ground propellants, the content of which is a classified matter. The NAVAIR missile propellants are both liquid and solid. Rather than include this item in this submission, CNM (MAT-03) is referred to Mr. I. Silver (NAVAIR-330) for more details and possible inclusion in the NAVORD (or NAVAIR's) 1634's. Use of liquid propellants with the Navy's Bull Pup missile and the AQM/37 air target system represents a strong safety problem rather than one for air or water pollution. It is to be noted that the NAVORDSYSCOM effort in the development of ammunition, explosives, propellants, and chemical waste material disposal through reclamation, salvage, chemical or biological degradation to reduce air and water pollutants will have applicability to the solution of similar problems of the fleet, CNM, and other DOD activities. (Ammunition and explosive waste materials exist at air and ammunition staging areas under cognizance of the fleet.)

E. NAVORD R&D REQUIREMENTS FOR POLLUTION CONTROL IN ORDER OF DECREASING PRIORITY

1. Pollution Survey. There is, at the present time, no thorough catalog of the extent to which NAVORD activities are contributing to pollution. The necessary preliminary assessment will be prepared under O&MN funding which has been requested. Environmental degradation attributable to exploratory development can be studied only with additional funding. Much of this developmental work involves high energy, exotic, often toxic chemicals; therefore, the inventory must be prepared by technical personnel skilled in this highly specialized field. The proposed "catalog" will be assembled by such scientists after conferring with their Navy counterparts who are active in this technology. It will address present as well as future problem areas. Without the inventory, it will not be possible to plan a coordinated, balanced pollution abatement program.

2. Explosive Reprocessing. Approximately 25,000 lbs. of explosive scrap (from processing, loading, reworking) are burned daily. The waste consists mostly of RDX, TNT and Explosive D. Undoubtedly these materials can be reclaimed by solvent extraction and by recrystallization. It may even be possible, in some cases, merely to ballmill some of the scrap as the only step prior to reuse. Suitable solvents would be: acetone for RDX, hot water and alcohol for TNT, and hot water for Explosive D. The precise procedures remain to be worked out and then scaled up. Some performance testing would be appropriate.

3. Biodegradation of Explosives. Currently overage and scrap explosives are disposed of by either detonation or by burning. Both methods of disposal lead to the air pollution problem. Although explosives may be neutralized by chemical decomposition, such a disposal technique is time consuming and usually reserved for laboratory-size samples. Large scale chemical decomposition would be at best a hazardous process. Preliminary studies conducted to date have proved the feasibility of non-violently degrading TNT by use of the

escherichia coli micro-organism. Initial studies indicate the degradation on a small scale is complete within 30-45 days and the investigators feel that the same time factor would apply to scaled up quantities of TNT. Such disposal would lend itself to lagoon type digestion methods.

4. Propellant Reclamation. It is reported that approximately 15 tons of propellant are destroyed daily by burning. There may well be little chance of reusing the waste for its original purpose, but there are other attractive uses. For example, composites can be treated with alkali to degrade the polymer. Maceration should follow, and the oxidizer can be leached out either for recovery or for use in solution. The residue, perhaps, can be used as a building material, after compaction, or as a conventional, nonpolluting fuel in special burners. Single and double-base propellants can be degraded in strong alkali and the ingredients separated with suitable solvents. Possible uses are as fertilizers, industrial chemicals, etc. The proposed methods, of which there are several, need to be evaluated and optimized.

5. Flare, igniter, pyrotechnic disposal. Many thousands of pounds of these materials—usually overage—are destroyed daily by burning. This is a particularly noxious situation because the ingredients often include heavy metal salts—often highly toxic. Possible solutions include ballmilling of the powders, pastes, and grains followed by selective solvent extraction and ingredient recovery. Because each system represents a special situation, a variety of methods must be studied and evaluated.

6. Improved Test Methods. Approximately 12,000 lbs. per year of explosives are deliberately detonated in underwater tests. Additional quantites are tested in air. Such tests are conducted, generally, in public waterways, navigable streams or in the ocean. Damage to commercial interests, public irritation, and ecological factors often are involved. Although NAVORD now has a program aimed at developing small scale tests to obviate the larger ones, this program needs emphasis. Such an effort is a long-term one and results will be slow in forthcoming. They will be attained only with theoretical studies supported by appropriate experiments.

7. Rework of OTTO Fuel. OTTO fuel is a nitrate ester monopropellant used in the Mk 46-1 and Mk 48 torpedoes. Under storage conditions, water and other contaminants are picked up. It is now felt that the absorbed water increases the vapor pressure which increases the toxicity of the fuel. Normal procedure is to dispose of the fuel from a charged torpedo as those torpedoes are being serviced on board the submarine tenders. Normal disposal of the fuel is by burning. Should a capability be developed to rework the OTTO fuel on board the tenders by removal of absorbed water and other contaminators, savings would result both in recovery of the basic propellant for reuse and in elimination of a pollution problem. Development of a safe econonucal means of reworking OTTO fuel at the shipboard level of maintenance will be investigated.

8. Silver Reclamation (See page 48).

9. Addendum to Each Present Task with Pollution Abatement Overtones. A new requirement of each ORDTASK will be that each Investigator examine his work and his specialty. He will be required to report the extent to which his program is contributing to pollution and to prepare suggestions for abatement.

VI. NOISE ABATEMENT

A. INTRODUCTION

1. The problem of airborne noise and its effect on man have been viewed with increasing concern by the President, Congress, federal agencies, and local and state areas especially those that are proximate to large airports. As with air pollution, noise produces adverse physiological effects on personnel, damage to materials and structures, and reduces Navy combat effectiveness by providing the enemy with acoustic signals for detection. Noise is generated by many sources–shipboard machinery (such as pumps, compressors), rapidly moving propellers, forced draft blowers, electrical transformers, and, perhaps worst of all, aircraft engines.

2. Federal legislation, Presidential executive orders, and DOD policy reflect the magnified importance of noise abatement as an integral part of the Environmental Protection Program. In more or less chronological order, on 8 Feb. 1969, DDR&E requested the Secretaries of Military Department to apply the provisions of the Noise Abatement Act (applicable to commercial aircraft) to military aircraft consistent with safety and performance. Walsh-Healey Public Contracts Act of 20 May 1969 set rigid environmental noise level requirements for government contractors. On 23 Jan. 1970 SECDEF notified the Secretary of Commerce that DOD will continue to support the Interagency Committee on Noise Abatement. In March 1970, a Presidential memo was formulated on the Abatement of Noise Pollution. This memo established the specific responsibilities of the agencies including DOD. "The DOD is directed to conduct noise research and establish standards for the unique or special situations encountered and make such information available through normal channels within the limits of national security."

B. PURPOSES OF NOISE ABATEMENT

1. Harmful effects of excessive airborne noise must be reduced to:

a. Alleviate the problem of acoustically–induced structural fatigue–(called "sonic fatigue") especially for supersonic aircraft–an effect that is aggravated when superimposed by low-frequency vibrations, heating, and static loads.

b. Provide an effective communications environment (including problems of speech interference).

c. Eliminate the possibility of permanent hearing damage–again very applicable to flight personnel and ground crew.

d. Minimize degradation of human performance–short term memory, manual motor performance, disorientation, etc.

e. Decrease annoyance and degradation of morale.

f. Improve Navy/community relationships.

g. Eliminate enemy detection of Naval aircraft involved in reconnaissance/surveillance and special operations.

2. As with other Naval pollution abatement problems, solutions for noise reduction should be accomplished with minimum sacrifice of performance effectiveness, weight, and cost. Noise abatement R&D must also include such parameters as frequency, amplitude, spatial and temporal characteristics, etc.

C AIRCRAFT ENGINES

1. The two major sources of noise are those associated with aircraft engines and shipboard airborne noise. NASA (LANGLEY & LEWIS) has the prime federal agency responsibility for R&D in aircraft noise abatement as reflected in the funding cited in Table 5 for the three year period FY 1969-1971. A list of typical research efforts being conducted by the federal agencies is included as Table 6. Noise derived from aircraft originates from the moving parts and air within the engine, and the ejection of the air and gaseous products through the jets into the atmosphere. Because of the extensive effort by NASA, and, of late, a significant increase by the Air Force, Navy R&D in this area has been supported at a relatively low level of funding. As with the engine air-emission program, results of noise abatement R&D conducted by the other government activities will be implemented directly into the Navy.

2. Regarding propulsion noise sources, NASA has an extensive acoustics R&D program that includes basic studies of propellers, rotors, fans, compressors, and jet exhausts—atmospheric noise propagation. Application efforts are concerned with development of facilities and equipments for full scale model tests and engine fabrication, and the specialized instrumentation for noise measurements.

3. The Department of Transportation's Noise Reduction and Control Program includes the following highlights:

a. Investigation of the parameters that effect generation of noise from aircraft.

b. Development of guidelines for engine redesign to minimize the noise and the ensuing hardware modifications.

c. Development of improved techniques for noise abatement.

d. Safety aspects of noise abatement procedures—flight profiles and ground operations.

e. Systems analysis of all aspects of aircraft noise abatement including the technical, economic, operational and psychological features of the problem.

4. <u>Objectives</u>. Since the problem of aircraft noise abatement is applicable to both military tactics and Environmental Protection, a two-fold overall objective has been described for this program as follows:

a. Development of quiet propulsion technology and systems for aerial reconnaissance/surveillance and for special operations aircraft without significant loss of mission effectiveness.

b. Development of technology to reduce general aircraft propulsion noise levels below proposed government standards for civilian (as well as military) health and welfare enhancement.

5. Navy Effort. The major Navy effort with aircraft noise abatement includes the following:

a. Quiet propulsion studies for the TRIM aircraft (Trails and Roads Interdiction Mission). This is essentially concerned with propeller aircraft, using either reciprocating or turbine engines. For the former engine, effort is being directed toward the Wankel Engine principle–using rotating rotors in lieu of pistons, and utilizing automotive type exhaust mufflers to handle the reduced air flow.

b. Standard Navy Engine Test Cell at various NARF's. Design and fabrication of test cell facilities using concrete and acoustic linings to reduce the noise level over all frequencies by a 75 dB drop at a radius of 2000 feet–equivalent reduction to "Sleep criteria." The relatively noisy J75 jet engine will be used for noise spectrum generation. Design of the test facility is to provide the capability of handling anticipated jet engines for the 1980 decade requirements.

c. Engine-in-airframe Maintenance–During the engine maintenance and overhaul period (while engines are being run), aircraft are checked for integrity. Procedures and arrangements are made to abate the engine noise (back end in, sound screens, placed near exhaust, etc.). Planning criteria required.

d. Jet Engine–Limited effort is conducted by the Navy in the abatement of noise from jet engines, which is greatest during take-off. The limited effort has not produced any significant benefit. Noise abatement by adjustment of distance between stationary and rotating compressor or fan blades can only be achieved by reduction of the thrust and/or flight range–which is unacceptable. Results from the NASA Quiet Engine Program will be directly applicable to Navy aircraft. The Air Force is investigating attenuation of jet engine exhaust noise by droplets of a liquid dispersed in the gas phase ("Acoustic Absorption and Diffraction by a Cloud of Vaporizing or Condensing Liquid Droplets").

6. Navy RDT&E Requirements. In view of the extensive effort conducted by NASA on the "Quiet Engine Program" and the high risk of achieving noise abatement with the limited R&D funds available, no new requirements are recommended.

D. SHIPBOARD NOISE ABATEMENT

1. Aside from aircraft engine noise, one of the principle areas of noise associated with Naval operations is that of shipboard equipment MIL-STD-740B (SHIPS) Notice 1 of 22 June 1965 is a "Military Standard, Airborne and Structureborne Noise Measurements and Acceptance Criteria of Shipboard Equipment." Airborne noise is considered undesired sound in air; structureborne noise is undesired vibration in or of solid bodies such as machinery, foundations, or ship structures.

2. As expressed previously, shipboard airborne noise affects personnel in three significant ways–(a) excessive levels can interfere with the ability to communicate commands, (b) compensable hearing damage may occur, and (c) reduction of personnel efficiency because

of annoyance or sleep loss. Principal attention has been given to steady state noise without prominent tones, and it has been found that levels exceed by 10 to 20 dB those considered acceptable in a nonshipboard environment. Many shipboard noises, however, actually do contain pure tones or are intermittent, impulsive, or fluctuating in level; they have received minimal attention. These findings are contained in a NAVSHIPS's (037) report "Steady State Airborne Noise Criteria for Shipboard Spaces" dated 1 April 1970, which also recommended new sound levels for shipboard spaces in terms at sound level A (dbA).

3. Problem Definition and Approach. The initial step in shipboard noise abatement is the determination, through laboratory tests and shipboard measurements and surveys, of the effects of the various types of noises described above on hearing, speech intelligibility, psychophysical responses and physiological processes. Means must also be developed to define and measure the noises in a meaningful way. The next step is the determination of the contribution of various equipments and systems to the overall noise ambient. Apart from engine rooms, the most serious problems arise from flanking paths and sources in nearby spaces and compartments. Finally, means must be developed to reduce the contribution of systems and equipment to the overall noise background. In addition to the survey and quantitative measurements, pertinent particulars of the surroundings will be noted (thickness of bulkheads, existence of acoustic treatment or resilient mounts, feasibility of installing treatment, etc.). Basic work on criteria and measurement techniques has been performed at the Navy Underwater R&D Center (NURDC), San Diego.

4. Navy Effort

a. Aircraft Carriers–The concept of insulation of flight and hangar decks was completed a decade ago. Noise reduction at present is accomplished by modifications in the aircraft engine operation: mixing outside air (3 or 4 to 1) to slow down and cool the jet exhaust–and changing its direction (deflection from "straight out") to reduce noise propagation.

b. Small Boats–Studies of radiated and on-board noise (performed by NSRDL/A). Significant improvements have been achieved in the form of high performance mufflers, improved absorption and barrier materials in engine compartments, silencers in air intake ducting and acoustic treatment in control and living spaces.

c. Submarines–Related to the important mission effectiveness item of underwater detection.

d. Minesweeping Boats (MSB s)- Reduction of noise from the MSB stack, where gas turbines were used for prime movers of generator sets. The problem was centered on the high frequency noise that would be harmful to the hearing of the crew, and the possibility that the airborne noise would be very severe to personnel in proximity of the boat.

5. Bureau of Medicine and Surgery (BUMED). BUMED is directly involved in the health and safety aspects of naval military and civilian personnel throughout the Naval Establishment. In the Noise Abatement Program, CDR Barboo of BUMED (732) initiated BUMEDINSTR. 6260.6B–Hearing Conservation Program of 5 March 1970 which outlines the hearing damage risk criteria and personnel protection methods for control of noise ashore or afloat.

6. RDT&E Requirements. A limited RDT&E effort has been conducted by NAVSHIPS with NSRDL/A support on the effects and control of shipboard airborne noise. As

stated in Problem Definition, a more intensive program is required to reduce noise to acceptable levels, including a study of the tonal and nonsteady noises. The reduction of noise levels below those recommended by the Bureau of Medicine and Surgery would be desirable, without significant sacrifice of weight and cost, and contributing to improved mission keeping capability.

TABLE 5
AIRCRAFT NOISE ABATEMENT RESEARCH FUNDING LEVELS

Agency	$ Millions		
	FY 69	FY 70	FY 71
DOT	.61	2.35	3.70
NASA	19.50	12.10	14.90
DOD	2.00* 3.60**	2.30* 9.46**	2.10* 6.09**
Industry	20.00	20.00	15.00

*Primary Emphasis–Reconnaissance/Surveillance Aircraft.
**Development and Construction of Aircraft/Engine Test Stand.

TABLE 6
AIRCRAFT NOISE ABATEMENT–FEDERAL AGENCY RESEARCH EFFORTS

DEPARTMENT OF TRANSPORTATION

Noise Reduction and Control
Systems Analysis
Sonic Boom Generation and Propagation
Human and Animal Response to Sonic Boom
Structural Response to Sonic Boom and Sonic Boom Instrumentation

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Quiet Engine Program
Propulsion Noise Prediction and Reduction
Acoustic Lining Studies
Atmospheric Propagation of Aircraft Noise
Noise Research Facility Development

DEPARTMENT OF DEFENSE

Army: Reconnaissance/Surveillance Aircraft
Helicopter Aural Detection
Gear Box Noise Reduction

TABLE 6 (Continued)

DEPARTMENT OF DEFENSE (Continued)

Air Force:	Quiet Aircraft Study
	Bio Acoustic Research
	Propulsion and Aircraft Acoustics
	Aircraft Noise Measurement Program
	Aircraft/Engine Test Stand Suppressors (ASD)
Navy:	Aircraft Carrier Environment Studies
	Quiet Propulsion Studies (Trim Aircraft)
	Aircraft/Engine Test Stand Suppressors

VII. U.S. NAVY ENVIRONMENTAL PROTECTION PROGRAM. RDT&E RECOMMENDATIONS

A. WATER POLLUTION

Pollutant Source	Project No.	Project Title	Cognizant SYSCOM/ Activity	RDT&E Recommendations: Existing Project	RDT&E Recommendations: New Project	Document Section	Reference Page
Oil Spills							
	1	Salvage Operations–SP-4/AUGAS & High Speed Pumping/Recovery Systems	SHIPS/SUPSALV		Initiate (System Dev)	III A3b	14
	2	Oil Slick Containment & Recovery System	FAC/SUPSALV	Increase Hdwe Stop Software		III A3c	14
	3	Oil Slick Combat Technology	FAC/SUPSALV		Coordinate Only	III A3c	15
	4	Bilge & Ballast Oil/Water Separation	SHIPS/MSC	Cont As Is		III A4a	16
	5	Oil in Water Monitoring & Measurement	SHIPS/MSC		Initiate	III A4a	17
	6	Fuel Tank–Filling Alarm & Tank Cleaning	SHIPS/SUP/MSC		Initiate (Sys. Dev.)	III A4b	17
	7	Slop Oil Containment & Disposal	SHIPS/SUP/MSC		Initiate	III A4c	18
	8	Jet Fuel Purification for Oilers	SHIPS/AIR		Initiate (Sys. Dev.)	III A4d	18
	9	Oil Deballast Facilities–Ashore	SUP/DFSA/MSC		Initiate (Engr. Study)	III A4c	18
	10	Used Lubricant Disposal/Reclamation	SUP/FAC		Initiate	III A4e	19
Sewage		Marine Sanitation–Treatment/Disposal System	SHIPS				
	11	Short Range		Cont. W/Mod		III B8b	29

A. WATER POLLUTION (Continued)

Pollutant Source	Project No.	Project Title	Cognizant SYSCOM/ Activity	RDT&E Recommendations Existing Project	New Project	Document Section	Reference Page
	12	Long Range (Exp. Dev.)		Increase		III B8c	29
	13	Intermediate Range (Adv. Dev.)		Increase		III B8d	30
	14	Galley Wastes & Trash	SHIPS	Initiate			31
		Shore Based Water & Sewage Disposal/ Treatment	FAC				32
	15	Adv. Base Integrated Water & Waste Mgmt System			Initiate	III C1a	32
	16	Adv. Base Waste Water Treatment/ Disposal		Cont. As Is		III C2	32
Industrial & Chemical Wastes	17	Electroplating, Chemical Cleaning, Battery Acids	ALL SYSCOMs		Initiate	III D1b	33
	18	Photographic Chemical Purification & Reclamation	AIR/ORD		Initiate	III D1a	33
	19	Aircraft Anti-Corrosive Rinse	AIR	Cont. As Is		III D1f	34
	20	Aircraft Cleaning & Stripping	AIR/FAC		Initiate	III D1d	34
	21	Laundry	SHIPS/SUP		Coordinate Only	III D1e	34

B. AIR POLLUTION

Pollutant Source	Project No.	Project Title	Cognizant SYSCOM/ Activity	RDT&E Recommendations Existing Project	RDT&E Recommendations New Project	Document Section	Reference Page
Mobile Sources		Aircraft Engine Exhaust Emissions					
	22	Emission Control—Additives & Engine Mod.	AIR	Cont. As Is		IV C1	39
	23	Emission Measurement	AIR/FAC	Increase		IV C1	40
	24	Vehicular Engine Exhaust Emissions	FAC		Survey Problem	IV C2	43
Stationary Sources	25	General Purpose Incinerators	FAC	Increase W/Mod		IV D2	45
		Special Incinerators—Classified Materials Ashore	FAC				45
	26	Long Range—Destruction/Disposal			Initiate	IV D3a(1)	45
	27	Short Range—Incineration		Cont. As Is		IV D3a(2)	45
	28	Disposal/Destruction of Classified Materials—Ships	SHIPS		Initiate	IV D3b	45
	29	Shipboard Industrial Sources	SHIPS		Survey Problem	IV D4a	46
	30	Ships Coatings	SHIPS		Initiate	IV D5b	46

C. ORDNANCE POLLUTION PROBLEMS

Pollutant Source	Project No.	Project Title	Cognizant SYSCOM/ Activity	RDT&E Recommendations Existing Project	RDT&E Recommendations New Project	Document Section	Reference Page
	31	Explosives	ORD		Initiate	V E2&3	49
	32	Propellants	ORD		Initiate	V E4	50
	33	Flare, Igniter, a Pyrotechnic Disposal	ORD		Initiate	V E5	50
	34	Underwater Explosion Testing	ORD		Initiate	V E6	50
	35	OTTO Fuel	ORD		Initiate	V E7	50
	36	Silver Reclamation	ORD		Initiate	V E8	48
D. NOISE ABATEMENT							
Aircraft	37	Quiet Propulsion Study--Trim Aircraft	AIR	Cont. As Is		VI C5a	53
	38	Engine Test Cells	AIR/FAC/ BUMED	Cont. As Is		VI C5b	53
	39	Engine-in-Airframe Maintenance	AIR/FAC/ BUMED	Cont. As Is		VI C5c	53
	40	Jet Engine	AIR/BUMED	Minor Effort & Coordinate		VI C5d	53
Shipboard	41	Airborne & Structure Borne Noise	SHIPS/ELEX/ BUMED	Increase		VI D6	54

APPENDIX A

FEDERAL AGENCIES INVOLVED IN PROGRAMS TO REDUCE EMISSIONS FROM MOBILE SOURCES

Agency	Program Area and Dates
National Air Pollution Control Administration	Controlling agency for all air pollution programs funded by U.S. Department of Health, Education, and Welfare (See Appendix B)
Atomic Energy Commission	Organic Rankine-Cycle Technology Investigation (1969-72)
	Status of High Energy Battery Developments (1969-70)
	Bimetallic Systems Program (electric power) (1969-75)
Department of Defense	Stratified Charge Engine (1969-70)
	Smoke Reduction in Turbine Aircraft Engines (1969-70)
	Industrial Gas Turbine Family (1969-75)
	AGT-1, 500 Gas Turbine Development (1969)
	Electrochemical Energy Storage for Vehicle Propulsion (1969-73)
	Exploratory Fuel Control Research (1969)
	Basic Combustion Research on Internal Combustion (1969-75)
Department of the Interior	Interactions Between Fuel Composition and Engine Factors Influencing Exhaust Emissions (1969-75)
	Products of Combustion of Distillate Fuels Used in Mobile Systems (1969-75)
	Evaluation of Fuel Composition Effects on Continuous Flow Combustion Propulsion Systems (1969-75)
	Characteristics of Photochemical Reactivity of Vehicle Emissions (1969-75)

Agency	Program Area and Dates
Department of Transportation	Measurement of Smoke from Gas Turbine Engines (1969)
	Computer Programs to Define the Influence of Combustion Parameters in Turbine Engines (1970)
	Study of Visible Exhaust Smoke from Aircraft Jet Engines (1969)
	Rankine-Cycle Freon-Engine Bus System (1969-70)
	Rankine-Cycle Steam-Engine Bus System (1969-70)
	Stirling-Cycle Bus System (1970-71)
	Hybrid/Electric Bus System (1970-71)
General Services Administration	Providing Fleets of Vehicles for Use in Demonstration and Mileage Accumulation Tests
	Fleet Test of Natural-Gas Powered Vehicles (1970)
National Aeronautics and Space Administration	Development of Thermal Reactors for Vehicle Pollution Control (1969-71)
	Studies on Boilers, Pumps, Radiators, and Condensers (1969-72)
	Metal-Air Batteries (1971-75)
	Interagency Advanced Power Group (1969, 1971) (Includes AEC, DOD, HEW, and NASA)
Post Office Department	Fleet Test of Natural-Gas Powered Vehicles (1970)

APPENDIX B

PROGRAMS SPONSORED BY NAPCA TO REDUCE EMISSIONS FROM MOBILE SOURCES

High Efficiency Induction Systems Evaluation (1969-71)

Carburetors, Reduction of Engine Exhaust Emissions (1969-70)

Influence of Fuel Atomization, Vaporization, and Mixing on Exhaust Emissions (1969-70)

Kinetics of Nitric Oxide at High Temperatures (1969-70)

Alternate Low Emission Fuels for Motor Vehicle Propulsion (1969-70)

Effects of Gasoline Additives on Carburetor and PCV System Performance as They Relate to Exhaust Emissions (APRAC-CAPE-2) (1969-70)

Emission Control Technique Evaluation (1969-70)

Evaluation of Exhaust Gas Recirculation for NO_x Control (1969-71)

Demonstrate Feasibility of Control of NO_x Emissions (1969)

Control of Nitrogen Oxides Emissions from Mobile Sources (1969-70)

Control of Particulate Emissions from Mobile Sources (1969-70)

Evaluation of Effects of Fuel Composition and Fuel Additives on Particulates in Exhaust Emissions (1969-70)

Fuel Volatility Effects on Driveability and Emissions (APRAC-CAPE-4) (1969-70)

Automotive Fueling Emissions (APRAC-CAPE-9) (1969-70)

Study of Two-Stroke-Cycle Spark-Ignition Engine Emissions (1969-70)

Development of Emission Factors for Off-Highway Internal Combustion Engine (1970)

Control of Emissions from Diesel-Powered Mobile Sources (1970)

Control of Particulate Emissions from Mobile Sources (diesel) (1970)

Fuel Injection System Analysis: Diesel Smoke Reduction (1969-70)

Investigation of Diesel-Powered Vehicle Odor and Smoke (1969-70)

Diesel Fuel Combustion Chemistry as Related to Odor (1969)

Control of Emissions from Aircraft (1969-70)

Rankine-Cycle Propulsion Systems for Vehicles (1969-70)

Low Emission Continuous Flow Combustors for Vehicle Propulsion Systems (1969-70)

Rankine-Cycle Bus Emission Evaluation (1970)

Gas Turbine Exhaust Emission Analysis (1969-70)

Irradiation Chamber Studies (1969-70)

Photochemistry and Kinetic Investigations (1969-70)

Elementary Reactions in Photochemical Smog (1969-70)

Field Studies of Photochemical Air Pollution (1969-70)

Atmospheric Reaction Studies in Los Angeles Atmosphere (APRAC-CAPE-7) (1969-70)

New Techniques for Exhaust Emissions (sampling) (1969-70)

Analytical Methods for Aromatics and Particulates in Auto Exhaust (APRAC-CAPE-12) (1970)

Improved Instrumentation for Determination of Exhaust Gases for NOx and Oxygenate Content (APRAC-CAPE-11) (1969-70)

Chamber Reactivity Studies (APRAC CAPE-1) (1970)

Response of Urban Population Groups to Diesel Exhaust Odors (1970)

Diesel Exhaust Odor Characterization (APRAC-CAPE-7) (1969-70)

Sampling System Evaluation (1969-70)

CO Profile Study (1970)

Diffusion Model of Urban Atmosphere (APRAC-CAPE-3) (1970)

Study of Air Pollution Aspects of Various Urban Forms (1970)

Development of Initial Guideline Document (1970)

Air Pollution Aspects of Various Roadway Configurations (Lower Manhattan Expressway) (1969-70)

Development of a Long-Range Program Plan for the Air Pollution Aspects of Environmental Planning (1969-70)

Engine Emission Reduction by Combustion Control (1969)

Kinetics of Nitrogen Oxides Automotive Pollution (1969-70)

UCB-ENG-2045-Combustion Gas Composition (1969-70)

Kinetics of Oxidation and Quenching of Combustibles in Exhaust Systems of Gasoline Engines (APRAC-CAPE-8) (1969-70)

Relation of Fuel Composition to Gaseous Exhaust Emissions from Automotive Vehicles (1969-70)

UCV-ENG-2365-Aromatic By-Products of Combustion (1969-70)

Liquid Fuel Ignition and Combustion (1969-70)

Gasoline Composition and Vehicle Exhaust Polynuclear Aromatic Content (APRAC-CAPE-6) (1969-70)

Combustion Process Analysis (1969)

Oxygenates in Automotive Emissions (1969-70)

Use of Electric Fields in Combustion (1969-70)

Long-Range R/D Program Plan for the Development of Motor Vehicle Control Technology (1969)

Long-Range Program Plan for Combustion Research (1969)

Long-Range R/D Program Plan For Air Pollution Instrumentation (1969)

Cost Effectiveness of Hydrocarbon Control (1969)

Technical Seminars, Advisory Committees, Etc. (1969)

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) CHIEF OF NAVAL MATERIAL NAVY DEPARTMENT WASHINGTON, D.C. 20390	2a. REPORT SECURITY CLASSIFICATION CLASSIFIED
	2b. GROUP NA

3. REPORT TITLE

REPORT OF U.S. NAVY ENVIRONMENTAL PROTECTION PROGRAM

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)
Summary Report

5. AUTHOR(S) (First name, middle initial, last name)

J. L. Kalinsky

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
21 August 1970	70	60

8a. CONTRACT OR GRANT NO. NA	9a. ORIGINATOR'S REPORT NUMBER(S)
b. PROJECT NO. F 38 532 Program Element 62714N	
c.	9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)
d.	

10. DISTRIBUTION STATEMENT

Distribution limited to U.S. Gov't agencies only as document covers the evaluation of commercial products and military hardware. Other requests for this document must be referred to the Chief of Naval Material (Code MAT 044P)

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
	Naval Material Command, Navy Department Washington, D. C. 20390

13. ABSTRACT

This report defines the Environmental Protection Problems of the U.S. Navy, ashore and afloat, and sets forth meaningful RDT&E requirements for each pollution problem area. After listing the major operational problems, the existing state-of-the art approaches and technology are described, and where applicable, a technical appraisal is rendered for short range and long range solutions.

After having coordinated with cognizant Federal agencies, requirements are established which reinforce and concentrate Navy resources in critical areas. The principles of pollution prevention and conservation of resources (treatment of waste or surplus material by reprocess, purification, and reclamation to provide a reusable or salable product) are advanced.

Major Navy problems considered are: shipboard sanitary waste treatment and disposal systems; oil pollution of water resulting from pumping of bilges, deballasting of fuel or cargo oil tanks, pumping of tank slop, accidental and deliberate fuel (JP-5 contamination) spillage; aircraft engine exhaust emissions and noise; and ordnance material (explosive, propellants, pyrotechnics, and Otto fuel) reprocessing and reclamation.

Other problem areas included are: industrial, galley, and trash wastes from ships; shore and ship destruction of classified material; ships' anti-fouling paints; aircraft cleaning and stripping; shipboard noise abatement; and waste oil disposal.

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Environmental Protection						
Environmental Pollution Control						
Pollution Control						
Pollution						
Oil Pollution						
Treatment of Waste						
Shipboard Sanitary Waste						
Aircraft Engine Exhaust Emissions						
Aircraft Exhaust						
Aircraft Noise						
Fuel Spillage						
Waste Oil Disposal						
Waste						
Spillage						
Exhaust						
Ordnance Material Reprocessing						
Ordnance Material Reclamation						