NRL Report 7563

Guide to NRL Cleaning and Salvaging Techniques for Reclaiming Equipment Contaminated with Seawater, Oil, and Smoke Deposits

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CONTENTS

ABSTRACT

This report was prepared as a result of continuing requests for information and assistance regarding the reclamation of equipment contaminated by oil, seawater, or fire. Information is given regarding the necessary supplies, their preparation and place of procurement. The personnel and equipment needed to establish a shore cleaning facility are outlined. In addition, methods of salvage are discussed that are satisfactory for the majority of cleaning problems encountered in the field.

PROBLEM STATUS

This is a final report on this phase of the problem. Work on other aspects of the problem is continuing.

AUTHORIZATION

NRL Problem C02-04
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GUIDE TO NRL CLEANING AND SALVAGING TECHNIQUES FOR RECLAIMING EQUIPMENT CONTAMINATED WITH SEAWATER, OIL, AND SMOKE DEPOSITS

INTRODUCTION

Through a series of basic and applied studies the Naval Research Laboratory has developed techniques for the reclamation of contaminated equipment (1-11). The effectiveness of the techniques has been amply demonstrated in field trials and in actual disasters where extensive damage has resulted from shipboard fires. The Naval Research Laboratory has aided and encouraged naval shore stations to develop on-site facilities to reclaim such damaged equipment. These procedures are also applicable to the routine cleaning of equipment during overhaul. This report outlines the techniques used to remove various contaminants, describes the equipment and personnel requirements, and lists the necessary supplies, their sources, and methods of preparation.

PROCEDURES

Preparation of the Equipment

Before contaminated equipment can be cleaned it must be opened to allow the cleaning solution to reach all parts of it, and to allow complete draining, rinsing, and drying. Open access doors and remove covers and plates. Cut the ties and sleeves from large wire bundles and loosen the boots on cable connectors. Remove fuses and panel lights. The extent of disassembly required depends on the extent of contamination. Items submerged in seawater must be opened more completely than those with superficial smoke deposits, but free rinsing and drying must always be provided. Circuit boards may be cleaned in place, but it is usually best to remove them, wire them together in bunches, and process them separately from the chassis.

Take care that the removed parts are not lost. Embossed metal tags are useful in marking bundles, cans, or bags of parts. Copper wire is useful in trying parts together and suspending them in the cleaning and rinsing tanks. Markings and paint on chassis and circuit boards may be removed by the cleaning process if they are not well bonded. If this information is vital, photographing the items before cleaning is advisable.

Use of the Proper Technique

The most common salvage procedures are diagrammed in Fig. 1. From the contaminants listed at the top, the recommended procedures can be followed through the diagram. Branches indicate most of the alternative treatments, but unusual combinations of contaminants may require variations. The heavy lines indicate the generally preferred treatment. In the *Preservative Treatment* section are the steps which should be taken immediately at the disaster or recovery site to limit deterioration of the equipment and make its cleaning easier. It is best to proceed with cleaning immediately; however, if this cannot be done within a few days, preservative compounds should be applied to limit corrosion. In the

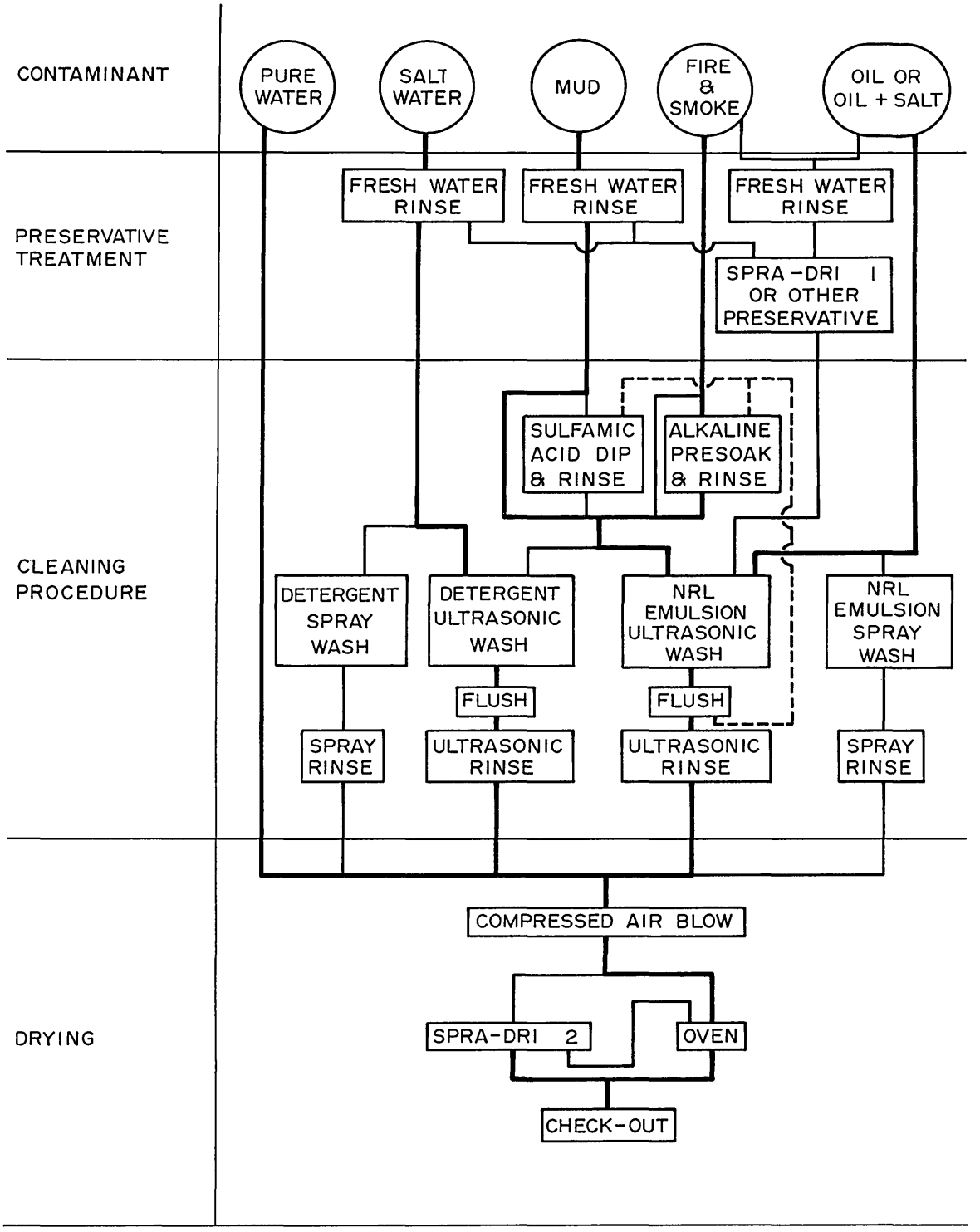

Fig. 1 — Diagram of the salvage procedures; follow downward from the contaminant to be removed

Cleaning Procedure section are the steps taken to remove the contaminants (and preservatives, if any) and rinse off the cleaning agent. Spray cleaning is less thorough than ultrasonic cleaning and should be resorted to only when the latter is impractical. The water which remains after cleaning is removed in the *Drying* steps, and the equipment is ready for checkout and repair or return to service.

The equipment and supplies needed are fully described later in this report. It is important that the proper cleaning agents be used or ineffective cleaning or damage to the equipment may result. Do not use whatever compound is handy or is being used for some other cleaning job. For example, organic or halogenated solvents are not effective in removing salt residues, and aluminum parts may be seriously corroded by strongly alkaline solutions or chlorinated solvents. The materials recommended in this report have been found effective and safe in use on a wide variety of equipment from 40-hp motors to spacecraft electronics.

Pure Water, Drying — Equipment may be contaminated with pure water as a result of rain leakage, potable water pipe breakage, accidental activation of fresh-water sprinklers, moisture condensation, etc. If no dirt or salts have been carried into the equipment, cleaning should not be necessary, although a rinse with fresh water might be advisable.

Blow the water off with low-pressure air. Dry in an oven (or equivalent) for 4-16 hr. The water-displacing fluid Spra-Dri may be used in place of an oven or to speed drying. Use Formula 1 for mechanical equipment, Formula 2 for electrical contacts and electronic equipment. Do not place sprayed equipment in a closed or recirculating oven until the bulk of the fluid has evaporated. Do not use oily moisture-displacing sprays, as these materials collect dust and can adversely affect insulation resistance in the presence of moisture (12). Electronic and electrical equipment should be checked for proper operation, and defective components replaced, and adjustments or realignments made before returning the equipment to service.

Salt Water Only — The equipment should be thoroughly rinsed with fresh water as soon as possible. If cleaning cannot be done in a few days, it should be treated with a preservative compound, preferably Spra-Dri, Formula No. 1, and then cleaned as described under *Oil or Oil + Salt*, below. If cleaning can be done quickly, the equipment should be kept submerged in fresh water, opened to provide access, ultrasonically washed with the detergent solution, ultrasonically rinsed, and dried as previously described.

Oil or Oil + Salt — If the equipment cannot be cleaned within a few days it should be rinsed with fresh water and treated with a preservative compound, preferably Spra-Dri, Formula No. 1. Cleaning is done with the NRL emulsion cleaning composition, preferably in an ultrasonic tank, after the equipment is opened to provide access. Use 20 to 50 vol-% of the concentrate in fresh water, depending on the amount of oily residue to be removed. If the oil contamination is extremely heavy a spray precleaning with 50% emulsion cleaner, kept well mixed, will facilitate preparation of the equipment and extend the life of the emulsion in the tank. After cleaning, flush off the emulsion with fresh water and place the equipment in the ultrasonic rinse tank. Dry as previously described.

Fire and Smoke — The contaminants resulting from fires are diverse. There may be carbon (soot), salts (if salt water was used in fire fighting), acids and "varnish" condensed from the smoke, and fire-fighting chemicals. Ultrasonic cleaning should be used, as spray cleaning has little effect on the adherent smoke residues. Either the NRL emulsion

cleaner or a detergent may be used, unless preservatives have been applied. Adherent deposits and "varnish" may require the use of an alkaline presoak. Soaking for 2-5 min at 120-160°F should be adequate. Then process the equipment through ultrasonic washing and rinsing and dry it as previously described under *Oil or Oil + Salt.*

Mud — Floods and sinkings in rivers and estuaries often deposit extremely adherent coatings of mud on the submerged equipment. Upon recovery such equipment should be flushed thoroughly with fresh water and kept submerged in it until cleaned, if this can be done within a few days. The cleaning and drying procedures are similar to those previously described, except that hand scrubbing may be necessary to loosen the mud deposits. In some cases, where marl or other soil containing limestone particles is involved, a brief dip (less than 5 min) in inhibited sulfamic acid will partially dissolve and loosen the deposit. CAUTION! *This is a hazardous agent and should be used only under the direction of a chemist and with protective clothing and procedures to prevent contact.*

Use of the Ultrasonic Tanks

Preparation — Air dissolved in the working fluid reduces the energy of the cavitation, which is responsible for the scrubbing and agitation needed for effective cleaning. Avoid aeration of the water when filling the tanks by using a hose held below the surface of the fluid. Deaerate the fluid by operating the transducers for 15-30 min while heating the fluid to its working temperature. Deaeration can be hastened by raising the temperature to 190°F, but the tank must then be cooled back to its working temperature. For rinsing and detergent washing the tanks should be kept at 120 to 160°F, depending on the temperature sensitivity of the equipment to be cleaned. *The NRL cleaning emulsion should not be used above 135°F as the flash point of the solvent is 140°.*

Cleaning — The items to be cleaned should be suspended, not resting on the wash tank bottom. This is essential if smaller tanks with bottom-mounted transducers are used. Lay pipes or rods across the tank and hang the equipment from them with wire or small chains. A traveling hoist is useful for heavy items. The equipment should be moved occasionally during cleaning, and large items should be turned 180° halfway through, to be sure that all parts receive adequate agitation. Small items such as circuit boards, with salt contamination, should be clean in 2-3 min. If adherent deposits do not come off in 5 min some additional treatment or manual scrubbing will be required. Immerse complete chassis 5-10 min depending on the size and weight. Immerse seawater-soaked motors and generators 10-20 min (see note on motors below). Hardware and small parts removed from equipment may be cleaned in metal beakers or tin cans suspended or floating in the tank.

Rinsing — After removing the equipment from the wash tank, flush it with water to reduce carryover, and suspend it in the ultrasonic rinse tank for the same length of time used for washing, turning it in a similar manner. Any equipment with crevices which is cleaned ultrasonically must be rinsed the same way in order to remove the cleaning agent driven into the crevices during washing. The rinse water must be kept low in dissolved solids, as these will leave a residue upon drying. When rinsing sensitive electronic equipment a final dip or flush with distilled or deionized water will prevent this.

Refilling — The wash tank can be used continuously for a day or two before draining it and refilling it with a fresh solution. Place the metal cover on the tank when it is not

in use. The rinse water should be changed about every 8 hr. Its condition may be monitored by evaporating samples to dryness and looking for residue, by making chemical tests for chloride, or by measuring its electrical conductivity.

Notes on Particular Equipment

Unsealed Voids — Some components such as electrical meters have cases which are not hermetically sealed, but are tight enough to prevent adequate cleaning, rinsing, and drying. Sometimes these can be opened and cleaned economically, but often it is cheaper to replace them. This is usually the case with meters having pivot bearings. "Waterproof" potentiometers, switches, and circuit breakers sometimes cause problems, but these can usually be eliminated by more thorough rinsing and drying. If the equipment is being cleaned during routine overhaul or if the contamination is superficial, unsealed meters should be removed and not put through the cleaning process.

Breakage — On rare occasions leads or junctions in solid state devices will be broken during ultrasonic cleaning. However, this is a small price to pay for preventing the progressive deterioration which would follow inadequate cleaning. The possibility of such damage is increased with longer immersion. Solid molded devices are immune because the internal parts cannot vibrate. The reliability of the cleaned equipment may be better than when it was new, as other weaknesses such as cold solder joints may turn up, and flux deposits, fingerprints, and manufacturing debris are removed.

Lubricated Parts — Lubricants are removed by the cleaning processes, and gear trains, bearings, cams, etc. must be relubricated with the specified grease or oil during checkout. Sealed ball bearings must be replaced; and oil wicks should be removed and discarded before the equipment is cleaned, and afterward replaced by new ones. Mechanical equipment with oil-bath lubrication which has been flooded with seawater can be readily cleaned with the NRL emulsion cleaner because it simultaneously removes oil and salt. For example, a flooded submarine propulsion reduction gear, its bearings, and the turbine bearings were cleaned with the emulsion by pumping it through the lubricating oil system.

Motors (and Generators) — Information on the recovery of seawater-flooded electric motors is quite variable. Some sources say that flushing and baking are adequate, others claim that salvage is impossible. The experience of this Laboratory indicates that spray cleaning is adequate only for fractional-hp ac units, with ultrasonic cleaning preferred. Larger units and all dc units must be ultrasonically cleaned. They should be disassembled before cleaning, any sealed bearings or oil wicks and packing discarded, and stators and rotors cleaned separately. Because of their mass and many crevices, motors should be given extended and thorough exposure to the ultrasonic agitation. Small motors should be immersed about 10 min, those around 10 hp for 15 min, and larger ones 20 min. The agitation is most effective with the axis of the unit toward the transducers, but it should also be rotated (or the transducers moved) to expose all sides. After cleaning and drying, carbon brushes should be replaced and bearings replaced, repacked, and relubricated as appropriate.

EQUIPMENT NEEDED

Ultrasonic Equipment

Three stainless-steel (304L or 316L) tanks, at least 4 X 4 X 4 ft, should be provided. These tanks should be constructed of 12-gauge or heavier sheet and have adequate reinforcement to support double the weight of water required to fill them. A stainless steel valve and piping system should be installed on each tank to permit complete gravity draining. A stainless steel steam coil should be installed, preferably on a side adjacent to the transducers or on the bottom of each tank, to maintain the desired operating temperature. One of these tanks is to be used for ultrasonic cleaning of the equipment, one is to be used for ultrasonic rinsing of the equipment in fresh water, and the third is to be used as a presoaking tank in case mud- or smoke-contaminated equipment is encountered. A metal cover should be provided for the cleaning tank.

Each of the two ultrasonic tanks used for cleaning and rinsing should be equipped with nine 1000-W magnetostrictive immersible transducers about 11 X 14 X 4 in. in size. Racks to hold the transducers on the sides of the tanks are available from the supplier of the ultrasonic equipment. The tanks can be constructed locally, or they can be purchased from the supplier of the ultrasonic equipment.

A solid-state generator, or a bank of solid-state generators, capable of 9-kW total output should be provided for each of the two ultrasonic tanks. If it should become necessary to clean equipment which is too large to fit into the 4 X 4 X 4 ft ultrasonic tanks, a larger tank could be constructed, and if necessary all eighteen immersible transducers could be used in that tank.

An overhead track with hoists should be provided for immersion and removal of heavy equipment from the tanks.

If smaller tanks with bottom-mounted transducers are used for small salvage jobs, they should be high-intensity units with magnetostrictive transducers, having at least 6 W/sq. in. over the entire bottom of the tank.

Spraying Equipment

Equipment that cannot be dismantled for cleaning in ultrasonic tanks can often be cleaned by spraying with a detergent solution or the NRL cleaning emulsion followed by fresh-water spray rinsing and drying. Both a Binks Spray Gun 140B (manufactured by the Binks Manufacturing Co., 3118 Carrol Avenue, Chicago, Ill.) and an ordinary steam jenny have been found satisfactory for such spray cleaning. In the Binks Spray Gun the detergent or NRL cleaning emulsion concentrate is mixed with the desired amount of water before spraying. With the steam jenny a detergent solution or the NRL cleaning emulsion concentrate is used in the cleaning tank and water is mixed with it at the time of use.

Compressed Air

Air for the spraying equipment should be oil-free, and available in adequate volume at 80-psi pressure. Air for blowing water from the equipment before drying must be dry, oil-free, and reduced to 10- to 20-psi pressure to avoid damage to delicate equipment.

Drying Equipment

Vacuum or forced-draft ovens large enough to accommodate the equipment being cleaned and with accurate temperature controls are preferable for final drying of the cleaned equipment. If ovens are not available, a small room equipped with an exhaust fan and heaters can be used. Either electric, gasoline, or kerosene (fuel-oil) heaters are satisfactory for heating such a room. A portable parachute drying tower, Federal Stock 2 RM 8340-376-3341, can be used to heat the room or to construct and heat a temporary enclosure. Dehumidifiers could also be used to remove the moisture from the room. The temperature in these drying facilities should be between 120 and 160°F depending on the temperature sensitivity of the equipment being dried. If a heated room is used for drying, its temperature should be at least 30°F above the ambient temperature.

If drying equipment is not available the water-displacing fluid described below may be used. It may also be used with drying equipment for more rapid drying. Adequate ventilation must be provided if it is used.

Other Services

The working area should have bench space for preparing the equipment, hot and cold water, and drainage. Electrical power for the ultrasonic generators is needed, and electricity or steam for the tank heaters. Noise from the tanks may be irritating to personnel nearby, and those engaged in the cleaning work should be provided ear protectors. Rubber gloves and aprons may also be desirable.

SUPPLIES NEEDED

NRL Emulsion Cleaner

The emulsion concentrate is not available through the supply system, but may be easily mixed according to the following formula:

Dry Cleaning Solvent, Type II, Federal Spec. P-D-680 (formerly P-S-661) — 94 vol-%

Stock No. W6850-281-1986 (55-gal drum)
Stock No. W6850-285-8011 (55-gal drum)
Stock No. W6850-274-5421 (5-gal can)

Fuel Oil, Diesel Marine, Type I, Military Specification Mil-F-16884F — 5 vol-%

Surfactant: Polyethylene Glycol 400 Dioleate 1 vol-%

The surfactant is available from several sources, three of which are

Armak Chemicals Division (as polyethylene glycol 400 dioleate)
Akzona, Inc.
Box 1805
Chicago, Ill. 60690

Emery Industries, Inc. (as Emerest 2648)
Carew Tower
Cincinnati, Ohio 45202

Glyco Chemicals, Inc. (as Pegosperse 400 DO)
P. O. Box 700
Greenwich, Conn. 06830

If the PEG 400 dioleate is not available, alternate materials are PEG 300 dioleate, or PEG 300 dilaurate, from Armak. Another material would be PEG 400 dilaurate from Armak, Emery (as Emerest 2652), Glyco (as Pegosperse 400 DL), and Witco Chemical Corp (277 Park Avenue, New York, N.Y. 10017) (as Emcol H-38A). In an emergency, Detergent, General Purpose, Specification Mil-D-16791E Type II (oil-soluble, non-ionic) may be used, but the emulsion will not have optimum properties. This material is available under stock nos. 7930-531-9715 (1-gal can) and 7930-531-9716 (5-gal can).

The following data may be useful in mixing the concentrate:

	A	B	C
To prepare:	180 gal (24 cu ft)	50 gal (6.7 cu ft)	5 gal (0.67 cu ft)
Solvent	169 gal	47 gal	4-3/4 gal
Diesel fuel	9 gal	2-1/2 gal (10 qt)	1 qt
Surfactant	1.8 gal (7.2 qt)	2 qt	6.4 fl oz (190 ml)

The amount prepared with formula A is sufficient to fill the recommended tank with 48 cu ft of emulsion with 50% concentrate and 50% water. Formula B is readily prepared by starting with a 55-gal drum of solvent, removing 8 gal, putting in the diesel fuel and surfactant, and mixing. Formula C is similarly prepared by removing a quart of solvent from a 5-gal can, replacing it with the surfactant and diesel fuel, and mixing.

The shelf life of the concentrate is in excess of one year. For use, mix it with fresh water, using 20 to 50% depending on the amount of oily contaminant on the equipment. A milky emulsion should form readily upon stirring. It is normal for the well-mixed emulsion to begin separating after standing for about a half-hour. The water used for preparing the emulsion should not have a hardness greater than 10 ppm. If it is harder than this the emulsion will be less stable, and a water softener should be added. Tetrasodium ethylenediaminetetraacetate dihydrate (Na_4 EDTA) is recommended, and is available from several sources. Three of these are

Ciba-Geigy Industrial Chemicals (as Sequestrene NA4)
Saw Mill River Road
Ardsley, N.Y. 10502

GAF Corporation (as Nullapon BF 78)
Chemical Division
140 West 51st St.
New York, N.Y. 10020

Stauffer Chemical Co. (as Na_4 EDTA)
Industrial Chemical Division
299 Park Avenue
New York, N.Y. 10017

For a water hardness of 20 ppm add 10 oz of the softener per 100 gal, and for a hardness of 40 ppm add 20 oz per 100 gal.

Detergents

A number of detergents have been found effective in cleaning equipment with little or no oily contamination. Although the anionic detergents are slightly more effective, non-ionic materials have the advantage of leaving a nonconductive residue if they should be incompletely rinsed, and they are less affected by salts from the contaminated equipment. An effective material is Detergent, General Purpose, Specification Mil-D-16791E Type I (water-soluble, non-ionic), available under the following stock numbers:

7930-282-9699 (1-gal can)
7930-985-6911 (5-gal can).

The detergent is mixed with fresh water at a concentration of 1 oz per gallon (about 1 gal in 125 gal; 2.8 gal in a 48-cu-ft tank). This detergent can be more easily mixed with the water if it is first diluted with isopropyl alcohol, 1 part detergent to 2 parts alcohol. It can also be mixed with a portion of the water in a smaller container, stirred and heated until dissolved, then added to the remainder of the water in the tank.

Water-Displacing Fluid

The water-displacing fluid Spra-Dri is available in pressurized aerosol cans or in 5-gal cans or 55-gal drums. Paint-spraying equipment may be used to apply the fluid if it is purchased in the latter containers. It is available from

(Office)	(Plant)
Reed Tool Company, Inc.	Reed Tool Company, Inc.
Cleco Pneumatic Division	Cleco Pneumatic Division
Houston, Texas 77040	Perfecting Service Plant
	332 Atando Avenue (P.O. Box 1949)
	Charlotte, N.C. 28201.

Two different formulas are made:

1. Formula No. 1, for Moisture and Rust Control, is for the temporary preservation of any equipment pending cleaning, and for drying mechanical and electrical equipment except for electrical contacts.

2. Formula No. 2, for Electronics Moisture Control, is for electronic equipment and for electrical equipment having open contacts.

This material is flammable (flash point 84°F) and must not be used near open flames or other ignition sources. Sprayed equipment should not be placed in closed or recirculating ovens until the bulk of the fluid has evaporated. It is moderately toxic (MAC = 100 ppm) and if it is used indoors a paint-spraying hood, chemical fume hood, or other well-ventilated area should be used. Personnel should wear rubber gloves to prevent skin contact.

Aggressive Precleaners

Fire and Smoke — An alkaline presoak is often required to remove smoke and soot deposits. An effective material is trisodium phosphate, which should be available locally. If not, it can be obtained from

Ashland Chemical Company
Box 2219
Columbus, Ohio 43216

Olin Corporation
120 Long Ridge Road
Stamford, Conn. 06904

Stauffer Chemical Co.
Industrial Chemical Division
299 Park Avenue
New York, N.Y. 10017.

Use 2-3 oz of trisodium phosphate per gallon of water (45 to 70 lb in a 48-cu-ft tank). The temperature of the tank should be maintained at 120 to 160°F depending on the temperature sensitivity of the contaminated equipment. Workers should wear rubber gloves to minimize contact with this alkaline solution.

Mud — If mud deposits containing carbonates prove difficult to remove, a brief dip in an acid solution may prove helpful by dissolving the carbonates. The use of sulfamic acid is recommended for this purpose. An inhibitor, thiourea, should be used with it to reduce the attack of the acid on metals. Magnesium, and to a lesser extent aluminum, are still attacked, so the length of exposure should be minimized. CAUTION! *Sulfamic acid is a hazardous material and should be used only under the supervision of a chemist. Protective equipment, clothing, and procedures must be used to prevent contact with the dry acid or solution, and to prevent inhalation of the powder during mixing.* Both sulfamic acid and thiourea are available from the following suppliers. The practical grade materials are satisfactory.

Eastman Organic Chemicals
Eastman Kodak Co.
Rochester, N.Y. 14650

Gallard-Schlesinger Chem. Mfg. Corp.
584 Mineola Avenue
Carle Place, N.Y. 11514

G. Frederick Smith Chem. Co.
867 McKinley Avenue
Columbus, Ohio 43223

Dissolve the chemicals in cold water in the following proportions:

	Wt-%	Oz/gal	Lb/cu-ft soln.
Sulfamic acid	5	6.4	3
Thiourea	1	1.3	0.6

Use the solution at room temperature. See the precautions above.

PERSONNEL REQUIREMENTS

An effective team for the reclamation of contaminated equipment should comprise the following trained personnel:

1. Leaders — At least two persons should be available and trained to direct cleaning operations. They should be familiar with electronic, electrical, and mechanical equipment.

2. Chemist — One chemist should be available to supervise the preparation of cleaning solutions and to consult on the effectiveness of cleaning operations.

3. Helpers or Aides — It is advisable to have a nucleus of trained helpers available to carry out the necessary cleaning tasks. For large salvage tasks others can be trained as needed. Some of these should be capable of partially disassembling the equipment to prepare it for cleaning.

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13. ABSTRACT

This report was prepared as a result of continuing requests for information and assistance regarding the reclamation of equipment contaminated by oil, seawater, or fire. Information is given regarding the necessary supplies, their preparation and place of procurement. The personnel and equipment needed to establish a shore cleaning facility are outlined. In addition, methods of salvage are discussed that are satisfactory for the majority of cleaning problems encountered in the field.

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Electronic equipment salvaging						
Electrical equipment salvaging						
Ultrasonic cleaning						
Seawater contamination						
Fire contamination						
Oil contamination						
Salvage						
Cleaning						