

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM																
1. REPORT NUMBER NRI. Report 7751	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER																
4. TITLE (and Subtitle) ARTIFICIAL SEA SLICKS: THEIR PRACTICAL APPLI- CATIONS AND ROLE IN FUNDAMENTAL RESEARCH		5. TYPE OF REPORT & PERIOD COVERED Interim report																
7. AUTHOR(s) William R. Barger and William D. Garrett		6. PERFORMING ORG. REPORT NUMBER																
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Research Laboratory Washington, D.C. 20375		8. CONTRACT OR GRANT NUMBER(s)																
11. CONTROLLING OFFICE NAME AND ADDRESS Department of the Navy Office of Naval Research, Arlington, Va. 22217 and Naval Facilities Engineering Command, Alexandria, Va. 22332		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS NRL Problems G02-03; G02-07 RR 131-03-41-5907 (ONR) YF 53-554-001-02001 (NFAC)																
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		12. REPORT DATE June 4, 1974																
		13. NUMBER OF PAGES 16																
		15. SECURITY CLASS. (of this report) Unclassified																
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE																
16. DISTRIBUTION STATEMENT (of this Report) Approved for public release; distribution unlimited.																		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)																		
18. SUPPLEMENTARY NOTES																		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number)																		
<table border="0"> <tr> <td>Air-sea interactions</td> <td>Organic chemical films</td> <td>Underwater visibility</td> </tr> <tr> <td>Capillary waves</td> <td>Seamarkers</td> <td>Water vapor flux</td> </tr> <tr> <td>Gravity waves</td> <td>Sea surface films</td> <td>Wave damping</td> </tr> <tr> <td>Monomolecular films</td> <td>Sea surface modification</td> <td></td> </tr> <tr> <td>Oil-control films</td> <td>Surface chemistry</td> <td></td> </tr> </table>				Air-sea interactions	Organic chemical films	Underwater visibility	Capillary waves	Seamarkers	Water vapor flux	Gravity waves	Sea surface films	Wave damping	Monomolecular films	Sea surface modification		Oil-control films	Surface chemistry	
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<p>Artificial sea slicks are man-made, monomolecular, organic films adsorbed at the air-sea interface. They are formed from spontaneously spreading, water-insoluble polar liquids. Techniques for generating artificial sea slicks from surface vessels and from the air have been devised. The chemical structure of the film-forming material to be used in a specific sea slick application is determined by the air-sea parameter to be modified and by the desired longevity of the slick.</p> <p>Research into the chemical modification of air-sea interactions has led to several practical applications for artificial sea slicks. The ability of organic surface films to damp capillary waves</p>																		

20. Abstract (Continued)

renders the area covered by the film highly visible and sensible under most environmental conditions. The attenuation of both capillary and high-frequency gravity waves by artificial sea slicks has been examined under open-ocean conditions. The wave-damping property has been used as a basis for the development of seamarkers that generate highly visible, persistent ripple-damped zones on the sea surface. Field research has also demonstrated that slicks do not enhance underwater visibility but can markedly improve the clarity of objects beneath the water when viewed through the air-water interface. Large artificial slicks have been used as a tool to elucidate the mechanisms of wind-wave interactions and air-sea exchange processes. The most widely used application of film-forming organic chemicals is for the control and containment of oil spills. By greatly altering surface forces, these films cause the oil to draw back into a thicker layer that occupies a considerably reduced area of the water surface, thereby facilitating and increasing the efficiency of oil retrieval operations.

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ARTIFICIAL SEA SLICKS: THEIR PRACTICAL APPLICATIONS AND ROLE IN FUNDAMENTAL RESEARCH

INTRODUCTION

In April 1967, personnel of the Ocean Sciences Division generated a series of small artificial sea slicks in the Chesapeake Bay. These surface films were formed from nontoxic, biodegradable chemicals of high purity to determine their relative durability and impact upon air-sea interfacial processes, principally the degree to which the films damped and resisted the formation of capillary ripples and gravity waves of short length. The pragmatic intention of this research was the selection of a material that would spread spontaneously into a persistent monomolecular film and produce useful modifications of sea surface properties and air-sea interfacial exchange processes. The initial choices of chemicals were based in part on knowledge gained by earlier studies of the chemical composition of naturally occurring sea slicks.

Controlled laboratory and sea surface experiments indicated that optimum environmental performance for most applications was demonstrated by surface films of oleyl alcohol (9-octadecen-1-ol, *cis* isomer), a nontoxic, chemically unsaturated fatty alcohol [1]. This liquid spread rapidly into a coherent monomolecular surface film, produced intense wave damping, and did not interact chemically with seawater. Although the most intense wave attenuation effects were produced by films of sorbitan monooleate, a more surface-active compound, its persistence at the sea surface was less than oleyl alcohol because of greater solubility as a consequence of its molecular structure [2]. The selection of a film-forming substance for modifying a particular air-sea interfacial parameter depends on a balance between film durability and performance criteria (Appendix A).

APPLICATIONS

One of the most notable manifestations of a slick, a consequence of its effects on capillary waves, is its high visibility under most conditions. The decreased average wave slope produces a light reflectance anomaly, so that the slick may appear either lighter or darker than the surrounding rippled water surface, depending upon the angle of view with respect to the sun. It was the high visibility of slicks produced by small quantities of organic material that was the basis for the development of novel seamarker package [3] for rescue and recovery operations at sea. This invention was patented as a Chemical Sea Surface Marker in 1972 [4].

This application of organic surface films is depicted in Fig. 1, an aerial photograph of three seamarks taken from an altitude of 600 ft. The upper surface mark is a wave-damped zone elongated in the direction of the wind. This chemical seamarker was generated by

Note: Manuscript submitted April 3, 1974.

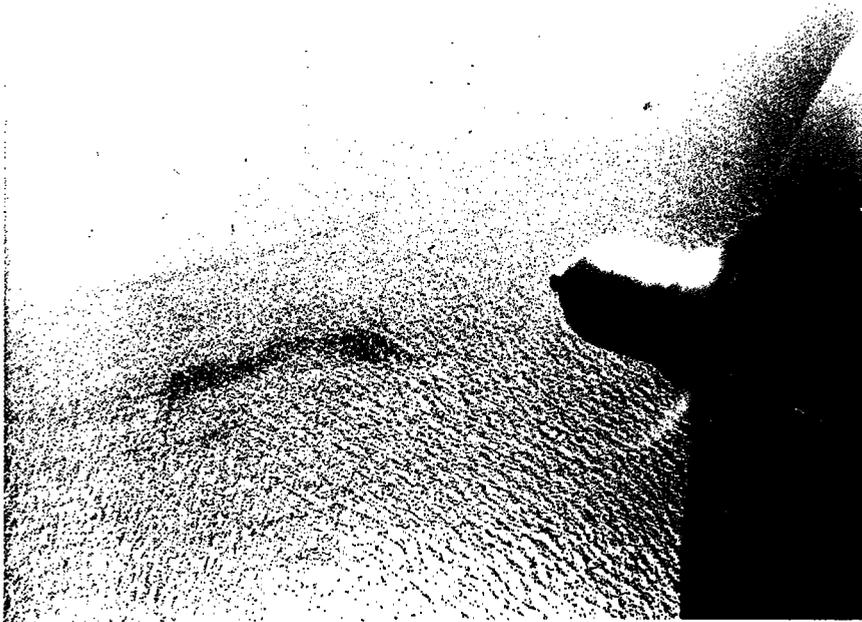


Fig. 1 — Two NRL-developed sea surface markers (dark zones) on either side of a standard Navy dye marker (faint white line)

a floating package composed of oleyl alcohol and sodium fluorescein dye mixed with chemicals that generate gas upon contact with water and gradually dispense the slick. The center mark (barely visible) is a narrow band produced by a standard Navy dye marker package composed of sodium fluorescein, a water-soluble chemical. The lower slick patch in the figure was formed by the release of 27 g of oleyl alcohol from a subsurface seltzer-type, slow-release dispenser. At this viewing angle the slicks appear dark, because the sun glitter pattern that reflects light toward the observer is weak where capillary waves are absent. The dye-only stripe (center) is barely visible under these viewing conditions. At certain other angles, on the other hand, the slick visibility is poor and the dye marker is more apparent. Consequently, the use of both dye and surface film seamarkers together would assure visibility at all angles and would increase the distance at which a mark on the surface could be detected.

Another application of artificial sea slicks that has been proposed is the enhancement of underwater visibility as a result of reduced light backscattering by a ripple-free water surface. In folklore as well as modern practice, fish oils have been used to calm the sea surface and clarify the underwater scene. According to Franklin [5], pearl divers carried and released such surface-active oils from their mouths to mollify the sea surface and reduce underwater shadows and bright spots caused by wave-induced refractions of light. To test the validity of this notion, 0.085-km² artificial slicks (Fig. 2) were generated in July 1970 above the Tektite II habitat, which rested in 17 m of water in Lameshur Bay, St. John Island, in the U.S. Virgin Islands [6]. On the basis of previous research [1], oleyl alcohol was selected for this application because it would produce a calmer, more intensely

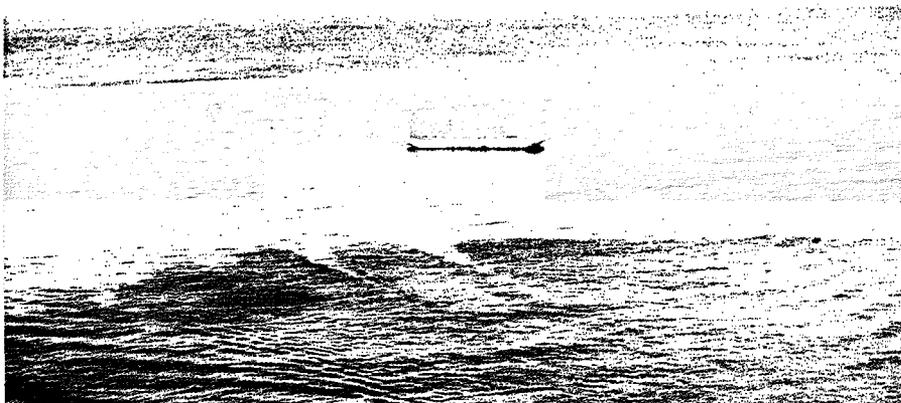


Fig. 2 — Service barge for the Tektite II habitat in Lameshur Bay, Virgin Islands, surrounded by monomolecular sea surface film of oleyl alcohol

wave-damped sea surface than either fish or vegetable oils and because it was desirable to determine the maximum possible improvement in underwater visibility. Photographic and visual observations were obtained by divers in the water beneath the surface film. Similar observations of underwater objects were made from vantage points above the sea surface before and after slick passage. Relative irradiance data and sun angles were measured for these experimental situations. A number of experiments were performed in the neighborhood of the Tektite II habitat in 17 m of water and in shallower water elsewhere in Lameshur Bay. In this series of underwater experiments there were no visual, photographic, or irradiance data that indicated significant visibility enhancement within the underwater environment because of the modification of the water surface by the artificial slicks and the attendant decreases in wave slope.

On the other hand, the visibility of underwater objects observed from above the air-water interface was greatly increased by the glassy water surface condition produced by the artificial slick. The multiple reflected images of the sky caused by the numerous small waves were eliminated, and the water surface approached that of a glass plate on which there were only minor perturbations caused by gravity waves of longer wavelength. Details of underwater objects that had been obscured by the multiple reflection pattern of a rippled surface could be seen clearly through the smoothed air-water interface when the artificial slick was present. An example of this effect is shown in a photograph (Fig. 3) of the two 3.8-m-diameter cylindrical segments of the habitat and the 1.37-m-diameter tunnel connecting them. The uppermost portion of the habitat was about 7 m below the water surface. The picture was taken looking down through a water surface covered with a monomolecular film of oleyl alcohol. When viewed through a rippled surface in the absence of a wave-damping organic film, only the blurred outline of the habitat could be discerned, while objects with smaller dimensions could not be visually resolved.



Fig. 3 — Tektite II habitat viewed through the water surface from 1 m above. Ripples had been eliminated by a monomolecular organic surface film.

STUDY OF AIR-SEA INTERACTIONS

On a larger scale than that used in the previous applications, a 0.5-km² artificial slick was produced on the surface of Buzzards Bay, Massachusetts, at its entrance to the Atlantic Ocean [7]. The experiment was conducted as a cooperative effort between the Naval Research Laboratory and the Massachusetts Institute of Technology to assess the influence of an organic surface film on air-sea interaction dynamics and the turbulent boundary layer and to evaluate the role of capillary waves on these processes. The surface film was formed from oleyl alcohol dispensed at a predetermined rate from a motorboat running normal to the wind. The stripes of surface film produced in this manner merged into a rectangular continuous slick 1.0 by 0.5 km, the length of which was aligned in the wind direction. The slick was positioned to pass a fixed spar platform instrumented to provide wind velocity and wave amplitude data.

One of the more significant findings of this open-sea experiment (the nearest land up-wind was Block Island, at a distance of 41.9 km) was that the surface film decreased the net energy of the wind-driven sea and interfered with the generation of wind waves. Not only was there an absence of capillary waves, but there was also an obvious decrease in the energy of waves in the gravity spectrum with wavelengths up to 9.75 m. Thus, the ocean and atmosphere appeared to be partially uncoupled by the slick, suggesting that the effect could be even more pronounced in the case of a more extensive organic film where the wind fetch is longer.

The Buzzard's Bay research suggested that large slicks, if they could be maintained under stormy sea conditions with reasonable logistics, might be used to allay wave damage by reducing the net energy of wind-driven seas. In addition, subsequent analyses and interpretations of this work by Wu [8] and Garrett [9], indicated that the reduction of water vapor transport from sea to air by a wave-damping film was a distinct possibility. This latter proposition was influential in the design of a further joint effort between this laboratory and the National Hurricane Research Laboratory (NHRL) of the Department of Commerce, Coral Gables, Florida [10].

Over the last few years, experimental data and computer modeling have indicated that a substantial portion of the driving energy for a hurricane is extracted from the warm underlying water by evaporative processes. This energy is subsequently released into the storm as heat by the condensation of water vapor. Consequently, the NHRL considered several methods to reduce the ocean-to-atmosphere flux of water vapor. A modest and speculative effort was made to examine the influence of certain organic film-forming compounds on the transfer of energy from sea to air.

A great amount of research has been performed on the use of monomolecular films composed of linear, polar molecules to retard evaporation from lakes and reservoirs. These studies provided the original rationale for the concept of using monolayers to modify tropical disturbances. However, the obvious fragility of these thin films under stresses imposed by wind and waves and the great reduction of their vapor-blocking characteristics by surface dilations on a wave-covered surface have prevented serious consideration of their use at sea. As stated previously, surface films on the sea may reduce vapor transport by several possible mechanisms other than by blocking the transit of water molecules through closely packed, adlineated hydrocarbon chains of the molecules constituting the surface film. Any organic surface film diminishes two wave processes, capillary waves and breaking water, which normally enhance the water vapor flux. Furthermore, reduced wind-shear velocities near a film-covered sea surface should result in decreased water vapor transport.

In the joint experiment with the NHRL, an artificial slick was generated by dispensing oleyl alcohol with a pressurized dispenser operated from the research vessel *Virginia Key*. The slick was formed 24 km east of Miami near the axis of the Gulf Stream. A volume of 19 ℓ of the liquid film-forming material was dispensed in an increasing spiral pattern for 54 min, producing a nearly continuous circular slick (Fig. 4) 0.70 km^2 in area. At this coverage ratio ($27 \ell/\text{km}^2$), 18.5 gal. of oleyl alcohol would be required to cover 1 n.mi.². This surface concentration requirement was about 12 times that calculated to cover a plane water surface with a monomolecular layer of oleyl alcohol, where one molecule occupies an area of 30 \AA^2 . This deviation from ideality can be accounted for by several factors.

1. Many highly surface-active liquids that are water insoluble do not spread over their own monomolecular film (autophobicity). Excess liquid over that required for condensed monolayer formation does not spread into a uniform thin film but remains as many floating fluid lenses surrounded by a monomolecular film. This excess liquid is in equilibrium with the film and constitutes a reservoir of film-forming agent which is available to resupply film when natural dispersive forces remove it from the surface.

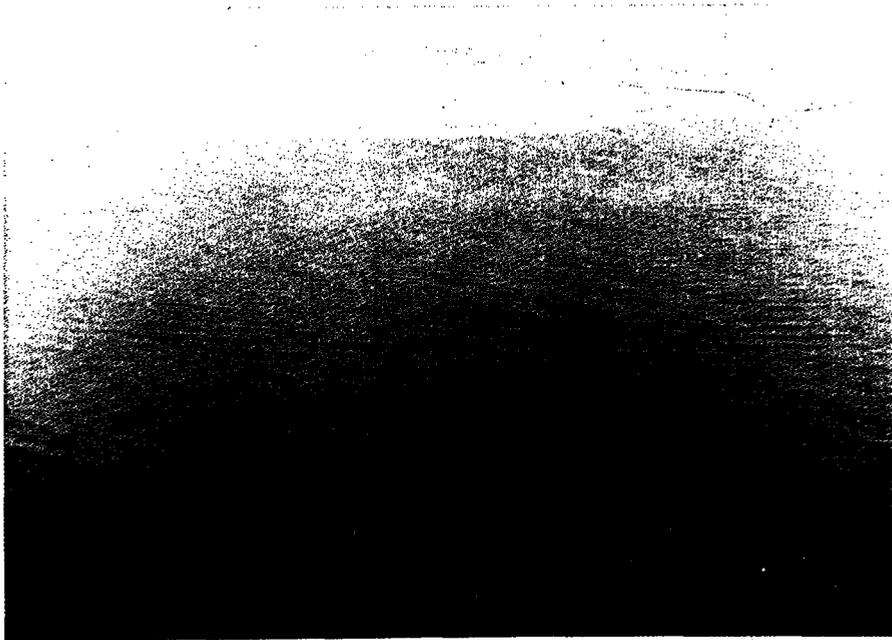


Fig. 4 — A circular, artificial sea slick of oleyl alcohol being generated 24 km east of Miami in the Gulf Stream [10] (From "Experiments with Monomolecular Films on the Surface of the open Sea," by W.D. Mallinger and T.P. Mickelson, *J. Phys. Ocean.* 3, 328 (1973). Used by permission of American Meteorological Society and the authors.

2. The nonplanar condition of a wave-covered sea increases the real surface area and requires greater quantities of film-forming material for complete coverage.

3. Surface film is physically dislodged from the air-water interface by the action of waves, breaking water, and bursting bubbles of air. Consequently, the quantity of chemical per unit area required to maintain surface coverage increases with sea surface roughness. As stated previously, the chemicals used in these applications were chosen on the basis of effectiveness and sea surface durability. Their rate of loss due to solubility or vaporization is extremely slow in contrast to the loss rate caused by the mechanically disruptive effects of a high sea state.

Perhaps the most significant result of the Gulf Stream experiment was confirmation of an earlier conclusion [7] that the energy spectrum of gravity waves (0.29 to 0.60 Hz) was reduced by the slick. Under the relatively calm conditions of this experiment, the energy content of waves within the slick was 54% of the wave energy of the "clean" non-slicked water nearby [10]. These data were obtained from a laser-wave profilometer operated from a low-flying aircraft, whereas the Buzzards Bay wave amplitude data were measured with a capacitance wave gage. Thus, this important observation was confirmed by two distinctly different measurement systems, one of which was not in contact with the sea surface. According to Davies and Rideal [11] the direct damping of gravity waves

by surface films would not be significant over distances represented by the slick dimensions produced in these experiments. However, decreased gravity wave energy as a consequence of the elimination of the capillary ripples in a wind-driven sea has been demonstrated.

CONTROL OF OIL SPILLS

Chemical films that reduce the surface tension of water have been developed to confine and control spills of petroleum products on water [2, 12]. The application of suitable surface-active agents to the water around the edge of an oil spill reduces the water surface tension, one of the principal forces causing oil to spread into thin layers. The unmodified surface tension of the oil and the oil-water interfacial tension can then draw the oil layer into a significantly smaller area of increased thickness. Because oil-collection devices perform with greater efficiency on thicker oil layers, the use of chemical film to control oil on water has been adopted by the Navy as well as the civilian community.

Decreasing the area of the oil film with surface-active chemicals does not cause emulsification or dispersal of the oil into the water but confines it on the water surface. The chemicals used in this approach to oil spill control qualify as "collecting agents" in the "National Oil and Hazardous Materials Pollution Contingency Plan" of 1970 [13] and are considered to be generally acceptable providing that these materials do not in themselves or in combination with the oil increase the pollution hazard. Because the recovery of spilled petroleum is usually desired, surface-film control and confinement is playing an important role as an assist to oil-retrieval systems.

In April 1969, a paper was presented at a national meeting of the American Chemical Society that identified the physical and chemical factors involved in the use of organic surface films in the control of oil on water [14]. A successful open-sea demonstration of this technique was performed under sustained winds of 9 m/s in 6-ft seas in May 1970 [2]. Subsequent research at this laboratory, supported by the U.S. Coast Guard, was performed to (a) determine the physical and chemical criteria that govern the selection of film-forming materials with optimum characteristics for the control of oil on water and (b) to evaluate the influence of environmental parameters on the effectiveness of surface films in oil control and recovery operations. The results of this research were used to specify chemical formulations that best meet the requirements imposed by various oil spill situations.

Additional research and development was supported by the Naval Facilities Engineering Command to establish procedures for the use of surface films against spill situations that would be prevalent during naval fuel-handling operations. These studies were performed largely in test tanks or under realistic field conditions and were part of a development program for a comprehensive multielement oil-spill control and removal system adapted to Navy requirements. Ship personnel were provided with a small-scale oil-spill control kit that includes the NRL-developed oil-collecting agent and dispenser. NRL personnel assisted in preparing an instruction manual [15] and a Navy training film [16] describing the use of the shipboard oil-pollution control kit. Federal stock numbers have been assigned to the selected surface-active agent, a solvent to enhance its activity in cold weather, and a premixed blend of agent and solvent to be used in the ship's kit. These

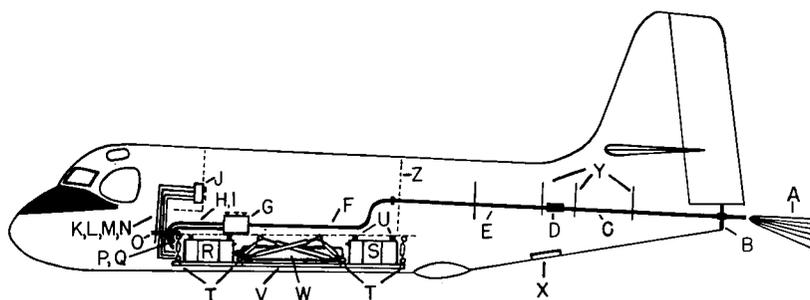
items are available through the Navy and the Department of Defense supply systems. This oil-collecting agent that improves the efficiency of oil-collection devices is a new and useful addition to the Navy's arsenal of oil-pollution control equipment.

AERIAL DISPENSING OF FILM-FORMING CHEMICALS

Experience in generating artificial slicks from surface vessels has indicated that specific techniques of application must be used to create continuous coverage by the organic film in a predetermined pattern. The monomolecular film spreading from a drop of oleyl alcohol on water moves at a rate of 38.7 cm/s [14]. However, this is the initial spreading velocity adjacent to the source, and the rate of film propagation falls off rapidly with distance to 7 cm/s at 2.7 m from the supply of film-forming agent. Furthermore, spreading does not occur upwind and is quite slow normal to the wind. Consequently, it is necessary to "paint" or distribute the slick-forming chemical somewhat uniformly over the area where coverage is desired. A fine stream of liquid chemical from a pressurized dispenser has been successfully dispensed from a surface vessel at a rate adjusted for the speed of the vessel. Usually the dispensing vessel is operated normal to the wind with 10- to 20-m spacing between slick-laying passes. This spacing interval is close enough so that the spontaneous spreading of the surface-active chemical produces film continuity within 15 min.

From the described exercises it has been estimated that approximately 20 gal. of chemical and 4 operating hours would be required to cover 1 mi² of sea surface from a boat under relatively calm conditions. In rough seas the rate of loss of the adsorbed organic material from the air-sea interface is accelerated by such factors as the dispersive effects of breaking waves and ejection into the atmosphere by bursting bubbles. Consequently, it is not possible to achieve the area coverage cited above from a surface vessel operating under highly dynamic sea conditions because the previously generated slick is destroyed before the entire area can be adequately covered.

Coverage of a relatively large sea surface area in an acceptably short time requires aerial dispensing. The advantages of this approach are obvious, but it was necessary to demonstrate that proper concentrations of film-forming material could be distributed from an aircraft to effectively generate an artificial slick. A gas-pressurized system (Fig. 5) was designed and constructed for mounting in the torpedo bay of a Navy S-2D (Grumman), a fixed-wing, twin-engine aircraft capable of low-speed, low-level flight. The dispensing equipment does not require power from the aircraft but is actuated by pressurized nitrogen from a gas cylinder carried between two 30-gal. drums of chemicals in the torpedo bay. The pressure system allows precise control of the chemical flow rate during dispensing, and each drum of chemicals can be dispensed separately. This system carries a maximum of 200 l of liquid, film-forming chemical. The drums are not pressurized until just before dispensing is commenced. In this aircraft the operator sprays the liquids upon command of the pilot as the target area is crossed. Only one person is required to operate the equipment, but a trained observer can assist substantially by judging necessary changes in chemical flow rate, altitude, and flightpath. The drums of chemicals can be readily reloaded on the ground without being removed from the aircraft by pumping more chemicals into them using pressurized nitrogen from the cylinder mounted in the aircraft. The gas cylinder contains enough gas to dispense and replenish the chemical load several times.



- | | | | | | |
|---|---|---|--|---|---|
| A | chemical droplets | J | pressure control box | R | forward 30-gal. steel drum |
| B | tail plate, 10.5-in. diameter | K | copper tubing, 0.25-in. o.d. by 15 ft, nitrogen cylinder to pressure control | S | aft 30-gal. steel drum |
| C | brass pipe, 1-in. o.d. by 12 ft | L | copper tubing, 0.25-in. o.d. by 15 ft, pressure control to forward drum | T | supporting turnbuckles, eight 1 ft minimum length and two 2 ft minimum length |
| D | coupling, hose, 8-in. (1-in. i.d.; 2-in. o.d.), over 1-in. i.d. copper sleeve | M | copper tubing, 0.25-in. o.d. by 15 ft, pressure control to aft drum | U | aluminum bar spacers, 1-in. square |
| E | brass pipe, 1-in. o.d. by 10 ft | N | copper tubing, 0.25-in. o.d. by 9 ft, pressure relief valve to floor plate | V | aluminum rack |
| F | hose, 12 ft 6 in. (1-in. i.d.; 2-in. o.d.), flow control to brass pipe | O | floor plate, 9-in. diameter | W | nitrogen cylinder |
| G | flow control box in aisle | P | hose, 8 ft (1-in. i.d.; 2-in. o.d.), floor plate to forward drum | X | access door |
| H | hose, 2 ft (1-in. i.d.; 2-in. o.d.), flow control to floor plate (forward) | Q | hose, 12 ft (1-in. i.d.; 2-in. o.d.), floor plate to aft drum | Y | aluminum supports |
| I | hose, 2 ft (1-in. i.d.; 2-in. o.d.), flow control to floor plate (aft) | | | Z | aft wall of compartment |

Fig. 5 — Airborne chemical dispensing system as mounted in Navy S-2D aircraft

In April 1973, a trial dispensing flight was conducted over the Atlantic Ocean, 12 mi east of Delaware. A volume of 200 l of oleyl alcohol was carried in the two tanks. A single 500-ft pass at 120 knots while dispensing the chemical at a rate of 4.8 gal./min for 60 s produced a slick strip 2 mi long and approximately 0.1 mi wide. Figure 6 is a photograph of two such stripes, one parallel and one normal to the wind direction. (The wind speed was 10 knots in the same direction as the waves and swells.) In general, slicks formed into the wind are narrower because there is less dispersion of the spray pattern by crosswind effects. Such slicks contain a higher concentration of film-forming material and are more resistant to dispersion by wind and wave effects. However, more aircraft passes are needed to produce a wide slick when formed into the wind. The dispensing pattern to be followed should be dictated by the slick geometry eventually desired.

Aircraft passes were made at 100, 300, 400, 500, and 800 ft to determine the optimum dispensing altitude. On the basis of visual and photographic observations, 500 ft was selected as the ideal altitude for this dispensing system. (The slicks in Fig. 6 were dispensed from 500 ft.) Below 500 ft the slick stripes are narrow and aircraft operation is more hazardous. Above 500 ft, the downwind portion of the slick stripe is not clearly defined and has a wind-streaked appearance. This indicates that the concentration of film-forming chemical is low because wind streaking is the first manifestation of the breakup of a natural slick as breezes increase past the point at which it can remain intact.

The surface concentration achieved by aerial dispensing (23.8 gal./mi²) was about 29% greater than concentrations produced by a carefully controlled slick dispenser operated from



Fig. 6 — Perpendicular artificial sea slick stripes, each 2 mi in length, produced by aerial dispensing of oleyl alcohol from an altitude of 500 ft

a surface vessel. The airborne system is capable of generating a 2 mi² artificial slick without reloading in the reasonably short time of about 50 min. The exact time required for the creation of a slick of this size depends on the geometrical shape desired, the number of passes required, and the turnaround time of the aircraft. Slicks of this size should be of suitable magnitude to allow a determination of possible long-fetch, wind-wave effects such as gravity wave attenuation and the reduction of water vapor flux.

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Appendix A

CHEMICAL CONSIDERATIONS FOR THE SELECTION OF MATERIALS FOR MODIFYING THE SEA SURFACE

Chemical structure determines the impact of a surface film on various air-sea interfacial properties, its persistence under environmental stress, and the practical uses it may serve. Three typical film-forming compounds are reviewed in Table A1 to illustrate the influence of molecular structure and summarize the practical uses that have been demonstrated for sea surface films formed from them. All of these polar, nonionic molecules are quite surface active (i.e., they have high equilibrium spreading pressure) and contain one or more hydrophilic functional groups at one end of the molecule with a hydrophobic hydrocarbon chain comprising the opposite molecular segment. They absorb strongly at high-energy phase boundaries. At the air-water interface they spread spontaneously into monomolecular films whose physical characteristics are determined by molecular geometry. As reviewed in the table, molecules with nonlinear hydrocarbon chains cannot pack together closely. Consequently, intermolecular cohesive forces are not high and their organic films possess fluid characteristics. When compressed past their collapse point, they respread readily when compressional forces relax. On the other hand, linear molecules (e.g., 1-hexadecanol) form rigid, solid films whose spreading rates are several orders of magnitude slower than the more fluid films of the nonlinear compounds. Although the "solid" films are quite surface active, they do not respond rapidly to the dilations and contractions of a wavy water surface. Thus, aside from their use to retard evaporation from relatively calm waters, the solid films have not found other applications, such as wave suppression where mobile films are essential.*

Oleyl alcohol (*cis* isomer of 9-octadecen-1-ol) has many existing and potential uses at the air-sea interface. Although it does not reduce surface tension as greatly as some compounds containing multiple hydrophilic functional groups, its low solubility in water and ease of dispensing make its sea surface film both durable and effective. The numerous applications of oleyl alcohol have been discussed previously in this report. The last listed use of this compound (Table A1), the calming of rough water to facilitate sea operations, is an obvious extension of its wave-calming qualities. However, that application has not been assessed through field evaluations.

Sorbitan monooleate is used primarily as an oil-control agent because of its effect in lowering surface tension. It also spreads into mobile films with strong wave-damping qualities that are of value in other applications. On the negative side, its surface lifetime is less than that of oleyl alcohol because of its greater solubility in water. Its moderate viscosity [A1] requires a greater dispensing energy, and at low temperatures an organic alcohol solvent is essential to assure fluidity.

Molecular geometry and the number and nature of functional groups determine the properties of the molecule and thus its durability and influence on the air-sea interface.

*W.D. Garrett and W.R. Barger, "Control and Confinement of Oil Pollution on Water with Monomolecular Surface Films," NRL Memorandum Report 2451, June 1972, (AD 744943).

Table A1
Applications and Properties of Artificial-Slick-Forming Chemicals

Chemical	Applications	Molecular Geometry	Equilibrium Spreading Pressure (dynes/cm)	Dispensing Characteristics	Monolayer Properties
Oleyl alcohol (9-octadecen-1-ol (<i>cis</i>))	Seamarker Underwater viewing enhancement Formation of large slicks for fundamental studies of air-water interactions Damping of rough water to facilitate sea operations	Bent chain, 1 hydrophilic group	31	Rapid spreading, low viscosity	Low-solubility durable fluid film that re-spreads after compression
Sorbitan mono-oleate (sorbitan ester of oleic acid)	Oil-spill control Seamarker	Bent chain, 5 hydrophilic groups	42	A moderate-viscosity liquid; solvent is required at low water temperatures to assure fluidity	Slightly soluble fluid film that respreads after compression
Cetyl alcohol (1-hexadecanol)	Evaporation retardation of lakes and reservoirs	Straight chain, 1 hydrophilic group	40	A solid, very slow to spread; special techniques are required to form large film	Low-solubility, solid film that is very slow to respread after collapse

