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Anti-Submarine Warfare Laboratory

REPORT NO. NADC-AW-N5916 5 JUN 1959

TECHNICAL NOTE
SUBMARINE WAKE DETECTION PROGRAM (U)

P. M. MOSER

Transcript of a talk given by Mr. Paul M. Moser at the infrared symposium of 5 December 1957 at the Naval Air Development Center, Johnsville, Pennsylvania.

THIS TECHNICAL NOTE IS AUTHORIZED FOR DISTRIBUTION. THE OPINIONS EXPRESSED DO NOT NECESSARILY REPRESENT THE VIEWS OF THE U. S. NAVAL AIR DEVELOPMENT CENTER.

(b) (6)

Director

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- -

INTRODUCTION

The submarine wake detection program at the Naval Air Development Center (NADEVCEN) is proceeding in two concurrent phases: 1. a paper study phase which is an attempt to enumerate, classify and study all the modifications that the presence or passage of a submarine may produce in its environment, and 2. an experimental phase which consists of studies over the ocean using heavier-than-air craft and laboratory studies using a tank of water and models under controlled environmental conditions.

Each of these phases will be discussed in turn.

ENUMERATION AND CLASSIFICATION OF WAKE PHENOMENA

When a submarine passes through a body of water it modifies the water in its path and leaves a wake. Consider the possible nature of this modification. There is no reason to believe that the wake is a simple phenomenon; it probably involves a number of phenomena, some being more readily detectable than others. For this reason it is stated that even though historically wakes have been characterized by their thermal radiating power, it need not be assumed that the wake phenomenon is essentially thermal. For purposes of classification wake phenomena are divided into three groups:

1. Essentially Thermal - Actual temperature changes produced in the water.

2. Nonessentially Thermal - Changes in the character of the water which are detectable by certain temperature measuring devices, even though there may be no actual temperature changes, e.g., changes in the emissivity of the surface.

3. Nonthermal - Changes in the character of the water involving no temperature changes in either the wake or in the detector, e.g., turbulence.

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FIELD	GROUP	SUB-GROUP

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Submarine, Wake, Detection, Antisubmarine, Infrared, Airborne, Surface Effects, Sea Surface, Underwater Sound, Propagation, Thermal Front, Nonacoustic

19. ABSTRACT *(Continue on reverse if necessary and identify by block number)*

The submarine wake detection program at the Naval Air Development Center is proceeding in two concurrent phases: (1) a paper study phase which is an attempt to enumerate, classify and study all the modifications that the presence or passage of a submarine may produce in its environment, and (2) an experimental phase which consists of studies over the ocean using heavier-than-air craft and laboratory studies using a tank of water and models under controlled environmental conditions.

More than forty phenomena that potentially could be associated with submarine wakes have been classified into categories such as thermal, optical, mechanical, electrical, magnetic, electromagnetic, chemical, biological and nuclear.

The experimental work revolves around a dual-channel, high-sensitivity infrared radiometer which was built by Barnes Engineering Company.

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Each of these three groups will be broken down in turn, neglecting for the time the feasibility of detecting these phenomena.

1. Essentially thermal phenomena

a. Direct heating of water due to the submarine - All of the energy obtained from fuel used on the submarine is eventually degraded into heat regardless of the efficiency of the power plant. This direct heating may be broken down into two categories:

(1) Direct transfer of heat from the normally warm submarine to the cold water.

(2) The gradual degradation to heat of the energy of turbulent motion of the water in the submarine's wake.

b. The motion of the submarine or its heating of the water may produce large slow-moving whorls of water circulation. This circulation may bring to the surface the normally colder (or warmer) sub-surface water.

c. Inhibition of evaporation by surface films. The surface temperature of the sea is determined in part by the rate of evaporation, which is a cooling process. The evaporation rate is determined by the air and sea temperatures, relative humidity, impurities in or on the water, turbulence, etc. If the submarine leaves a film of oil on the surface the evaporation rate in that region will be reduced. In this way the submarine's wake temperature may rise to several degrees above that of the surrounding water. Conversely, if there is normally a thin surface film on the water and this film is scarred by passage of the submarine, the evaporation will be enhanced, thus producing a cold wake.

2. Nonessentially thermal phenomena

a. Changes in the radiation efficiency of the surface. (The magnitude of these changes may be a function of wave length.)

b. Changes in the reflectivity of the surface.

These two foregoing changes may be:

(1) Physical changes - The emission spectrum of a substance is a function of surface character. It is postulated that the water surface is "semi-crystalline" and that disturbances in it influence its emission spectrum. Such disturbances are:

(a) Breaking of the surface by rising bubbles
(b) Turbulent swirling of the surface water
(c) Straining of the surface film by "humping"
(d) Rupture of the surface film by "humping."

(2) Chemical changes

(a) Formation of a film of insoluble exhaust products (snorkel) and escaped lubricating oils.

(b) Presence of soluble and suspended material in the body of the water (from the snorkel and from the galvanic decomposition of the submarine's zinc hull plates).

(3) Combination of chemical and physical changes

(a) A thin oil film can damp tiny capillary waves and produce a smoothness of the surface.

3. <u>Nonthermal phenomena</u>

a. Optical phenomena (involving surface films)

(1) Change of plane polarized light to elliptically polarized light by reflection from the surface
(2) Strains or ruptures in surface film observed with crossed polaroids (photoelastic effects)
(3) Interference colors (requires thick films - of the order of a few wave lengths in thickness)
(4) Change in reflectivity
(5) Change in surface index of refraction
(6) Fluorescence of the wake
(7) Changes in absorptivity.

b. Mechanical phenomena

(1) Surface tension changes
(2) Presence of bubbles
(3) Motion of the water in the wake

(4) Ripple velocity changes produced by surface tension changes
(5) Changes in the evaporation rate.

c. Electrical phenomena

(1) Electrical conductivity changes of water
(2) Electromotive force induced by the movement of an electrical conductor (sea water) through a magnetic field (the earth's field)
(3) Temperature gradient potential
(4) Electrolyte concentration gradient potential
(5) Potential due to unequal diffusion rates of positive and negative ions
(6) Potential developed across the interface of contiguous immiscible liquids
(7) Triboelectric potential (frictional electricity)
(8) Balloelectric potential (Lenard potential) - produced by a change in the surface area of a substance; e.g., an expanding bubble
(9) Electrokinetic potentials (zeta potentials) - due to motion of a solid through a liquid

(a) Sedimentation potential (Dorn effect) - potential due to particles passing through a liquid
(b) Streaming potentials - due to a fluid streaming past a solid.

d. Magnetic phenomena

Since sea water is an electrical conductor, electric currents with their associated magnetic fields will be produced by the potentials cited under "electrical phenomena" above.

e. Radio and microwave phenomena

(1) Propagation of surface waves and their partial reflection from the wake
(2) Surface dielectric constant changes
(3) Reflection off surface at various angles of incidence observing intensity and polarization changes
(4) Surface resistivity changes.

f. Chemical phenomena

(1) Changes in the chemicals present in the water detectable by

(a) Taking liquid samples (e.g., the more saline subsurface water may have been pushed to the surface)
(b) Spectroscopic analysis from a distance
(c) Seeding the wake chemically to detect impurities (e.g., CO_2 can be detected by seeding with CaO which forms $CaCO_3$ (a white chalk) or by use of acid-base indicators such as litmus).

g. Biological phenomena

(1) Waste products of barnacles clinging to the submarine
(2) Attraction or aversion of marine life to the wake
(3) Waste products from the submarine's crew.

h. Nuclear phenomena

(1) Induced radioactivity in the wake
(2) Fluorescence and phosphorescence
(3) Cerenkov effect.

E X P E R I M E N T A L   S T U D I E S

AIRBORNE RADIOMETRIC INVESTIGATIONS

The experimental phase of wake detection studies at the NADEVCEN currently revolves about a dual channel Barnes radiometer. This radiometer has the following characteristics:

8 in. Cassegrain optical system
Focal length 12 in.
Effective focal ratio f/1.9
Field of view of each channel 32.8 x 6.56 milliradians (approximately 2 x 0.4 degrees)
Thermistor detectors immersed in germanium lenses
Temperature sensitivity - temperature variations of 0.003 centigrade degree in a black body are detectable
System bandpass adjustable to 0.1, 1.0 and 2.0 cps.

The Barnes radiometer was installed in the camera hatch of a P2V-5 aircraft looking straight downward (within a few degrees). Three flights were made during October 1957; two daytime and one at night. Radiation measurements of sea backgrounds were made while varying the following parameters: altitude, system bandwidth, and direction of travel with respect to the sun and moon. Radiometer response to the following were observed: flying over small clouds, flying through rain clouds, flying over luminescent streaks in the water, flying under clouds, passage of clouds between the sun (and also the moon) and the sea surface observed, flying over water of various depths, flying over ship wakes and the wakes of snorkeling and surfaced submarines at various altitudes, flying through and over the exhaust trail of submarines and banking the plane.

Noise of four different origins was observed.

1. <u>System noise</u>

a. Essential system noise such as Johnson noise
b. Microphonics

System noise was detectable only when the optical system was covered and the gain greatly increased.

2. <u>Noise from the water surface</u>

a. Temperature fluctuations
b. Emissivity fluctuations
c. Reflections off surface from sun and moon
d. Luminescent streaks on surface

3. <u>Noise from the air transmission path</u>

a. Fluctuating attenuation due to variations in concentration and temperature of atmospheric CO_2 and water vapor
b. Fluctuating radiation from atmospheric H_2O and CO_2 due to changes in temperature and concentration
c. Effects of clouds, haze and fog

4. <u>Noise from the optical system</u>

a. Temperature fluctuations in the reference due to turbulent air circulation and air temperature changes
b. Perhaps temperature fluctuations in mirror surfaces.

From a consideration of variations in the frequency and amplitude characteristic of noise as a function of altitude, it seems that at altitudes greater than 1500 feet a broad-banded infrared detector (with only germanium lenses acting as filters) has fluctuations in the air transmission path as its chief source of noise. In other words, such a detector can hardly "see" the ocean surface. It should be noted, however, that the surface area viewed varies as the square of the altitude of the radiometer; therefore, changes in noise character with altitude are to be expected also from this changing of area of integration.

If the product of the room temperature black body curve and a typical atmospheric transmission curve is made, it is apparent that the input to the radiometer should be filtered to pass radiation only in the band from 8 to 13 microns. Such a filter might well consist of a cell of CO_2 and H_2O vapor maintained at constant temperature and pressure.

LABORATORY TANK STUDIES

1. Facilities

The laboratory tank facilities will permit generating and observing wakes of various types under controlled environmental conditions at relatively low cost. The NADEVCEN laboratory facilities consist of a large, high-ceiling room with its own air-conditioning system to provide temperature and humidity control. The tank is constructed of stainless steel and is approximately 10 feet long, 5 feet wide and 4 feet deep. The Barnes radiometer will be mounted in a scanning system which will yield thermal maps of the surface of the water in the tank. It will be possible to set up and measure vertical temperature gradients in the water. Submarine models will be dragged or propelled through the water at various speeds and depths. A temperature controlled "black sky" will be constructed over the tank to study the effect of "sky temperature." Hot and cold water will be available for filling the tank. It will be possible to illuminate the water with infrared radiation to determine if reflectivity changes are associated with wakes. Deformation of the water surface by passage of a submarine model will be investigated by observing the surface reflection of light which has been passed through a grating. By use of detectors yielding smaller fields of view, it will be possible to analyze model wakes for fine structure.

2. Approach to a typical problem

One problem in infrared wake detection that lends itself to tank studies is that of reflections from the sea surface. Although this difficulty is mitigated to a certain extent by use of an 8 to 13 micron filter, further steps must be taken if infrared wake detection techniques are to be used for daylight operation. Since radiation reflected obliquely from the water surface is partially plane polarized perpendicular to the plane of incidence and since radiation emitted obliquely from the surface is partly plane polarized parallel to the plane of emission, it seems that wake contrasts could be improved by use of a properly oriented polarizing filter mounted on the radiometer. The radiometer would be mounted to look down obliquely on the water.

It is proposed to construct such a polarizer by arranging a number of sheets of silver chloride or of some other suitable material at the Brewsterian angle in a framework that is mountable on the Barnes radiometer. This polarizer may also be helpful for detecting extremely thin oil films (of the order of a few molecules thick) since plane polarized radiation incident obliquely upon the water's surface (provided its plane of polarization is not parallel to or perpendicular to the plane of incidence) is reflected elliptically polarized if there is a thin film on the surface.

3. Information to be gained

It is believed that the following information can be gained most efficiently through these tank studies:

a. Optimum filtering against reflections
b. Effect of polarization
c. Optimum viewing angle
d. Effect of oil films
e. Effect of varying angle of incidence of light
f. Effect of varying wind speed and direction with respect to viewing angle and direction of incident light
g. Effect of magnitude of vertical temperature gradient on wake development
h. Effect of wind on surface temperature
i. Effect of humidity on surface temperature

j. Effect of large difference between air and water temperatures on background noise and on wake intensity

k. Physical structure of the wake (Is it a continuous surface or does it consist of a number of patches?)

l. Wake depth (Is the fundamental wake a surface effect only or does it exist beneath the surface also?)

(b)(6)

Paul M. Moser

26 Aug 2016

MEMORANDUM FOR THE RECORD

FROM: Division Director EO & Special Mission Sensors, Avionics, Sensors and E* Warfare Dept (AIR 4.5.6

TO: Office of Counsel, Naval Air Warfare Center, Aircraft Division (NAWCAD)

Subj: SECURITY RECOMMENDAION FOR FOIA REQUEST, DON FOIA CASE FILE NUMBER 2015-008952

Ref: (a) SECNAVINST 5720.42F, DON FOIA Program, 06 Jan 99

(b) Executive Order 13526

1. Recommendation. AIR 4.5.6 reviewed each document and has the following recommendations listed by each separate document covered under the subject:

   a. Document (2) of Subj. NAVAIRDEVCEN Report No NADC-AW-N5916, 5 Jun 1959, "Submarine Wake Detection Program" (AD-C955796). Information found to be unclassified and releasable in its entirety.

   b. Document (3) of Subj. NAVAIRDEVCEN Report No NADC-AW-N5917, 8 Oct 1959, "Infrared Wake Detection" (AD-C955804). Information found to be unclassified and releasable in its entirety.

   c. Document (4) of Subj. NAVAIRDEVCEN Report No. NADC-AW-L5932, 23 Feb 1960, "Submarine Wake Detection" (AD-C955797). Portions of the report found to be classified under Section 3.3(4) under reference (b). Remaining portions of the document found to be unclassified and releasable.

   d. Document (5) of Subj. NAVAIRDEVCEN Report No. NADC-AW-L6005, 30 Mar 1962, "Submarine Wake Detection, Flight Trials of the Reconofax Camera" (AD-C955798). Information found to be unclassified and releasable in its entirety.

   e. Document (6) of Subj. NAVAIRDEVCEN Report No. NADC-AW-N6207, 3 May 1962, "Airborne Infrared Oceanographic Mapping" (AD-C955799). Information found to be unclassified and releasable in its entirety.

   f. Document (7) of Subj. NAVAIRDEVCEN Report No. NADC-AW-N6208, 8 Jun 1962, "NAVAIRDEVCEN Airborne Infrared Developments" (AD-C955801). Information found to be unclassified and releasable in its entirety.

   g. [redacted]

[redacted]

h. Document (11) of Subj. NAVAIRDEVCEN Report No. NADC-AW-N6304, 20 Jun 1963, "Use of an Airborne Passive Infrared Mapping Set for Submarine Wake Studies" (AD-338356L). Portions of the report are found to be exempted under reference (b) Section 3.3(6). Remaining portions of the document found to be unclassified and releasable.

i. Document (12) of Subj. NAVAIRDEVCEN Report No. NADC-AW-6303, 31 Jul 1963, Submarine Wake Detection, Flight Trials of the AN/AAD-2 Infrared Mapping Set in a Cessna 310-B Aircraft" (AD-340804). Information found to be unclassified and releasable in its entirety.

j. [redacted]

k. Document (14) of Subj. NAVAIRDEVCEN Report No. NADC-87161-50, 28 Oct 1987, "Applications of Airborne Passive Infrared Mapping Devices to Military Oceanography" (Reprinted from Proceedings of the First U.S. Navy Symposium on Military Oceanography, Volume II, 17-19 June 1964) (AD-C042316). Information found to be unclassified and releasable in its entirety.

l. Document (15) of Subj. NAVAIRDEVCEN Report No. NADC-AW-6421, 27 Aug-1964, "Infrared Radiation from Ships" (AD-353610L). Portions of the report found to be exempt under reference (b) Section 3.3(6). Remaining portions of the document found to be unclassified and releasable.

m. [redacted]

n. [redacted]

o. [redacted]

2. Basis of Recommendation. All information was reviewed with current class guides and what is considered open source information. Appropriate recommendations made above with respect to findings. Documents found with portions releasable were sanitized based on class guides and reference (b). Such disclosure of Department of the Navy classified information would give potential adversaries insight that would present a significant threat to national security.

3. Exemptions Utilized. Two separate exemptions were utilized in the determination of what information should be sanitized or exempted from release via Freedom of Information Act (FOIA) request process. All current Classified Military Information (CMI) has been sanitized out of the document under FOIA Exemption 3, Executive Order 13526 Sections 3.3(4) and 3.3(6). This Executive Order Section covers CMI that was originally classified over 25 years ago from date of this memorandum. Subject matter experts within AIR 4.5.6 were utilized in making the exemption determinations.

4. Point of Contact. The point of contact for this security review and recommendation is Mr. Paul W. Reimel, AIR 4.5.6 Division Director, paul.reimel@navy.mil, 301-342-0100.

8/30/2016

X Paul W. Reimel

Paul W. Reimel

Signed by: REIMEL.PAUL.W.1229241016

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