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U.S. NAVAL AIR DEVELOPMENT CENTER

JOHNSVILLE, PENNSYLVANIA

Anti-Submarine Warfare Laboratory

REPORT NO. NADC-AW-N5917 8 OCT 1959

TECHNICAL NOTE
INFRARED WAKE DETECTION (U)

BUREAU OF AERONAUTICS
TED Project No. ADC AV-43001

P. M. MOSER

Transcript of a talk given by Mr. Paul M. Moser at the Project Clinker presentation of 3-4 March 1959 at the Naval Research Laboratory, Washington, D. C.

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(U) As part of a program to investigate the detectability of submarine wakes, a dual-channel infrared radiometer built by Barnes Engineering Company is being used for airborne overwater measurements and in submarine model tank experiments. The radiometer employs two thermistor bolometer detectors immersed in germanium lenses at the focus of a Cassegrainian optical system of 12-in focal length and 8-in diameter. Each detector provides an instantaneous field of view of 7 by 33 mrad and a noise-equivalent temperature difference of 0.0016 K.

(C) Profiles of wakes from snorkelling submarines displayed on a strip chart recorder reveal amplitudes of 0.1 to 0.2 K and widths of 350 to 400 ft.

(C) In the tank experiments, a submarine model (initially, a right circular cylinder 6.5 in long and 0.6 in in diameter) is drawn through the water at various depths and speeds while the radiometer views the surface either at a fixed angle or scanning perpendicular

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to the direction of travel of the model. The vertical temperature structure in the water is controlled by varying the air temperature in the room over a period of many hours by means of a heater/air conditioner. Temperature gradients of the order of 1 K/in are achievable over the first several inches of water depth. Model velocities are scaled to full size submarines through Froude numbers. In a representative run, a maximum wake intensity (temperature change) of about 0.1 K occurs about 25 seconds after passage of the model and gradually decays over a period of the order of 10 min. Wake widths (measured at half-intensity points) range from 1 to 8 inches. Wakes are detectable by the radiometer to model centerline depths of 2.6 diameters.

(C) In another tank experiment, a hovering nuclear submarine was simulated by placing a stationary, 150-watt electric heater at a depth of 18 in and turning it on for 4 min. After 1 min the surface temperature began to increase by about 0.4 K and to fluctuate over a range of about 0.2 K. After the power was switched off, the surface temperature decreased over a period of 2 to 3 min to a temperature that was temporarily 0.1 K below its initial value. Thus, because of a vertical temperature gradient in the water and convection induced by the heater, a submerged heat source was able to produce a cool effect on the surface.

(U) The report also describes current and future work with airborne passive infrared imaging devices including the AN/AAR-9(XA-2), AN/AAS-4(XA-2), Reconofax Camera, AN/AAR-13(XH-1), and the Infrared Antisubmarine Warfare Bomb Director Sight Unit.

Anti-Submarine Warfare Laboratory

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I N T R O D U C T I O N

When a submarine passes through a body of water it modifies the water in its path and leaves a wake. This wake, which may persist for several hours, can be detected at the surface of the water as a change in temperature, as a change in surface character or both. In this discussion two classes of wakes will be considered:

Class 1 - Wakes characterized by a mechanical reconfiguration of the water surface.

Class 2 - Wakes characterized by alterations from the normal temperature structure of the water surface.

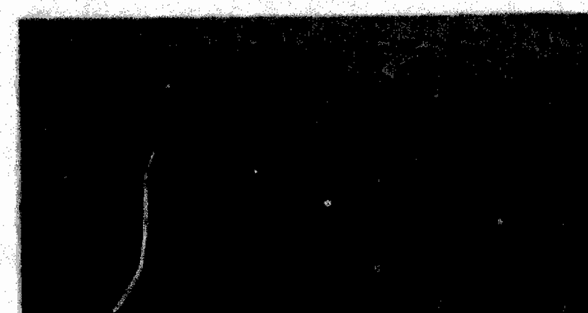

FIGURE 1 - Visible Light Photograph of Wakes Generated by a Snorkelling Submarine

Wakes of the first class can often be detected visually. Figure 1 is a visible light photograph showing two wakes of this class generated by a snorkelling submarine moving through a very calm sea. The "bow wave," which diverges at an angle dependent on the submarine's speed and the speed of wave propagation, appears here as two fine straight dark lines. A second narrower wake, which appears bright by reflected sunlight, is seen directly behind the submarine and seems to be splitting into two portions. Figure 2 shows another view of the same wake. From this angle the "bow wave" is perceptible for only a short distance and the central wake is seen to have attained an essentially constant width. The visible length of this wake was 5 to 8 miles. These photographs were taken from an altitude of 1500 feet under hazy conditions.

Wakes of the second class can be detected by dragging a thermometer through the water. During the spring of 1949, a group from the Naval Air Development Center (NADEVCEN) conducted a series of experiments at Key West, Florida in which a thermistor, which was sensitive to temperature fluctuations as small as 0.01 Fahrenheit degree, was mounted on a

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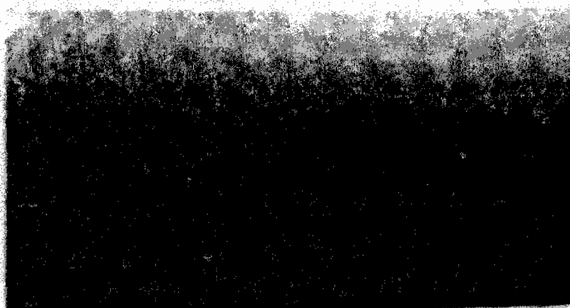

FIGURE 2 - Visible Light Photograph of Wakes Generated by Two Snorkelling Submarines

float suspended from the bow of a patrol craft and passed through wakes generated by submarines operating at depths from surface to 170 feet. Within the wakes, the water temperature at an average depth of 14 inches was found to be 0.03 to 0.30 Fahrenheit degree less than the temperature of the adjacent water. These thermal wakes ranged in width from 60 to 800 feet and were detectable for times of the order of one hour after passage of the submarine.

THE RADIOMETER

It would be desirable to have an airborne device capable of detecting both types of wakes. All bodies having a finite absolute temperature emit radiation at a rate governed by the Stefan-Boltzmann law

$$W = \rho \sigma T^4$$

where W represents the power radiated in watts, σ is a constant, T is the absolute temperature and ρ, the emissivity, is a number ranging from zero to unity depending on the character of the radiating surface. Since most of the power radiated from the ocean lies in the infrared portion of the electromagnetic spectrum, it is apparent that a device capable of collecting and measuring this radiation, i.e., an infrared radiometer, responds to both ocean surface temperature changes and surface character changes associated with submarine wakes. It is possible to detect wakes with a simple sensitive radiometer; however, such a device does not permit discrimination against normal background variations such as wind streaks, cloud images in the water, and patches of warm or cool water that may yield indications on a strip chart recorder similar to those from a wake. The radiometer is a very useful instrument for collecting information on sea background thermal noise and for estimating wake widths and intensities.

A dual channel radiometer having the following characteristics was purchased from the Barnes Engineering Company in August 1957:

Focal length	12 in.
Diameter of collecting optics	8 in.

Effective focal ratio	f/1.9
Thermistor detectors immersed in germanium lenses	2
Field of view of each detector	approx 2 x 0.4°
Chopping frequency	20 cps
System bandpass (adjustable)	0.1, 1.0 and 2.0 cps
System noise (2 cps bandwidth)	0.4 µv, rms
Signal produced by a temperature change of 1 centigrade degree in an extended area blackbody	approx 250 µv
Extended-area blackbody temperature change required to yield signal with signal-to-rms-noise ratio of unity (2 cps bandwidth)	approx 0.0016° C
Weight	167 lb

In the following discussion the expression "effective" temperature difference, ΔT_{eff} is defined as that temperature difference in an extended area blackbody source at room temperature that produces the same radiometer output signal as that being measured. No attempt has been made to correct given data for atmospheric absorption and radiation or for nonunity emissivity of target surfaces, or for time- or position-dependent variations in these properties. The only optical filtering introduced was that due to the germanium lenses which are transparent for wavelengths greater than 2 microns.

The Barnes radiometer was installed in a P2V-5 aircraft with its field-of-view directed nearly straight down. One nighttime and two daytime flights were made off the New Jersey coast during October 1957. Thermal noise backgrounds were monitored over the ocean as a function of aircraft altitude, banking of the aircraft, elevation of the sun and moon, cloud cover, and ocean depth. Signals were obtained from wakes of surface vessels and surfaced and snorkelling submarines.

Noise of four different origins was observed:

1. Noise in the System's Electronics

The electronic system noise consisted of essential system noise such as Johnson noise and microphonic noise. When the aircraft was in flight with the optical system covered, it was found that the system noise, for a 2 cps bandwidth, was approximately twice the value measured in the laboratory. Therefore, the electronic system rms noise was equivalent, approximately, to the signal developed by a target temperature change ΔT_{eff} = 0.003 centigrade degree. Electronic system noise was detectable only when the optical system was covered.

2. Noise Generated in the System's Optics

When the optical system was opened to view the ocean surface, additional noise, believed due to temperature fluctuations in the radiometer's blackbody reference caused by turbulent air circulation and air temperature changes, was observed. It is believed that the high frequency air turbulence effects (which were subsequently simulated in the laboratory by directing an electric fan on the radiometer) were fairly well integrated. Air temperature variations along the aircraft's path, which were especially noticeable when the aircraft changed altitude, accounted for a continual slow drift in the radiometer output as the blackbody reference attempted to arrive at an equilibrium temperature.

3. Noise from the Water Surface

Noise was observed from the ocean surface due to temperature and/or emissivity fluctuations, reflections of sun and moon radiation, and luminescent streaks of biological origin.

4. Noise from the Atmospheric Transmission Path

Noise was also developed in the atmospheric transmission path due to fluctuating attenuation and radiation from clouds, haze, and fog and from variations in concentration and temperature of atmospheric water vapor and carbon dioxide.

Before discussing noise levels quantitatively, several factors which have bearing on their significance must be mentioned. First, consideration will be given to the target area viewed by each detector when the aircraft is traveling at a speed of 300 feet per second at a typical altitude of 1000 feet. Each detector views instantaneously a patch approximately 33 by 7 feet. The 7-foot edges are parallel to the direction of aircraft travel. By adjusting the system bandwidth, one can adjust the size of the effective field of view, i.e., the target area viewed during one time constant of the system, to values of 33 by 31 feet, 33 by 55 feet and 33 by 487 feet. Accordingly, the area over which position-dependent target temperature variations are averaged can be adjusted electronically. It is believed that, in this respect, the result obtained is equivalent to what can also be obtained by use of a much larger instantaneous field of view (using a larger detector) and a correspondingly shorter integration time. There is an extra advantage, however, to the use of integration over time (using small detectors and relatively narrow bandwidth) as compared with integration over area viewed instantaneously (using large detectors and relatively wide bandwidth) if there is a desire to integrate over any given target area. The reason for this is that greater discrimination against time-dependent noise (microphonics, Johnson noise, air turbulence noise, etc) is obtained in the former case than in the latter.

In these radiometer flights information on thermal noise from the ocean was desired; therefore, the maximum bandwidth of 2 cps was used. Data were recorded on an RD-47A strip chart recorder. The charts were analyzed by counting the number of noise peaks per unit time and measuring their amplitudes for a large number of representative time intervals. Particular attention was given to fluctuations of repetition rate ranging from 0.2 to 2 per second. If it is assumed that these fluctuations are due to thermal anomalies in the ocean surface, then the dimensions of such anomalies would be of the same order of magnitude as submarine wake dimensions, i.e., from 150 to 1500 feet. The peak-to-peak magnitude of these fluctuations ranged up to 0.04 centigrade degree in the nighttime exercise and up to 0.10 centigrade degree in the daytime exercises. The amplitude of the relatively high frequency thermal noise was considerably higher at low altitude (500 feet) than at altitudes above 1500 feet except when the aircraft passed over clouds. It is believed that the decrease in noise at higher altitudes was due not only to integration over larger areas of sea surface but also to an improvement in the constancy of atmospheric filtering with length of transmission path. Figure 3 shows a portion of a recorder chart obtained in one of the daytime exercises. (This chart was obtained on the same occasion as figures 1 and 2.) Signals from the wakes of two snorkelling submarines are seen. Negative going signals indicate a decrease in "effective temperature." It is not possible to determine from the available data whether the indications obtained from the wake on the radiometer are primarily temperature or emissivity effects or both.

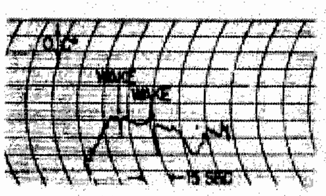

FIGURE 3 - Wakes from Snorkelling Submarines as Detected by Barnes Radiometer

Aircraft:	P2V-5	Date:	16 Oct 1957
Altitude:	500 Ft	Time:	1127
Speed:	180 Knots		
Sea State:	0-1		
Wake Widths:	350-400 Ft		

Although this procedure for monitoring noise levels is satisfactory in a qualitative way, more refined techniques must be employed if quantitative data are to be obtained. For future flights, it is planned to increase the bandwidth of the radiometer as much as possible and to record raw noise data on a frequency modulated magnetic tape recorder.

The equipment will then be flown under a variety of conditions. A number of optical filters will be installed on the radiometer in an attempt to determine the noise contribution of the atmosphere. The magnetic tapes will be analyzed in the laboratory with an audio frequency spectrum analyzer to yield noise power spectra.

S U B M A R I N E M O D E L S T U D I E S

To study the generation, development, and decay of wakes of various kinds under controlled environmental conditions, a submarine model facility has been established at the NADEVCEN; see figure 4. This photograph shows a large stainless steel tank (10 feet long, 5 feet wide and 4 feet deep) equipped with portholes, the Barnes radiometer mounted on a tripod and viewing a small patch on the water surface through a clock-driven scanning mirror, an extended area calibration standard, floodlights for simulating sun glare, an electric fan for simulating wind, and a motorized towed target loop. The vertical tubes which support the loop and the pulley housings are visible here. Figure 5 shows a view inside the tank. A model submarine (in this case simply a right circular cylinder 6-1/2 inches in length and 0.6 inch in diameter) is seen moving through the water creating a diverging pattern of ripples in addition to a thermal wake. The heat lamps seen in the photograph can be used for generating temperature gradients or thermal anomalies, and a vertical linear array of thermocouples provides information on the temperature structure in the water. Figure 6 shows the electronics rack and strip-chart recorder for the radiometer, the potentiometer used to obtain thermocouple readings, a psychrometer and a recording thermometer. A chart from this recording thermometer (figure 7) shows the mode of variation of room air temperature over a typical 24-hour period. Unless indicated otherwise the water temperature gradients to be described later were generated as a result of such daily variations. Figure 8 shows the type of vertical temperature structure that exists in the water typically at midafternoon. Note the abrupt change in temperature at the water-air interface.

FIGURE 4 - View of Model Submarine Facility

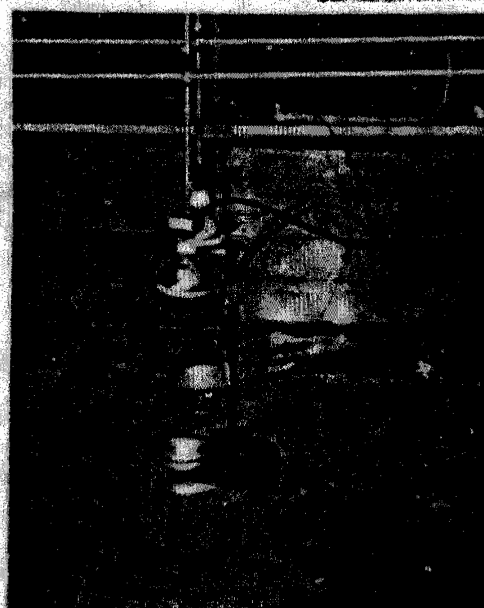

FIGURE 5 - Inside View of Model Tank

FIGURE 6 - Another View of Model Submarine Facility

If desired, the scanning mirror can be used in a fixed position to view any small element of area of the water surface. The chart shown in figure 9 was obtained by fixing the field of view of the radiometer directly over the line of motion of the submarine. At time zero, the submarine passed through at a center depth of 0.7 inch. After a delay of about 5 seconds, during which time most of the surface ripple activity had subsided, the surface temperature began to decrease for about 20 seconds through a maximum interval of 0.33 centigrade degree. Thereafter, the wake signal decayed slowly over a 20-minute period. The validity of the data beyond the 10-minute point is questionable insofar as there is always a certain amount of instrumental drift. The vertical temperature structure in the water prior to this run was given in figure 8. Motion of the water in the wake can be observed through the portholes by viewing suspended dust particles. As a rule, it is possible to perceive a very slow motion of the subsurface water for as long a time as the radiometer detects a surface temperature change. It is noted that even if there is a film of grease (which gradually accumulates over a period of days after refilling the tank) on the surface, which is unscarred by the passage of the model, there is no perceptible change in the character of the signals obtained.

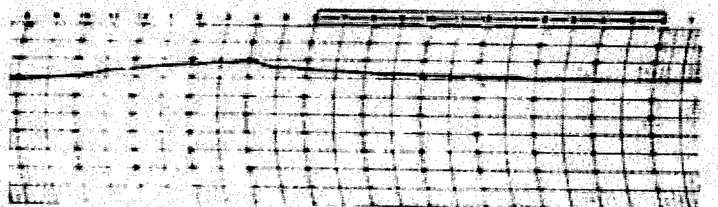

FIGURE 7 - Typical Daily Variation of Room Air Temperature

Date: 26 Jan 1959

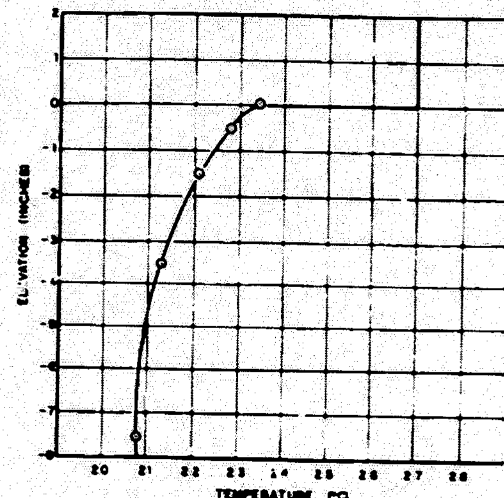

FIGURE 8 - Example of Vertical Temperature Structure in Model Tank

Date: 21 Jan 1959
Time: 1423

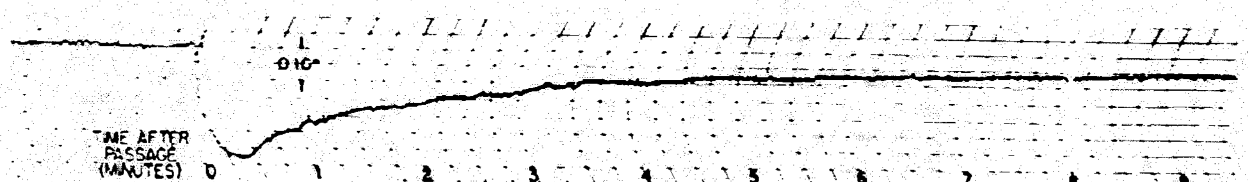

FIGURE 9 - Model Submarine Wake Intensity as a Function of Time

Depth of Model: 0.7 In.

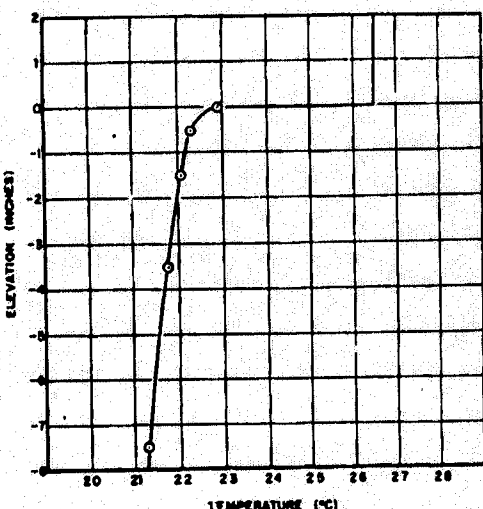

FIGURE 10 - Another Example of Vertical Temperature Structure in Model Tank

Date: 14 Jan 1959
Time: 1510

FIGURE 11 - Model Submarine Wake Intensity as a Function of Time

Depth of Model: 1.0 In.
Travel East

Figure 10 shows the vertical temperature structure in the water on another occasion. It is noted that (1) the temperature decrease in the first few inches of depth is not as great as in figure 8, and (2) a relatively strong gradient exists for only the first half-inch of depth. For a given submarine depth, the maximum intensity of the observed wake seems to depend on the first of these factors and its persistence seems dependent on the second. Figure 11 shows a wake signal obtained shortly after the data were taken for figure 10. It is noted that the submarine was travelling in an easterly direction. The chart shown in figure 12 was obtained shortly after the wake shown in figure 11 had apparently died out. The only change in experimental procedure was to run the model in the opposite direction. No clear-cut signal is apparent. This effect was investigated further by generating horizontal temperature gradients along the submarine's direction of travel. It was found that a horizontal temperature gradient in the water could either add to or subtract from the signal normally obtained, depending on the direction of travel of the submarine. Figure 13 shows how the model can produce only a "cold" wake when moving in an easterly direction but either a "warm" or "cold" (or neutral) wake when moving in the westerly direction. Since variations in actual sea temperature along a horizontal line do occur, it is apparent that a single wake could in some places be relatively "warm" and in other places relatively "cold."

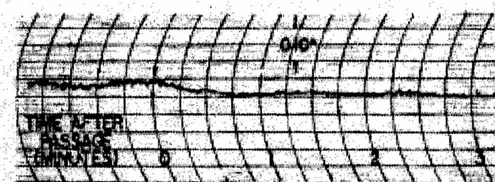

FIGURE 12 - Model Submarine Wake Intensity as a Function of Time

Depth of Model: 1.0 In.
Travel West

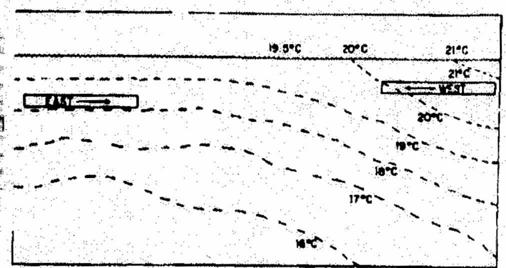

FIGURE 13 - Thermal Structure Postulated to Explain Dependence of Wake Intensity on Direction of Submarine Movement

When the scanning mirror over the tank is set into motion, it sweeps the field of view of the radiometer across the tank perpendicular to the direction of travel of the model. The present instrument scans across the tank in 15 seconds at a repetition rate of one per minute. Figure 14 shows the radiometer output for a number of such scans. (The recorder is stopped between scans.) The background surface temperature structure is shown in the first two traces. The model was then run through so that the scanner, on its next sweep, crossed its path 22 seconds after passage. In this third trace the wake is near its peak of development. Successive traces, taken at one-minute intervals, show the wake in decay.

Figure 15 is similar to figure 14 except that the scanner was made to cross the path of the submarine only 6 seconds after passage. The first trace shows the background from which the wake begins to emerge during the second trace. In the third trace the wake has already passed its peak and is in decay. Successive traces show the wake crumbling beyond recognition. Half-intensity wake widths, as measured from these charts and corrected for instrument broadening, range from one to eight inches.

FIGURE 14 - Radiometer Output for a Number of Scans Across Wake
Depth of Model: 1.0 In.

All of the previously described model wakes were "cold" with respect to the adjacent water. "Warm" wakes can be generated at will by controlling the initial vertical temperature structure in the water. If, for example, the room air temperature is suddenly decreased below the water temperature, the surface water temperature will drop below that of the subsurface water and a passage of the submarine will give rise to a "warm" wake. By blowing a fan across the surface of the water, it is possible to produce sharp vertical temperature gradients near the surface if the relative humidity in the room is not too high. A thin "skin" of cool water is produced on the surface of the water because of enhanced evaporation. The temperature of this "skin" approaches the wet bulb thermometer reading as a limit. Wakes obtained under these conditions exhibit a relatively intense maximum but only short persistence. The effect is visualized as a rupturing of this cold "skin" by the movement of subsurface water and the subsequent rapid healing of this "skin."

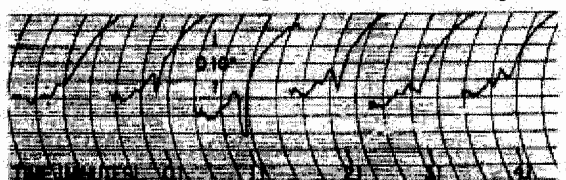

FIGURE 15 - Output of Scanning Radiometer Showing Growth and Decay of Wake
Depth of Model: 1.0 In.

Experiments have also been conducted using a heated stationary submarine model. The results of one such run are shown in figure 16. A 150-watt immersion heater was clamped horizontally in the tank at a depth of 18 inches in such a manner as not to interfere with the development of convection currents. The nonscanning radiometer viewed the surface of the water directly over the heater. At time zero, the heater was turned on for a period of 4 minutes. After about 1 minute, the surface temperature was noted to increase by about 0.4 centigrade degree and to fluctuate over a range of about 0.2 centigrade degree. A "motor effect" developed in the water and a steady state of water motion was attained before the heater was turned off. Warm water continued to rise to the surface for another 2 minutes and then for 1.5 minutes cooler water rose. Thereafter, the surface water temperature began to stabilize at a new temperature about 0.2 centigrade degree higher than the initial temperature. It is seen

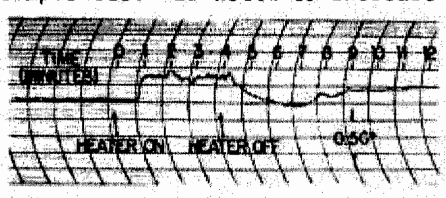

FIGURE 16 - Surface Temperature Changes Produced by an Immersed 150-Watt Heater (7" x 1-1/2" x 3/8") at a Depth of 18 Inches

that an intense heat source (e.g., a nuclear submarine) can, at least under controlled conditions, give rise to both warm and cold wakes.

Later experiments will be conducted with models on which it will be possible to vary independently the motion of the screws, the motion of the model through the water, and the heating of the model. These experiments will be carried out as a function of depth, speed, streamlining and size of the model, water temperature and temperature gradient, humidity, wind speed, oil films on the surface, salinity of the water, and the viewing angle, field of view, optical filtering and system bandwidth of the radiometer.

INFRARED IMAGING SYSTEMS

It is believed that for an infrared wake detector to be of value for fleet use it must present its information to an operator in the form of a thermal map or picture of the water surface. Not only must such a system have adequate sensitivity to detect wakes where they are already known to exist, but it must also provide the operator with sufficient information to permit his distinguishing wakes from nonwakes when no prior information regarding a wake's existence is available. Optimum use should be made of spectral filtering, space filtering, and electronic filtering. It is questionable, however, whether much improvement is to be gained in signal over background by space and electronic filtering because only slight characteristic differences exist between wake targets and nonwake sea backgrounds. Additionally, since there is such a wide range of variability in wake dimensions and intensities, the possibility of "educating" something like a band-pass filter to discriminate against background and not against signals seems remote. The ultimate decision as to whether or not a given indication represents a wake must be made by the human operator. Accordingly, the operator should be provided with the optimum amount of information on which to base his decision. The operator should be considered as a component in the detection system, and just as other components are matched for a maximum transfer of information so should the other components be matched to the operator by use of a presentation in the form of a good quality picture whose angular and tonal resolutions are comparable to those of the human eye.

Before proceeding to a discussion of actual systems, a number of practical points should be considered:

1. It is extremely unlikely that a universal submarine detection system will ever be developed.

2. It is not necessary for a wake detector to achieve anywhere near 100 percent probability of detection to contribute significantly to our submarine detection capability.

3. It is likely that if a fleet type wake detector does evolve, it will be just one of many ASW equipments on board the search aircraft. The relative reliabilities of these equipments vary with environmental conditions and the mode of operation of the submarine.

4. A practical wake detection system installed in a 200-knot aircraft and capable of detecting wakes 1-mile astern of a submarine has the same search rate as a system that can detect wakes 5 miles astern when installed in a 40-knot airship.

5. In an airborne detection system the three ratios, value/pound, value/cubic foot, and value/dollar, must be considered.

6. It should be possible for regular fleet personnel to operate, maintain, and repair such equipments.

Two conclusions that can be drawn from the above statements are:

1. An airborne wake detector should be compact, lightweight, easy to operate by a single man, and designed for use in heavier-than-air craft.

2. Attention should be concentrated on the more readily detectable portion of the wake directly behind the submarine.

The NADEVCEN has been directed to develop techniques for detecting thermal wakes of submerged submarines by use of small, lightweight, infrared equipments designed for installation in heavier-than-air craft. As part of this project a number of thermal mapping devices already in existence are being investigated. The purpose of this investigation is two-fold: (1) actual experience with a variety of thermal mappers will aid in determining optimum system parameters for a submarine wake detection device, and (2) if equipments already in production prove successful after only minor modification, infrared wake detectors will become available to the fleet in a much shorter time than if a completely new development program were to be initiated. Under this project steps have been taken to evaluate the following already existing equipments.

1. AN/AAR-9(XA-2)
2. AN/AAS-4(XA-2)
3. Reconofax Camera

[redacted]

4. AN/AAR-13
5. Infrared Antisubmarine Warfare Bomb Director Sight Unit

The AN/AAR-9(XA-2)

The AN/AAR-9(XA-2) is an infrared reconnaissance equipment built for the U. S. Air Force by Haller, Raymond and Brown, Inc. It is a line scan device that produces a continuous strip map. Scanning perpendicular to the flight path is achieved by rotation of a four-sided mirror. The total lateral scan angle is 72 degrees. The instantaneous field of view is variable between 0.2- and 0.5-degree square depending on the size of the detector used. Recording of the scan pattern is accomplished by intensity modulating a single line trace on a high definition cathode-ray tube. This trace, which is electronically synchronized with the rotation of the scanning mirror, is focused on a 35-mm film strip moving at a speed proportional to the ratio of velocity to altitude (V/H) of the aircraft. The AN/AAR-9 is designed for operation at altitudes from 500 to 25,000 feet at ground speeds up to Mach 1. A direct-viewing display of the thermal map being recorded is presented on a long-persistence-screen cathode-ray tube. In addition, there is a presentation on a small "A" scope. It is estimated that temperature fluctuations in an extended area target at room temperature of the order of 1 centigrade degree can be detected by this equipment with the lead telluride cells currently in use. Power consumption of the AN/AAR-9 is 1500 watts; its weight is 250 pounds; its volume is 6 cubic feet.

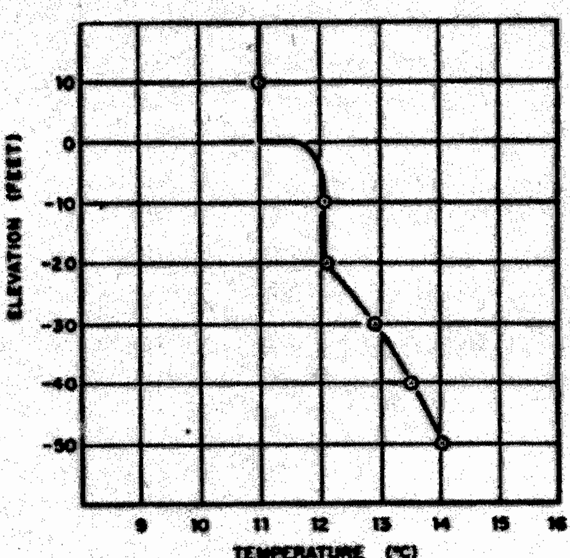

FIGURE 17 - Vertical Temperature Structure in Ocean

Date: 13 Nov 1958
Time: 1820

This equipment is currently installed on an Air Force B-50 aircraft, which was made available to the NADEVCEN for a submarine exercise on 13 November 1958 and which will be available again during March 1959. Figure 17 shows the air temperature and vertical temperature structure that existed in the ocean during the November exercise. It is noted that the subsurface water temperature is greater than the surface and air temperature. Figure 18 shows an infrared picture of a

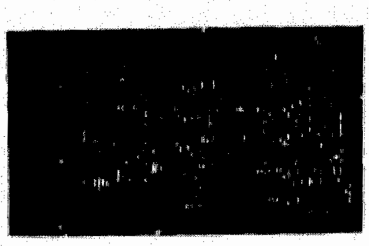

FIGURE 18 - Infrared Picture of Surfaced Submarine and its Wake Obtained With the AN/AAR-9

surfaced submarine and a 3200-foot section of its wake obtained with the AN/AAR-9 on that hazy night. The wake appears warm as might be expected from the temperature conditions in the water. The aircraft's altitude was 4000 feet. The sweep width for the AN/AAR-9 at this altitude is approximately 1 nautical mile.

The AN/AAS-4(XA-2)

The AN/AAS-4(XA-2) is an infrared reconnaissance equipment built for the U. S. Air Force by the Perkin-Elmer Corporation. It is an area scan device that yields video information on photographic film and also in a television-type raster on a long-persistence-screen cathode-ray tube at 93 frames per minute. Its overall field of view is 60 by 60 degrees. Its noise equivalent temperature difference is about 5 centigrade degrees. The (XA-3) version of this same equipment is expected to have an order of magnitude better sensitivity.

The AN/AAS-4(XA-2) is installed in the same B-50 aircraft as the AN/AAR-9 and was operated during the exercise of 13 November 1958. Its sensitivity was found to be inadequate for wake detection and its operation was discontinued midway in the exercise.

The Reconofax Camera

The Reconofax Camera is an experimental breadboard equipment built by Haller, Raymond and Brown, Inc. It is similar to the AN/AAR-9 except that (1) a larger effective lateral scan angle of 140 degrees is achieved by rotating a single mirror surface in front of its 3-inch collecting mirror, and (2) light from a glow modulator tube is focused on 70-mm photographic film for recording the infrared picture. The glow modulator tube is a much "quieter" source of light than a cathode-ray tube and has five to ten times the dynamic range of the latter. It is possible to record of the order of 100 shades of gray on film with a glow modulator tube. If desired, both spatial and temporal signal integration can be obtained on the photographic film by overlapping successive scans. The ability of photographic film to store tremendous amounts of information in a small space, plus its ability to serve as an active system component, and the fact that present day rapid processing techniques yield pictures only seconds after exposure present strong recommendations favoring its use.

The Reconofax Camera with a lead selenide cell is capable of detecting temperature changes of the order of 0.1 centigrade degree in an extended area blackbody at room temperature. A few limited exercises involving the Reconofax Camera were carried out during the summer of 1958 under NADEVCEN cognizance. Plans have been laid for further exercises to be held during the spring of 1959.

The AN/AAR-13

The AN/AAR-13 is an infrared reconnaissance equipment built for the U. S. Air Force by the Servo Corporation of America. It is a line scan device that yields a continuous strip map on photographic film. Its optical system consists of a linear array of sixty thermistor bolometer elements in the focal surface of a collecting mirror whose limiting aperture diameter is 6 inches. The line of bolometers is perpendicular to the direction of travel of the aircraft and the forward motion of the aircraft produces the forward scan. It was designed for use in 250- to 1000-knot aircraft operating in the altitude range of 1000 to 10,000 feet. Its weight is about 400 pounds and it is capable of detecting temperature changes of the order of 0.1 centigrade degree in an extended area blackbody at room temperature. The Air Force has granted NADEVCEN a loan of the AN/AAR-13 for evaluation as a wake detector. It is planned to install it in a P2V aircraft for trials during the late spring of 1959.

The Infrared Antisubmarine Warfare (IR/ASW) Bomb Director Sight Unit

The IR/ASW Bomb Director Sight Unit was built for the U. S. Navy by the Farrand Optical Company for detecting thermal radiation from surfaced and snorkelling submarines and their wakes. It is an area scan device that yields video information in the form of a twenty-line raster on a rotating cathode-ray tube. A linear array of twenty thermocouples is arranged to view instantaneously a line parallel to the direction of travel of the aircraft. The instantaneous field of view of the array is 7 by 1/3 degrees. Transverse scanning through an angle of 10 degrees at a rate of 2 scans per second is achieved by an oscillating plane mirror in front of the 12-inch diameter collecting mirror. The unit therefore sees two 7- by 10-degree twenty-line frames per second. The long persistence display cathode-ray tube rotates at a rate proportional to the ratio of V/H of the aircraft. For small values of V/H several successive transverse sweeps may overlap and provide signal integration on the cathode-ray tube. The IR/ASW Bomb Director Sight Unit is capable of detecting temperature changes of the order of 0.001 centigrade degree in an extended area blackbody. Its principal limitation as a search equipment seems to be its extremely narrow sweep width of 10 degrees. It is planned to install this equipment in a P2V aircraft for further evaluation during the summer of 1959.

(b)(6)
P. 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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