IAVAL RESEARCH

REVIEWS

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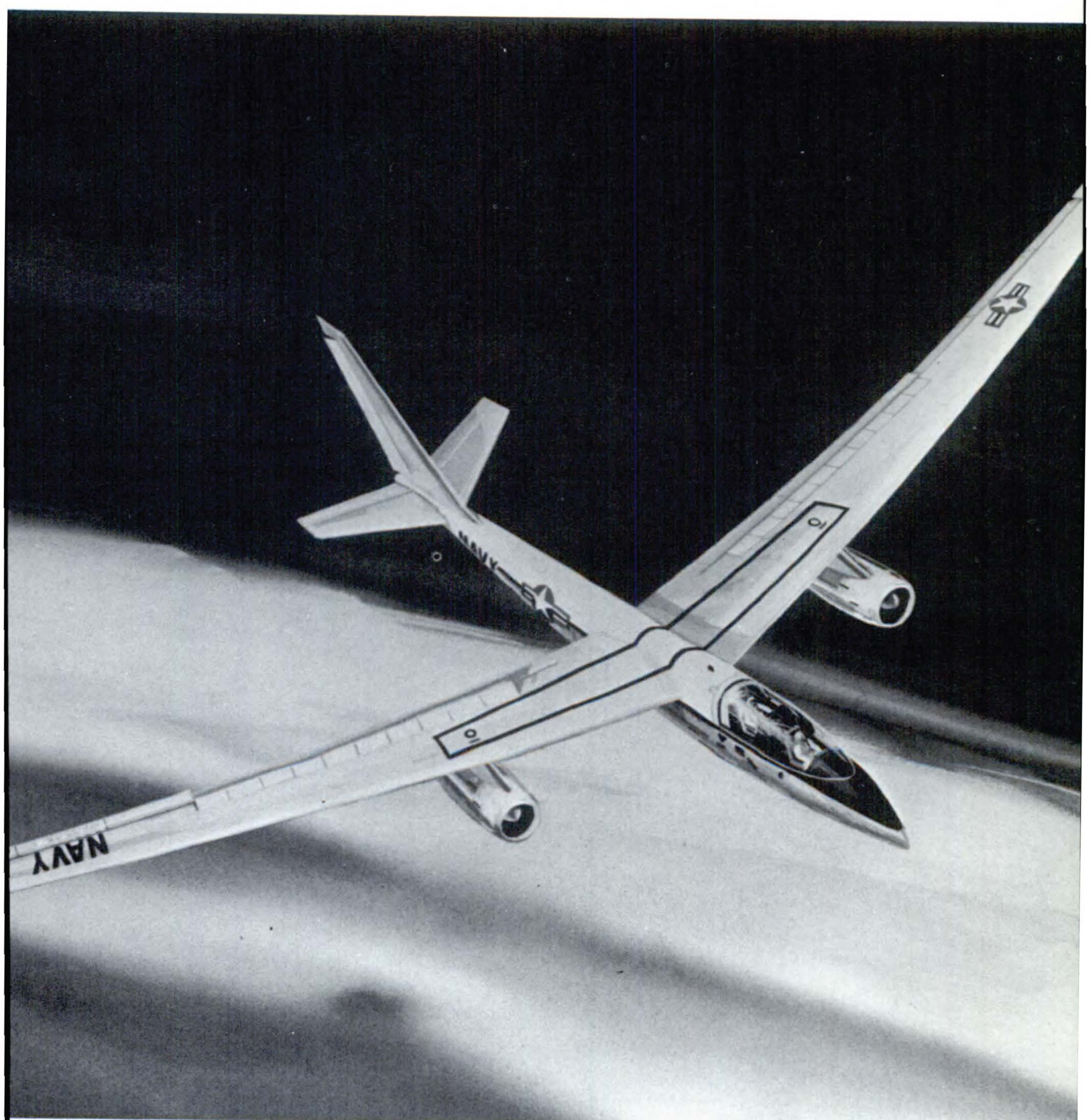

Portraits in Science

Since 1956 Dr. Max Brewer has been the Director of the Naval Arctic Research Laboratory at Point Barrow, Alaska, which is operated by the Office of Naval Research. During peak seasons the Laboratory supports more than 300 investigators. He is also responsible for 18 field stations and one ice island station, T-3. He has been the leader in establishing the Navy's drifting ice stations for research programs. Dr. Brewer has conducted important studies of thermal characteristics of perma frost (perennially frozen ground); these studies have been valuable in improving construction techniques in the Arctic region.

Acoustic Reflection and Diffraction Studies at NRL

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Sound is used by the Navy in the ocean in a way that is similar to the use of a flashlight by a man in a dark room. In both cases the purpose, of course, is to locate and identify objects. If the flashlight beam falls on an object, it is located. The visual image is interpreted by the man from his memory he compares with the previous experiences and identifies or classifies the object.

So far the man has a fairly simple or even an automatic task. But complicate his task by causing the flashlight to be on only intermittently; let the rate of flashing be under his control, but not to be on more than one half second in each five seconds, so that successive reflected images are definitely separated in time. In addition to objects on the floor of the room, allow objects to be suspended from the ceiling. All of these objects may be partially transparent. Assign the property to the light beam that it will bend in a way that depends on the direction in which it shines. Let everything in the room including the man move about. For the man to find his way through the room or pick out a specific object is similar to the task confronting a sonar operator trying to detect and classify objects under water. He learns to utilize significant characteristics of the returning echo when they are clearly evident or when there is a sufficient number of echoes. Descriptions of echoes such as "mushie" or "crisp" as well as the way that echoes change in time help to identify their source. Human intelligence and memory are utilized. Specific characteristics or their physical cause are not necessarily quantified. For one pulse sent out, three may return from the single object. The physical cause of echoes are of interest.

There are several properties of the reflecting body which contribute to the formation of echoes. The contributing properties of the reflector can be arbitrarily divided into three main categories as shown in Figure 1. The effects of the various characteristics of these objects on the reflection are sought by studying both theoretically and experimentally reflectors under each of the column headings of so-called simple shapes. There are a great number of bodies in the rigid and soft column. These are the simplest to treat theoretically and are characterized by the fact that sound energy does not cause the vibration of the body itself. Such cases

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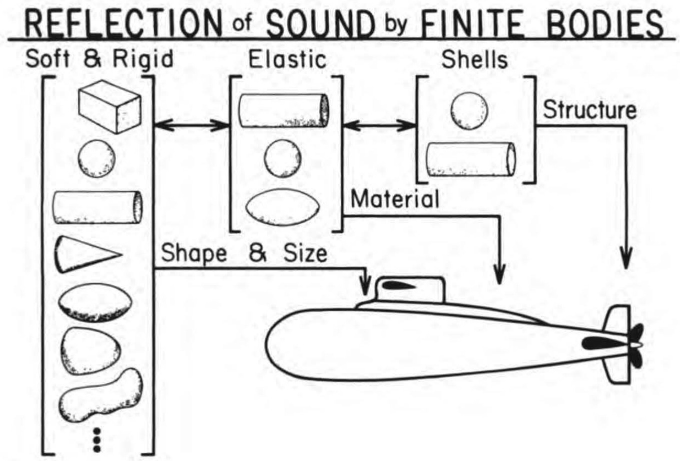

Figure 1 — Chart showing an arbitrary categorization of all problems of acoustic reflection

may be treated by a variety of theoretical techniques with varying degrees of approximation. Even in this case only the sphere and spheroid can be treated exactly over the entire frequency range. Experimental results for the rigid or soft case are difficult to get since few materials approach the ideal of acoustically rigid or soft except for the case of solid materials in air, or an air bubble in a solid or liquid. The experimental techniques for these situations are not reasonably achievable. A perusal of the acoustical literature will result in the impression that all scalar field problems, that is radiation, reflection, and scattering can be handled. It is true, that there are not very many reflection and scattering situations which have not been worked on with various degrees of generality by someone from the time of Lord Rayleigh to the present day. However, if one attempts to become predictive about a measurement of even the simplest field description, an agreement as good as ± 30 percent is seldom realized when the measurement is made. The relationship between experimental parameter control and accuracy is seldom established. If someone attempts to understand a physical measurement or utilize a theoretical treatment for a practical need, only an uncertain or "ball park" indication is available except in very few cases. Acoustic field experiments are not often refined to a degree that allows a differentiation between physical fact and presumptuous speculation based on abstract mathematical reasoning. This results in descriptions of phenomena that cannot be measured. Two methods of experimentation have been utilized at the Naval Research Laboratory that have permitted a close approximation to a theoretical description. Measurements of acoustic pressure are made in a water tank for situations that are mathematically described. The acoustic fields are carefully mapped, point by point. Also, schlieren visualization of acoustic wavefronts are made. The latter method allows a qualitative look at the entire acoustics at once. Cases that are treated by these means are the more complicated cases found in the middle column of Figure 1, in which the elastic properties of the body are included in the reflections; that is, sound penetrates the material of the body itself. In this category, a much smaller number of shapes are possible to deal with to any degree. Actually, the only case that may be completely described is that of the solid elastic sphere. For the prolate spheroid, which is the football shape below the sphere, functions have only recently become available to permit solutions of this shape. In the last column of Figure 1, the more complicated structures are introduced. Here again only the spherical shell can be treated theoretically and describing experimental conditions becomes much more difficult than for the case of the solid elastic body.

The water tank used for making scalar-field pressure measurements by means of pulsed sine waves is shown in Figure 2. The tank is made of 3 inch thick cypress wood and measures $6 \times 12 \times 6$ feet. Typical measurements of the reflection from a square reflector as a function of its orientation angle are shown in Figure 3. Here an experimental approximation to a rigid nonelastic material is made by using a rectangular block of a very dense material, and the results are compared to a calculation that ignores elasticity. Similar results are shown for a sphere of dense material immersed in water in Figure 4. Here the sphere parameter is the product of k and a. The symbol represents the wave number which equals $e\pi/\lambda$ (where λ is the wavelength of sound in water) and a, the radius of the sphere. The points are experimental measurements and the solid curve is computed.

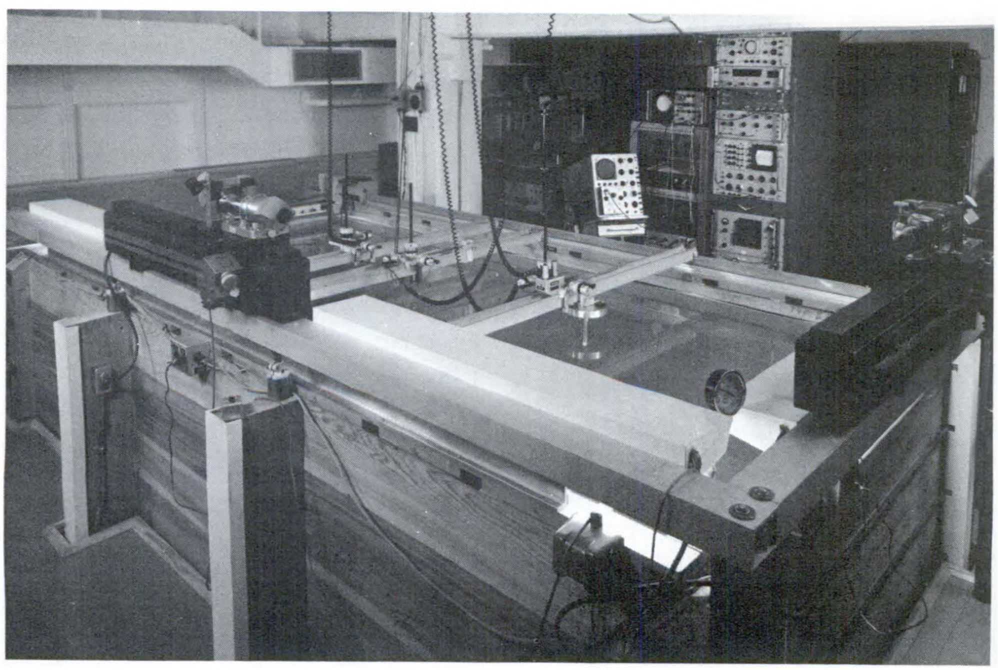

Figure 2 — Wooden tank used at NRL for pressure measurements of acoustic reflection and diffraction

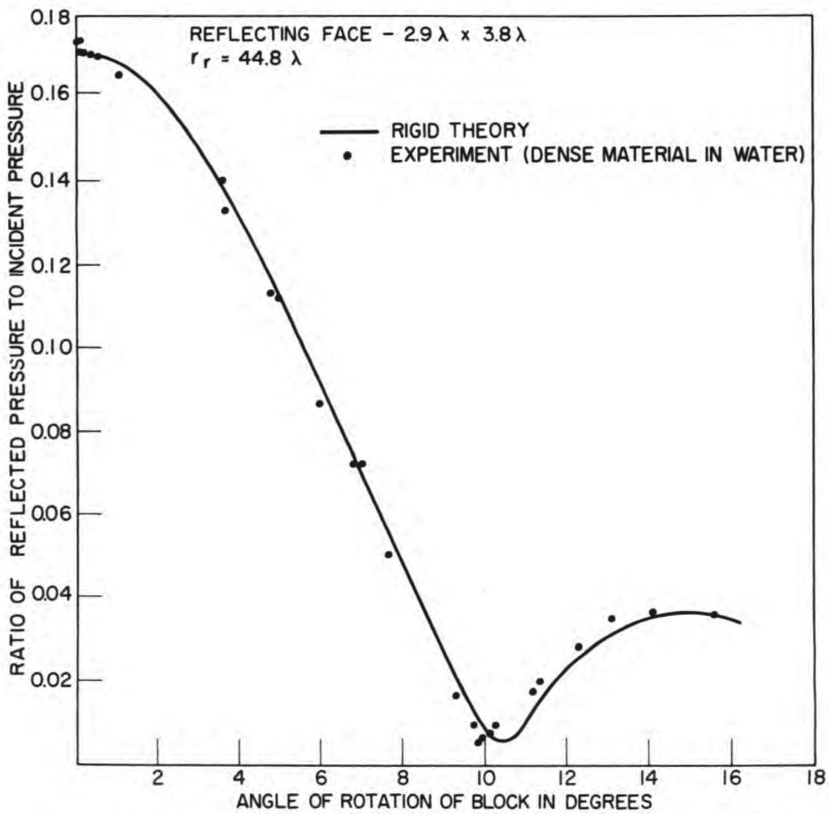

Figure 3 — The monostatically reflected acoustic pressure in the far field of a tungsten carbide block showing a comparison of theory and experiment. The wavelength of sound in water is λ and r_r is the distance of the hydrophone from the block.

The schlieren method of visualizing sound waves was developed the last half of the nineteenth century and is widely used today. A schematic diagram of such a system is shown in Figure 5. A parallel light beam is established between the two lenses on either side of the water tank and is focused to a point at which an optical stop is placed. The introduction of a sound pressure wave at right angles to the parallel light beam produces changes in the optical index of refraction of the water within that sound wave and results in a diffracted image at the image plane. Appropriate strobing of the light and the sound pulse, and a delay between them permits an image to be viewed as shown in Figure 6. Here the light streaks are the sound pressure waves; the source of sound is the transducer at the top of the picture; the sound is radiating downward; and the dark disk is the end of a solid aluminum cylinder. The surrounding acoustic medium is water. Vibrational energy enters the cylinder and subsequent radiation of this energy causes the radiated pattern seen around the cylinder. This allows the behavior of the energy in the cylinder to be studied. Here it can be seen that a single incident pulse gives rise to several returning and time separated echoes. Analysis has permitted identification of the cause of each. By this

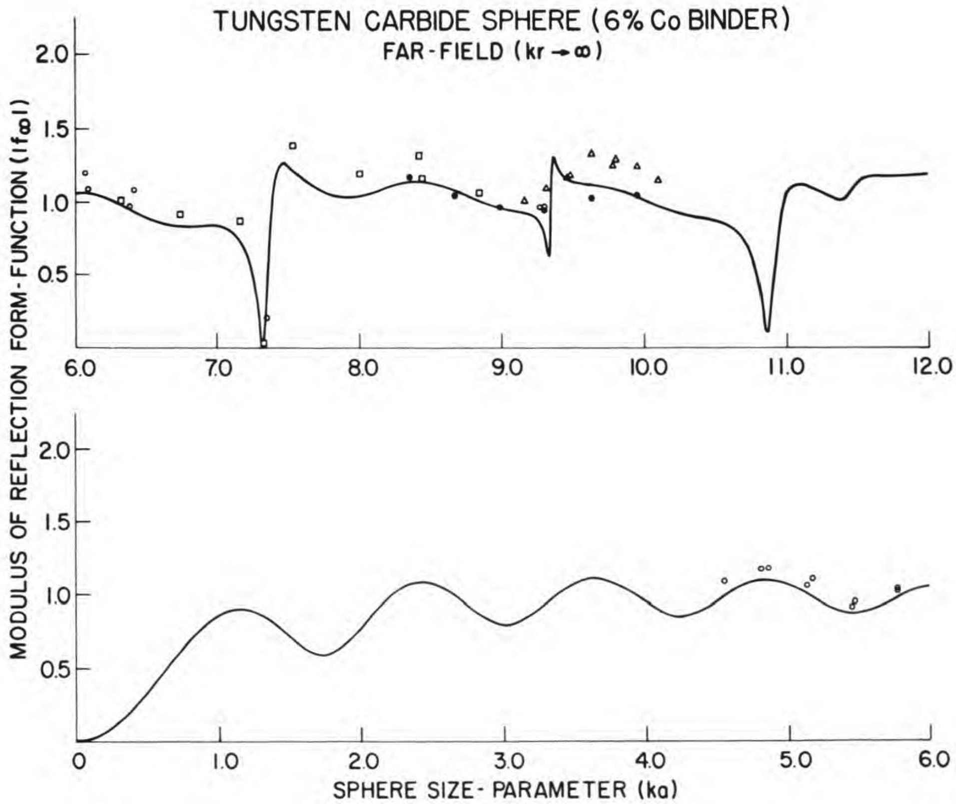

Figure 4 — Comparison of theory and experiment for the reflection in water by a sphere of dense material

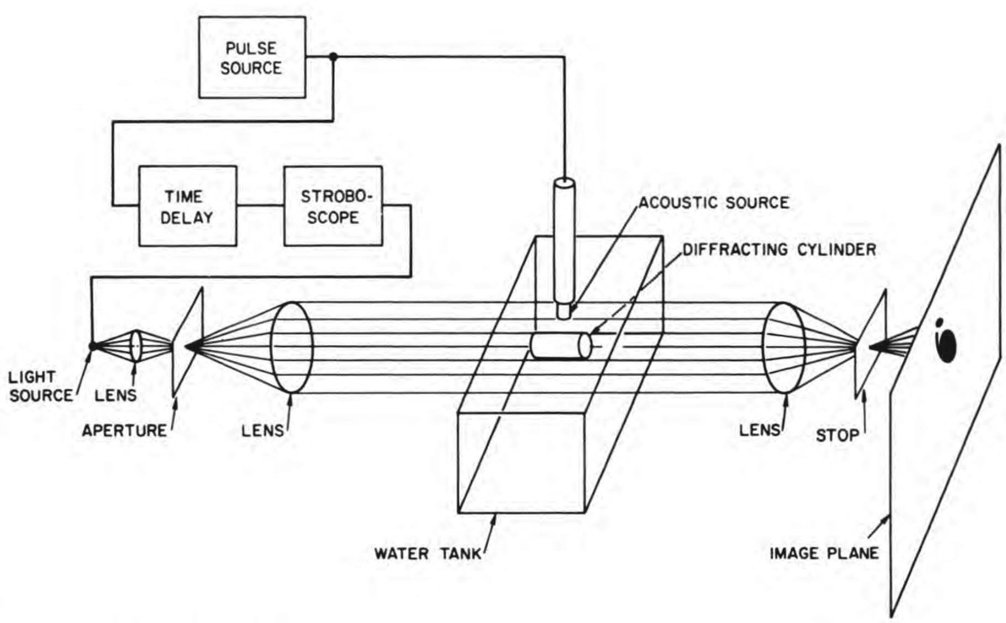

Figure 5 — A diagram of a schlieren system to visualize sound waves

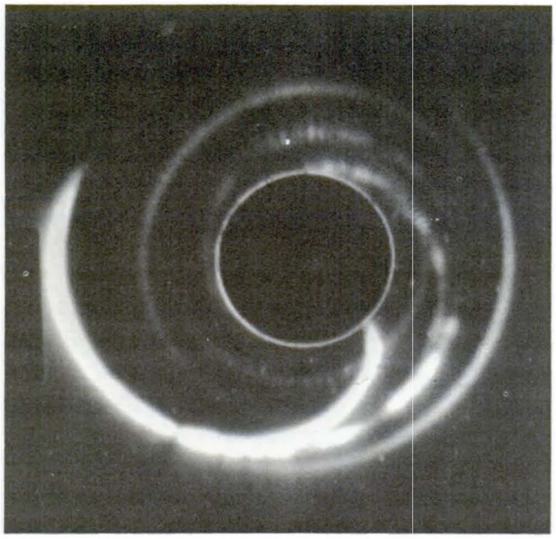

Figure 6 — A schlieren photograph of the multiple sound waves radiating from an aluminum cylinder in water when a single acoustic pulse is incident on it

means, the first radiated results of so-called creeping waves has been observed for the case of a cylinder in water. These are waves that contribute to the reflected and diffracted waves by traveling along the boundary and radiating from it. This schlieren technique can and has been applied to a variety of interesting acoustic situations. An example is shown in Figure 8. Here sound at a frequency of 6.6 MHz is reflected and transmitted by a tropical fish that has been placed in the schlieren-system water tank. Here also a single incident pulse has produced a complex echo pattern related to the internal structure of the fish. The elastic participation by the reflecting body, that plays an important role in the middle and last column of Figure 1, can be examined in detail. A picture similar to Figure 6 is shown in Figure 7 for a cylindrical shell with water on the inner part of the shell as well as the outside.

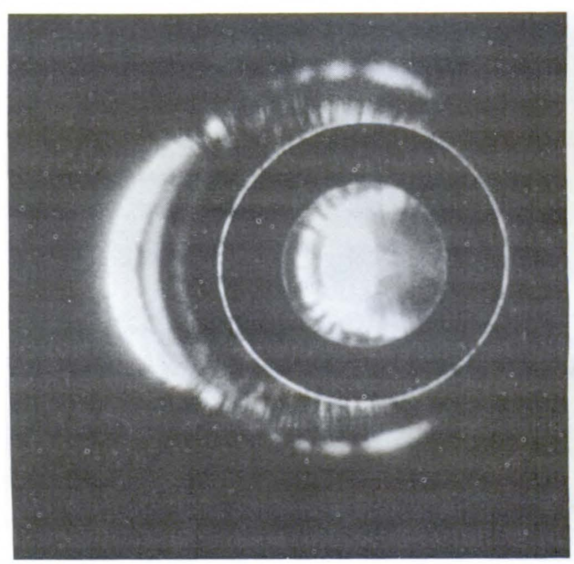

Figure 7 — A schlieren photograph of the multiple wave radiating from a cylinder aluminum shell in water when a single acoustic pulse is incident on it

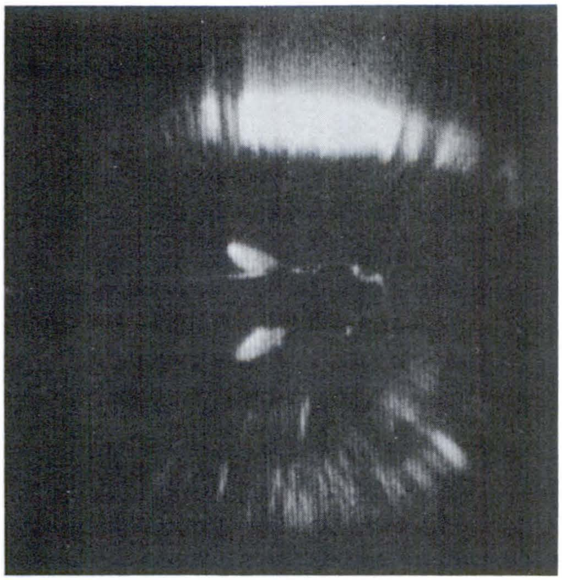

Figure 8 – Schlieren visualization of the reflection of sound by a fish separated into three wavefronts on the left of the fish. The bright pulse on the right of the fish is energy that is transmitted through and around the fish.

The schlieren technique is an excellent means of visualizing the entire acoustic field, but it is limited with regard to quantitative measurements and the size of the field to be viewed. For most three-dimensional fields, a large acoustic tank and point by point measurement in a free field is required. In order to treat some more realistic problems that are more closely associated with the Navy's immediate needs, another large tank is being constructed. This is the pool of the neutron reactor that has been functioning at NRL for the past fourteen years. The reactor portion has been deactivated, and the water previously used to

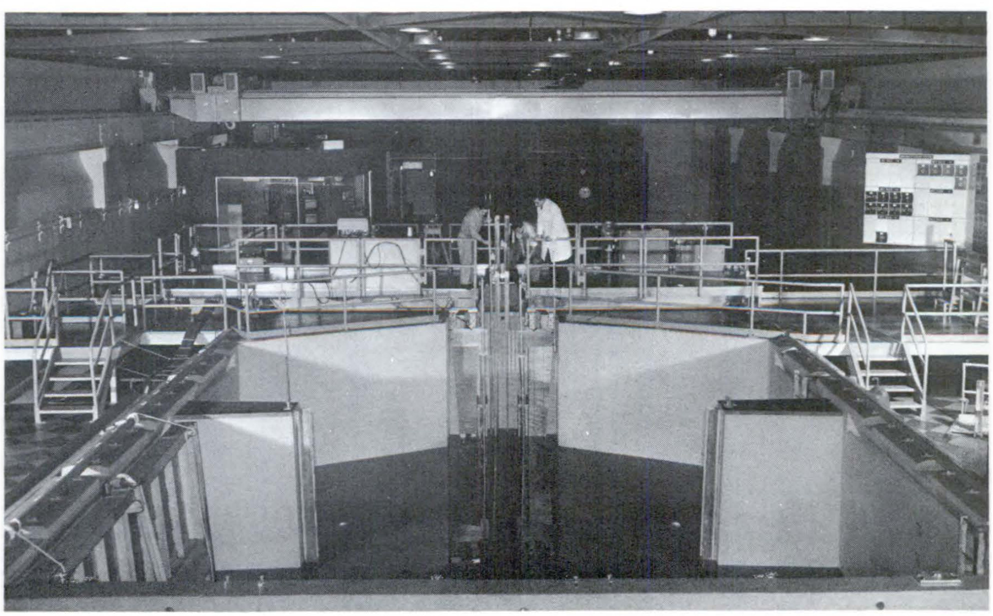

Figure 9 – The reactor pool at NRL that is to be used for acoustic reflection and diffraction studies

cool and shield the reactor will be used for acoustical measurements. It is anticipated that the pool shown in Figure 9 will be reactivated as an acoustic facility by Spring of 1971.

With these facilities and the experimental methods that have been developed, a greater variety of problems in acoustic reflection will be studied. Under controlled conditions in the laboratory, the effect of scaling-up in frequency by factors up to 1000 and appropriately scaling down in size will be examined in order to evaluate the applicability of scale model results in which parameter variation is relatively simple compared to full-scale problems for which parameter variation is at best difficult and costly and often not possible at all.

Navy Study Yields Improvements In Concrete

New techniques for making concrete with improved properties, including greater strength and fire resistance, have resulted from a research study on the microstructure of materials forming cements. The study is under the direction of Professors R. B. Williamson and P. K. Metha at the University of California at Berkeley under an Office of Naval Research contract. The study has experimented with the use of solidified and crushed portland cement instead of crushed rock as the aggregate in mixing concrete. Called cement paste aggregate (CPA) concrete, the processes of combining the cement paste aggregate with a regular cement matrix is characterized by a stronger bond between aggregate and matrix because both are the same chemically.

Tests have demonstrated that CPA concrete has greater tensile strength in the early stages of aging. The material has a much higher water content since larger amounts of water are needed to provide transpiration cooling. This results in concrete with greater fire resistance and also a superior radiation shielding capacity. In a test in the protection of steel against fire it was found that a one-quarter-inch thickness of CPA concrete provided the same 60 minutes protection of the steel as a three-quarter-inch thickness of regular concrete. This makes CPA concrete particularly useful as a fire wall aboard ship.

The material also lends itself for use in the construction of facilities at advance Navy and Marine bases, including aircraft runways. One advantage of CPA concrete is its increased capability for resisting the action of freezing water. Protecting against frost is obtained by entraining or trapping air in the concrete mix. In concrete made with crushed stone aggregate only the cement matrix contains the air. In CPA concrete the cement aggregate as well as the matrix will hold the air. In addition, at advanced bases it would not be necessary to rely on the local availability of crushed rock to mix concrete since the cement aggregate could be manufactured on the spot. CPA concrete also provides a use for old portland cement, thereby helping to solve a waste problem. Experiments are continuing aimed at determining the proper size and shape of the aggregate particles for the mixture.

In another development ferro-cement panels (concrete reinforced with wire mesh) have been combined with fiberglass reinforced plastic (FRP) through a laminating process to achieve more economical and efficient impact resistance. This technique appears to make possible the practical use of concrete for the full structure in vessels over 50 feet. A ferro-cement panel by itself does not have adequate impact resistance. Although an FRP skin alone can be made thick enough to provide sufficient impact resistance, it requires an expensive fabrication process.

Probing the Secrets of Arctic Ice*

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About ten percent of the World Ocean is covered all or part of the year by ice. Unlike the massive continental ice caps of Antarctica and Greenland, whose variations occur on a time scale of thousands of years, sea ice is a thin veneer of frozen water that is affected by environmental changes on a time scale of months to years. For example the southern boundaries of the sea ice in the North Atlantic have shifted hundreds of miles in recent historical times and on the whole it appears that sea-ice cover is one of the greatest variables in the environment of the earth's surface.

The role of sea ice in modifying the global circulation of the atmosphere is not quantitatively understood. The ice cover greatly reduces the transfer of momentum from the air to the water and suppresses drift currents and wind mixing. Also, the ice cover effectively reduces heat exchange between atmosphere and the ocean by reflecting solar radiation in summer and suppressing heat loss of the ocean to the atmosphere in winter. It is evident then, that the presence or absence of sea ice critically affects the dynamic and thermodynamic interaction of atmosphere and ocean not only in the polar regions but probably on a much larger and perhaps global scale.

Sea ice is a phenomenon with profound economic importance to the Soviet Union, Canada, Finland, and to a lesser extent to Denmark, Iceland, Sweden, Norway, Japan and the United States. The arctic ice sheet is also of great strategic importance. Future naval operations in the Arctic require up-to-date information on the extent, position, thickness, and break-up characteristics of sea ice. Under-ice navigation depends on better knowledge of under-ice contours, under-ice sonar propagation, through and under-ice communications as well as basic oceanographic and ocean physical measurements.

An understanding of the large scale response of sea ice to its environment is needed for solving many important practical and theoretical problems ranging from the interaction between the ice cover and global circulation, to navigation in and under the ice-covered sea.

*This article was extracted by R. McGregor, James Witting, and Anthony Sinopoli, Office of Naval Research from AIDJEX Bulletins prepared by J. O. Fletcher.

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For the past couple of decades a great amount of information about the arctic environment has been gathered, most of it by scientists living and working on drifting ice. Information gathered from single drifting ice stations, however, has been intrinsically inadequate to understand the dynamic interaction of ice, water, and atmosphere.

A massive effort is now being launched by several federal agencies and private institutions. The project, named AIDJEX (Arctic Ice Dynamics Joint Experiment), combines the effort of the Navy (Office of Naval Research, Office of the Oceanographer of the Navy), the National Science Foundation, the Advanced Research Projects Agency, the National Oceanographic and Atmospheric Administration, the Coast Guard, the National Aeronautics and Space Administration, and the U.S. Geological Survey. Private institutions include the University of Washington and Columbia University. The Canadian government has been invited to participate.

The aim of the AIDJEX program is to achieve quantitative understanding of the interaction between the fields of motion of the atmosphere, the pack ice, and the liquid ocean, and to develop the capability to simulate this interaction by means of a mathematical model. The ultimate goal is to predict ice movement and deformation and heat exchange

Sea Ice off Point Barrow

between the ocean and the atmosphere. Prediction of ice conditions is basic to the operation of surface ships and submarines in and under ice covered seas. The understanding of ocean atmosphere heat exchange is necessary to an understanding of the interaction between polar heat sinks and global climate.

The AIDJEX program approach was born during 1969 through the spontaneous coalition of a number of U.S. and Canadian arctic scientists. Many of these scientists had been engaged in arctic research for ten to twenty years and were acutely of the limits of what can be learned from single-station observations about the interactions of macroscale fields. The possibility of measuring the fields of wind and water stress by a network of observations had been discussed many times but was well beyond the means of any individual group.

In 1969, the Office of Naval Research commissioned a team from the University of Washington and Columbia University to design an experiment to achieve the objectives outlined above. In November of the same year Canadian and U.S. arctic scientists met in Washington, D.C. to discuss the experiment design. These activities led to the establishment of an AIDJEX coordinating office at the University of Washington funded by the National Science Foundation to further develop and evaluate scientific and operational plans for the AIDJEX experiment, to coordinate the activities of prospective participants and to recommend specific actions necessary to ensure that all vital preparations be undertaken at appropriate times.

The efforts of the coordinating office for AIDJEX has resulted in the design of an experiment aimed first at answering three basic questions:

1. *How is large-scale ice deformation related to the external stress fields?*

Sea ice as a substance has been thoroughly investigated in the laboratory, but practically no quantitative knowledge exists on the large-scale physical properties of sea ice as a geophysical phenomenon. It seems impossible at present to device a theoretical method by which both the inhomogeneous nature of the ice and the dependence of its strength on strain history can be adequately represented. The only acceptable alternative is to acquire an empirical understanding of the stress-strain relationship for sea ice. Such an understanding would be essential in formulating and testing various models to describe sea ice dynamics.

Fundamental to an understanding of the dynamic behavior of sea ice is a description of the interaction between the large-scale stress and strain fields. A major barrier to the understanding of ice dynamics is our present inability to predict the internal ice stress or even to measure it directly. The force due to internal stress at a point can be determined as a residual when the external stresses and the ice movement are known;

this in itself would be of significance, but would provide no new insight into the origin and transmission of internal stress. With an array of stations, it should be possible to find a causal relationship between the internal stress at a point and the regional stress and strain fields. However, the propagation of stress is complicated by nonuniformities in the ice such as leads and pressure ridges. In order to incorporate these effects into the above causal relationship, it is necessary to obtain a detailed morphological description of the ice within the test area. Frequent aerial survey flights, using current remote sensing techniques, will therefore be required. Such data would not only furnish new information on the role of leads and pressure ridges in large-scale ice deformation, but would also provide the input necessary for a parameterization of the ice cover. The immediate goal is the development of a functional relationship between the internal stress at a point and the regional stress and strain fields, a relationship which must include the regional strain history and a parameterization of the characteristics of the ice. Such a relationship is required in any predictive model of large-scale ice deformation.

2. How does ice topography interact with the large-scale stress and strain field?

The transfer of momentum between the atmosphere and the ice, and between the ice and the ocean, is regulated by the roughness of the ice topography; however, the topography is itself modified by the strains generated from the wind and water stresses. Our ability to answer Question 1 relies on achieving at least an empirical understanding of the dual nature of this interaction. Specifically, we must first be able to describe in simple terms the frictional coupling between components of the system, and to identify the various mechanisms involved in the deformation of the ice, before any useful model can be formulated.

An important objective of AIDJEX is to devise methods by which the stresses on the ice can be related to simple variables obtained by remote sensing techniques. The wind stress at a point could be calculated from observations of the wind vector at a given level, if an appropriate roughness length were known; however, at present no direct method exists for finding the roughness length characteristic of a particular type of surface. The wind stress can also be calculated without resorting to roughness lengths by using the gradient method. These values of stress can be used in conjunction with an assumed logarithmic wind profile to produce a roughness length. During AIDJEX, this method will be used to catalog the roughness lengths appropriate to a variety of surface topographies. Surfaces should be categorized according to their statistical properties. In particular, portions of the spatial spectral density are expected to correlate well with the aerodynamic roughness lengths. Accurate profiles of surface elevation would be needed to per-form the spectral analysis. If a good correlation can be established, aerial surveys would be sufficient to estimate roughness lengths.

Analogous to the wind stress, the water stress depends on the relative velocity of the ice over the water and upon the roughness of the lower surface. Current profiles obtained during AIDJEX will be used to calculate stresses and roughness lengths under the ice. These data will then be used to relate ice velocity and bottom roughness to water stress. Ultimately, however, it will be necessary to devise a valid way of relating the total water-stress to ice-velocity and to easily-observed morphological features of the ice.

Determinations of the roughness lengths at the bottom of the ice will be of limited value in the long-range objectives of AIDJEX, unless they can be related to the under-ice topography. If a statistically valid scheme for relating top and bottom profiles is found, then it will be possible to estimate bottom roughness on the basis of airborne observations of the top surface.

On a large-enough scale, pack ice must be in hydrostatic equilibrium. Locally, however, hummocks may exist without compensating bummocks, and subsurface protrusions may exist with no topside expression. Nevertheless, on a regional scale, the gross bottom topography (which regulates the form drag) must be correlated with the major deformities of the upper surface. To establish such a correlation, simultaneous top and bottom profiles will be required.

Of primary concern to AIDJEX is the way in which stress is transmitted through the ice pack. The propagation of stress is directly related to the formation and development of inhomogeneities in the ice. These features serve to relieve accumulated stress within the ice cover, but little quantitative information is available on the energy required to produce the observed deformation or on the mechanisms involved. Determinations of the internal stresses at the manned stations will therefore enhance the understanding of stress transmission only if they are interpreted in light surrounding deformational features.

Despite the seemingly chaotic way in which sea ice ruptures, certain generic types of fractures can be identified:

a. Parallel-edge cracks, caused by the weight of ice piled on the edge of a floe.
b. Perpendicular-edge cracks, caused by the buoyancy of ice pushed below the edge of a floe.
c. Long-wave cracks, caused by bending of the ice due to local atmospheric pressure gradients, or swell created by storms. These cracks appear in parallel series and cross ice of all thickness in nearly straight lines.
d. Thermal cracks, caused by cooling a contraction of parallel slabs of ice.

It can be shown by a simple quantitative estimate that the forces resulting from divergence and shear normally occurring in the atmosphere and ocean are far too small to break a homogeneous, plane parallel slab of ice of more than a meter in thickness. Therefore, pre-existing inhomogeneities in the ice must contribute to localized stress concentrations causing the observed deformation. In thick ice, ridging is always preceded by the formation of a jagged tension crack. Subsequent motion with a shear component then causes the ice to part along certain parts of the crack while ridges form along others (by overthrusting and parallel-edge cracking). Thermal cracks may be particularly important in this context. In the absence of external stresses they often fill with water and refreeze, but if an external stress field is present at the time, these cracks may influence the development of a statistically recognizable "normal" floe size distribution.

It can frequently be observed that the young ice covering a lead is compressed into a high pressure ridge by the convergence of the two adjacent heavy floe. However, we do not know the relative importance of any of the processes identified, and we do not know the percentage contribution of ice of different thicknesses to the total of existing ridges.

A detailed description of the geometry of ice floes and pressure ridges will render insight into the physical processes by which the ice pack is deformed. The spacing, orientation, and length of pressure ridges should be observed, together with their relationship to fracture patterns within the surrounding ice.

3. How do ice deformation and morphology affect the heat balance?

The heat loss from leads of open water during winter is at least two orders of magnitude more rapid than from thin ice of equal area. Local differences of this magnitude are probably greater than those found over any other kind of natural terrestrial surface.

Diverging ice motion thus has three important consequences:

a. It causes heating of the atmosphere by exposing the warm water surface.
b. It causes the rapid formation of new, relatively thin ice, which, by subsequent converging motion, can form pressure ridges.
c. It causes intense thermohaline convection in the ocean by the relatively dense brine rejected from the growing ice.

Thus, the dynamic behavior of the ice and its heat balance are closely related. In their report, "Glaciology in the Arctic," the Glaciology Panel of the Committee on Polar Research, National Academy of Sciences (1967), identify this relationship as crucial to an understanding of long-term ice variations:

> "The important scientific problems of the interaction among oceanic circulation, sea ice, and the atmospheric heat balance

and circulation are related to the practical possibility of artificially influencing climate on a large scale. Although the scope of these problems extends well beyond the field of glaciology, the Glaciology Panel believes that ice is a pivotal factor.

ARCTIC SEA-ICE COVER: STABLE OR UNSTABLE:

"An inherent instability of the arctic sea-ice cover would have important implications: removal of the sea-ice cover might be triggered by natural or human influences. Removal of an unstable sea-ice cover would, in turn, presumably have profound influences on the climate of the northern hemisphere. At least three conflicting views exist on this question, namely:

a. That there is an alternation between an ice-free and ice-covered Arctic Ocean as a result of various influences, including change of sea level.
b. That the sea-ice cover is unstable: if it were destroyed, the arctic heat balance would be altered toward conditions that would prevent reforming of the sea-ice cover.
c. That the sea-ice cover is stable, that is, that equilibrium conditions favor a sea-ice cover. If the cover were removed, it would re-establish itself within a few years.

"These hypotheses cannot be conclusively proven or disproven without consideration of the entire ocean-atmosphere circulation with all its ramifications. For instance, it seems possible that increased heat advection into the Arctic, instead of causing more ice to melt, might lead to a greater production of ice: increased circulation (higher wind velocities) causes more ice deformation, divergence, and a greater number of open leads. During most of the year, the heat loss from open water is two orders of magnitude greater than from thick ice. If the increase of the area of open water is substantial, even an excessive anomaly of heat advection cannot compensate for the local loss, and the result will be an increased ice production...."

During the winter, the rate at which heat is transferred between the ocean and the atmosphere is hightly sensitive to the extent of open water. The area of open water depends upon the dynamic behavior of the ice pack, which, in turn, depends upon the geometry and extent of open water. The production of new ice in leads acts as a valve which greatly reduces the sensible heat flux from the ocean to the atmosphere. The data required to deduce the sensible heat flux are identical to those required to deduce the wind stress.

The transfer of heat through the pack ice itself is regulated not only by ice thickness but to a large extent by the thickness of the snow blanket. Since snow is an effective barrier to heat transfer, regions of anomalous snow depths, for instance on the lee side of ridges and over summer drainage features, must be considered in any attempt to evaluate of regional energy balance. Thus, in addition to providing data on the distributions of leads and ice thickness, AIDJEX will attempt to determine relationships between snow depth and ice topography.

In the summer, the upper portion of the ice is essentially isothermal and there are only small temperature differences between ice and open water. Thermodynamic distinctions between leads, pressure ridges, and underformed ice are therefore concealed during this period; however, knowledge of the areal extent of leads is still necessary in order to calculate the amount of radiant energy absorbed by the ocean.

The only morphological features known to be significant to the summer energy balance are melt ponds. Because of the disparity between the albedos of ice and water, summer melt ponds absorb much greater amounts of short-wave radiation than the surrounding ice. The prevalence of melt ponds (greater than 50 percent coverage during certain periods of the ablation season) accounts for the low areal albedo averages which have been observed from aircraft and high towers. The low integrated albedos indicate a rate of energy absorption at the surface which is too large to be consistent with mass balance studies. In some unknown way, the melt ponds much dispose of this excess of energy. As a first step towards an understanding of the role of melt ponds in the regional energy balance, AIDJEX will furnish data on the geometry (coverage, shape, and depth) of melt ponds and their relationship to deformational features.

Station Array

The proposed experiments will be conducted from an array of drifting stations established in the Arctic Ocean. The array will consist of a number of observation stations, five of which will be manned. The size and shape of the array are designed to give measurements which will be of maximum use in the calculation of the stress-strain relationship. The number of stations necessarily represents a compromise between the desire for accuracy and statistical reliability on one hand, and financial and logistic considerations on the other.

The main array will consist of the five manned stations, with four initially arranged in a square around a central station. Typically, major ice features (such as leads, ridges and individual floes), have a scale of several kilometers, and atmospheric pressure systems have a scale of thousands of kilometers. It is desired that the square should be large compared to the ice features but small compared to the atmospheric pressure systems. Therefore, the initial square of manned stations should be 100 km on a side. It is desirable to minimize shoreline effects, which are a complication by locating the main array several hundred kilometers from shore.

Additional unmanned (or occasionally manned) stations will be placed outside of the main array, in a continuation of the 100 km grid of which the four outer manned stations will form the basic unit. These stations are necessary because (among other reasons) there is evidence that the ice drift at any point depends on the winds over an area of at least 20,000 km^2; this is larger than the main array. These unmanned outer stations will extend to a coast in at least one direction, so that it will be possible to estimate how far shore effects penetrate into the interior of the Arctic Ocean.

It is desirable to include some measurements of the ice drift on a smaller scale than the main array. From experience in other oceans, it appears that the scale of inertial and other wave motions that may contribute to ice deformation is on the order of 10 km. It is suggested that, as a first try, there should be a square of four unmanned (or occasionally manned) stations 20 km on a side around the central manned station. Depending on the initial results, it may prove desirable to relocate the unmanned stations or to establish a number of additional stations to increase the statistical reliability of the results, to permit the calculation of higher order velocity differences, or to permit intensive study of especially active regions. The plan now calls for observations at the unmanned stations to include only position, wind velocity, and atmospheric pressure. Additional meteorological and oceanographical observations may be added if they are easily automated and sufficiently valuable.

A base station will be needed to serve as a logistic headquarters for the project. It is essential that this base station have a reliable airstrip, since frequent logistic and scientific flights will be required. Experience on previous drifting stations has shown that air strips established on sea ice tend to develop cracks and break up. The useful lifetime of such an airstrip is measured in months and hence the pack ice does not provide a platform of sufficient permanence or dependability for a project of this magnitude. Therefore, the only sites considered suitable for establishing a base station are ice islands, which are large, thick icebergs composed of fresh-water ice.

Situating the logistic base at the central station would minimize flying time and conserve personnel and supplies. This will probably only be possible if an ice island whose area is small compared to the area of the inner square can be found in a suitable location. In this way the anomalous size, strength, and movement of the ice island will have only a small effect on the drift patterns of the surrounding pack ice. A larger ice island, such as T-3, could be used as a base station provided it is well outside of the inner square of unmanned stations. An exception might occur if suitable techniques can be found to determine the position of unmanned stations from a considerable distance. It might then be possible to locate the entire array of unmanned stations away from the

Ice Island Station, T-3

exact center of the larger square, and still use a large ice island as the center manned observing station. Otherwise, it will be necessary to establish a central manned station on the pack ice, and have a separate base station on an ice island.

Instruments and Observations

Sea Ice Observations

The area of the inner square (containing the Central Station) and a strip at least 20 kilometers wide (connecting the four manned outer stations) should be surveyed regularly during those intervals when observations are being taken at the surface. The systems used for these surveys must record surface temperatures and morphological features. Ideally, such systems should be capable of detecting narrow leads, melt ponds, pressure ridges with height estimates, surface roughness, and, if possible, ice thickness. Instrumentation will be mounted aboard aircraft, submarines, and satellites. Existing observational programs will be exploited whenever possible.

Imagery. Airborne sensors such as the infrared scanner (IRS), the sidelooking radar (SLR), and the optical laser, may be applied to the studies proposed in AIDJEX. Passive microwave and scatterometry systems (PMS) presently being studied and developed within the NASA Earth Resources program also might ultimately be used in the remote sensing of sea ice. Ground verification parties will provide data to calibrate and check the remote systems.

Profiling. Top surface profiles will be observed with an airborne *optical laser altimeter.* The laser system has a resolution of approximately a centimeter, but is unreliable if fog or cloud are present beneath the aircraft. Since its accuracy increases with decreasing altitude, low level (500 feet) flights avoid much of the preclusive weather and promise increased resolution. In addition to measuring ice roughness, the laser system may be used to detect ice which visual observations and high quality photography are unable to distinguish from open water. Techniques presently being studied indicate that laser imagery may also be capable of identifying major pack ice types. Surface topography is one of the basic criteria for visual identifying stages of ice development. Very early stages of ice development generally have smooth, level surfaces with only minor pressure ice formations. Later stages maintain a generally level surface but have frequent, more pronounced pressure formations, such as ridges and hummocks. Old sea ice has an uneven, gradually rolling surface caused by weathering. Since these parameters are revealed in the laser terrain profile, identification of ice types can usually be made through interpretation of the character of the profile.

Under-ice profiles will be taken with the submarine *acoustical ice canopy profiling system.* The resolution of this system is much lower than the laser system and, in the immediate vicinity of the stations, it may be necessary to supplement the data with observations of the local ice profile taken by other means. In a pilot project in the spring of 1970 substantial success was achieved in obtaining profiles of a limited area using scuba divers. Boreholes through the ice and small submersibles may also be exploited for this purpose.

Positioning and acceleration. Essential to the success of AIDJEX is the ability to obtain accurate relative positioning of the manned and unmanned stations. Without this ability, no reliable computations of ice strain and strain rate would be possible. Since the sampling interval must be small compared to the typical period of atmospheric systems, hourly observations are indicated. Total large scale strain rates exceeding 10 percent per day or so are not expected. Relative positions, obtained hourly, should be accurate to at least 0.1 percent of the total distance between stations; that is, to ± 50 meters in the outer square and to ± 10 meters in the inner square. During periods of large strain rates, satellite positioning of the manned stations would be adequate; however, during relatively quiet periods, the inaccuracies inherent in this system would be comparable to the expected deformation and more accurate positioning techniques will be required.

It is expected that accelerations of large magnitude and low frequency can be determined as second order differences of navigational fixes. Higher frequency accelerations will have to be observed directly by means of accelerometers.

Two methods of measuring wind stress should be considered: The profile method and the eddy flux method. The profile method has the advantage of low initial cost and easy maintenance, and the disadvantage of being somewhat empirical in concept. The eddy flux method involves sophisticated electronics and high cost, but also high precision.

Wind vector. Wind direction should be recorded continuously at the outer stations. A windvane with high damping should be mounted at the same, or a somewhat higher, level where wind velocity for stress computations is observed. Integrated (averaged) wind directions should be recorded at the same time intervals for which stress is recorded.

Observations of wind direction and velocity at the inner stations are desirable and should be contemplated if azimuth control is feasible for an unmanned station. If not, wind velocity alone should be recorded at the standard height (as above) and for the standard time interval. Wind data from the inner stations should be telemetered to the Central Station.

Radiation. Radiant energy fluxes are the most important components of the heat budget. The elements to be measured continuously at all manned stations are: incoming long-wave radiation, outgoing long-wave radiation, incoming short-wave radiation, and albedo. Since meltwater ponds absorb at least twice as much incoming short-wave radiation as clean ice, it will be essential that, during the melting season, the percentage area covered by ponds be surveyed as frequently as possible. The effective surface temperature will be monitored by infrared radiometer at selected periods on all types of surfaces (snow, ice, ponds, leads, pressure ridges, *etc.*). Airborne radiation measurements and cloud observations from an all-sky camera will be made to obtain a complete picture of the radiative energy balance.

Atmospheric pressure. Atmosphere surface pressure should be recorded at all stations and averaged automatically over the standard time interval. Pressure averages should be accurate to within ± 0.05 mb. Unless the sensors are mercury barometers, periodic calibrations, requiring visits to the unmanned stations, will be necessary.

Upper air. The logistic base station should be equipped with a radar-tracked radio-sonde that provides high resolution vertical profiles in the lowest few hundred meters. These observations are not only needed for the heat balance work, but would also be of considerable value for both survey and supply flights.

The frequency of upper air observations should follow the standard synoptic schedule, with provisions for more ascents when deemed necessary.

Oceanographic Observations

Water stress. The water stress, due to the relative motion of ice and water can be resolved into contributions from skin friction and form drag. Past measurement of friction drag have been made at locations chosen more for their convenience than for their representation of typical arctic pack ice. As in the case of wind stress, either a profile method or an eddy flux method may be employed. The profile method is simpler and more reliable for field use. This method requires measurements of vertical velocity profiles. Near each of the manned stations, current meters will be installed at different depths. In addition to the routine measurements of the frictional stress at each site, a series of experiments should be conducted to find roughness lengths characteristic of the bottom surface of various types of pack ice. Observations of the under-ice topography, current measurements, and ice velocity are needed or the calculation of form drag.

Tilt. Another force acting on sea ice is the pressure gradient force resulting from the component of gravity parallel to the sea surface. Measurements of the slope of the sea surface should be recorded continuously at each of the manned stations. Estimates of the sea surface slope can be obtained directly from hydrostatic leveling of the sea surface.

Observations of ice tilt offer the simplest method of obtaining the pressure gradient force but they require occasional calibration by direct hydrostatic leveling, since they involve the assumption that ice tilt corresponds to sea surface slope. The tiltmeter is basically a pendulum device which responds both to the ice tilt and to horizontal accelerations. There is no method of separating the two effects in the data recorded by such an instrument. Accelerations must therefore be determined independently from navigational data or accelerometers and then subtracted from the tiltmeter readings to give the ice tilt. Preliminary experiments need to be made to find the relative magnitudes of the two effects under actual field conditions.

Hydrostatic leveling of the sea surface is theoretically the best technique to obtain the absolute tilt of the sea surface. However, a practical hydrostatic system with continuous recording has not been developed. Therefore, absolute hydrostatic tilt measurements should be supplemented with continuous relative observation from a tiltmeter.

Transient ocean currents. In most cases, water stress, created by the movement of the ice over the ocean surface, retards ice drift. However, after long periods of unaccelerated drift a sizeable boundary layer, moving along with the ice, will develop in the ocean. The momentum of this layer may continue to drive the ice when the other driving forces have subsided. Furthermore, other transient ocean currents, which may or may not be induced by ice movement, could exchange momentum with the ice cover and, in doing so, affect its motion. An understanding of the interaction of transient currents with the ice cover is needed for the development of reliable forecasting models. AIDJEX offers, for the first time, the necessary network of stations to properly observe such transient phenomena as internal waves, inertial oscillations, and planetary waves. Observations will include profiles of salinity, temperature, and velocity. It is likely that these observations will also yield new information on the transfer of heat between the deep ocean and the ice cover.

Project Stages

Pilot experiments. The magnitude of effort involved in AIDJEX requires that as many of its elements as possible be tested before the combined experiment is begun. A number of recent, independent studies can be identified as direct contributions to the preparation for AIDJEX. Among these studies are:

- Airborne ice surveys and remote sensing studies by the Naval Oceanographic Office.
- Investigations of pressure ridges off the Alaskan coast near Point Barrow, and a review of all existing literature on the subject.
- Advanced experiments concerned with ice drift in the Gulf of St. Lawrence; wind drag coefficients of ice floes under neutral and unstable conditions were measured by means of a three-dimensional sonic anemometer.
- The diversified, continuing project at Lamont-Doherty laboratories, especially work on internal waves, Ekman drift, and satellite navigation has provided much of the basic information for the planning of AIDJEX.
- Experiments conducted by scientists of the University of Washington in Spring of 1970 aimed at examining deviations from geostrophic flow to a depth of 500 meters at closely spaced stations, as well as the spatial coherence of currents simultaneously observed at spacings of 3, 10, and 20 km. During the same experiment, J. D. Smith and collaborators (U. Wash.) mapped the bottom topography of a small (40 by 40 m) area of ice to investigate the effect of bottom topography on Reynolds stresses in the Ekman layer, while *W. J. Campbell* (USGS) conducted preliminary tests of ranging devices for the continuous observation of small-scale ice strain.

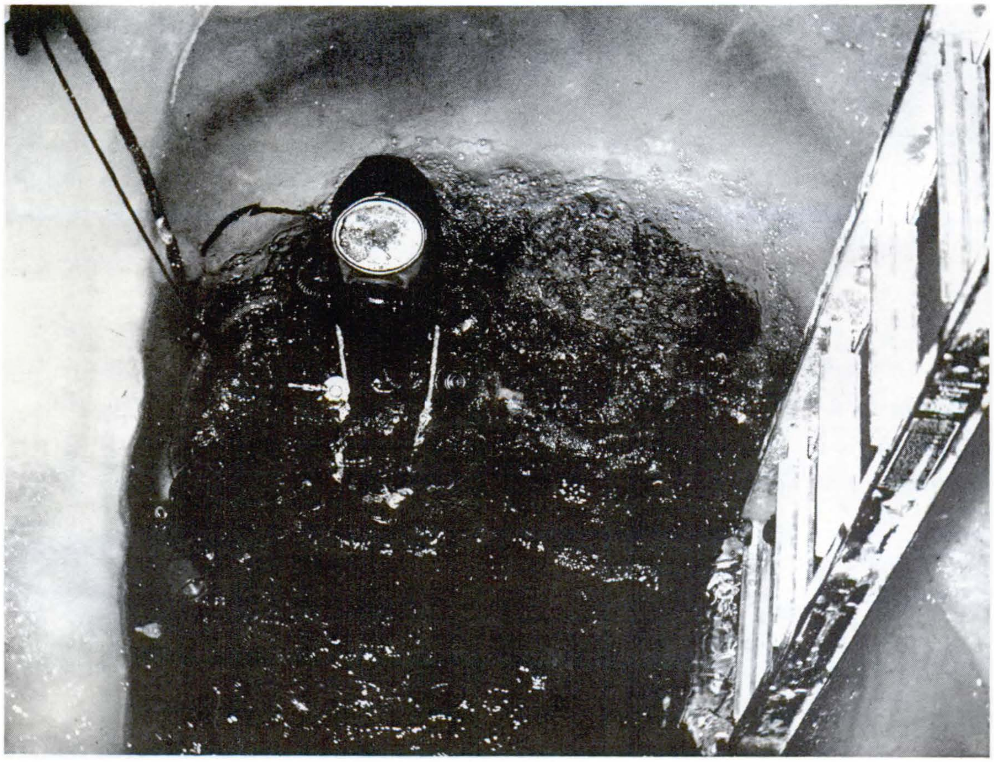
In addition to these preparatory projects it is planned to conduct, as an integral part of AIDJEX, a pilot experiment in Spring 1971. In this experiment, a "manned station," as fully equipped as possible, will be deployed to test sensors, recording apparatus, camp facilities, and whatever remote sensing and automatic equipment will be available at the time.

Main field program. The main field program will have a duration of at least one year in order to observe seasonal changes in the state of the ice cover. Although it would be desirable to run the experiment continuously throughout this period, such an approach seems inefficient and involves numerous technical difficulties. A more practical approach is to select several periods of special interest during which all systems would operate simultaneously. These periods of intensive data collection will each last approximately one month and will be chosen to provide representative data on conditions within the test area during the height of the melt season the middle of the winter, the fall freeze-up, and possibly, the spring transition from snow-covered to bare ice. Maintenance crews will occupy the manned stations between the periods of intensive observations. Routine navigation, certain oceanographic observations, and aerial surveys will be maintained throughout the year. Other observational programs would be continued according to the specific needs of individual projects. This phase of AIDJEX is tentatively scheduled to begin in the Spring of 1973. Upon completion of the field work, AIDJEX will coordinate the reduction, distribution and analysis of the data. The total duration of AIDJEX is expected to be six years.

Future Models

The primary goal of AIDJEX is the formulation of a predictive model which will yield forecasts of ice deformation and drift on the basis of a few easily measured quantities. The model presently envisioned computes each of the stresses from observations of wind, position, pressure, and surface characteristics. Wind stress is computed from observations of the wind vector at a given level, assuming a logarithmic profile and a roughness length characteristic of the surface. Water stress is computed from the velocity of the ice and a roughness length appropriate to the underside of the ice. This roughness length will be computed using a statistical relationship between the top surface topography and the bottom surface topography. The treatment of the internal stress, pressure gradient force, and coriolis force have been described above. The successful application of this model depends on several relationships, especially those pertaining to internal stress, transient ocean currents, and roughness lengths, which have yet to be established. It is possible that some laboratory experiments may be performed to verify some of the theoretical ideas.

Such a model, aside from providing insight into the mechanics of ice deformation, will make it possible to estimate, from a given atmospheric pressure field, what the ice conditions in a given location will be. Forecasts will be possible to the same extent that atmospheric pressure can be forecast. From a practical point of view, "ice forecasting" is concerned with the following six features: drift fields, shear zones, open water, thick level ice, deformed ice, and thin ice. A measure of the probable occurrence of all of these features can be forecast with a functional model of the kind outlined above.



Diver in entry hole on T-3

The next step will be to relate, in quantitative terms, the ice strain field and heat balance, *i.e.* ice production. Only estimates of unknown reliability exist on the amount of ice exported from the Arctic Basin into the Greenland Sea and the Atlantic Ocean. Also unknown is the role and contribution of young ice in the formation of pressure ridges. The ability to relate ice strain and the formation of new ice would provide an approach to both problems. When a given area of pack ice undergoes repeated extension and compression, the new ice forming during the periods of extension will be later compressed into ridges, but will prevent the complete restoration of the previous area. This will result in an outward flux of ice. The effects of ice strain on the heat budget will also be needed for a refinement of the input parameters to models of the large-scale atmospheric circulation over the Arctic.

Ultimately, all empirical relationships and models developed in the context of AIDJEX should be incorporated into the modelling of atmospheric and oceanic circulations on a global scale. Only then will it be possible to examine the global consequences of natural or artificial modifications in the extent, thickness, or circulation of the Arctic ice cover.

On the Naval Research Reserve

Joint Drill on Nuclear Power Problems

The members of NRRC 13-14, Portland, Oregon and NRRC 13-5, Corvallis, Oregon recently met for a combined drill. The training objective of the drill was to combine the talents of the two groups in a discussion of the engineering and ecological problems in utilization and siting of nuclear power reactors. The Portland unit has several members who are closely associated with the electric power industry, and the Corvallis unit contains a number with ecological training.

To introduce the program, Mr. Carl Rempel of the State Engineer's Office discussed his experiences as a member of the Governor's Task Force on Nuclear Plant Siting. Following Mr. Rempel's remarks, there was an open forum discussion.

It was emphasized that the necessary increase in power generating potential to meet the needs of our growing population must be carefully planned to minimize its impact on the environment. All members agreed that joint drills such as this are a most valuable addition to the training program of the Research Reserve.

Promotion Selections

Congratulations are extended to officers listed below who were selected for promotion by the Fiscal Year 1971 Reserve Selection Boards.

There were 176 Naval Reserve line officers selected for promotion to Captain. One was a member of the Research Reserve Program:

Howard, William L. NRRC 6-17

There were twenty-five Naval Reserve WAVE line officers selected for promotion to Commander. Two were members of the Research Reserve Program:

	NRRC
Jones, Constance J.	8-5
Mervis, Rosalyn M.	4-3

From the male officer list, there were nine-hundred ninety-seven officers selected for promotion to Commander. Twenty-one were members of the Research Reserve Program:

	NRRC		*NRRC*
Ammerman, Don J.	5-12	Levin, Herman	9-12
Anderson, Benny A.	3-5	Marra, Bruce L.	4-3

Busharis, John G.	3-2	Martin, George W.	5-8
Cavanna, Cesar E.	12-2	Maycock, Paul D.	8-12
Eldredge, Hugh G., Jr.	6-18	Miller, Max K.	8-12
England, Loy D.	8-5	Pitt, Woodrow W., Jr.	6-3
Gilman, Walter L.	3-14	Post, Arthur H., Jr.	1-1
Hammond, William E.	6-6	Rehme, John A., Jr.	5-10
Hays, James F.	1-1	Rogers, Walter J., Jr.	6-19
Hoover, Alan E.	6-18	Snedeker, Earl K., Jr.	4-1
Larson, Herbert W.	4-5		

Seminar Planned on Cold Regions Research

The Naval Research Reserve Company 1-1, Boston, Massachusetts, will conduct a seminar on cold regions research from 19-30 July 1971 at the Naval War College, Newport, Rhode Island.

The purpose of the seminar is to make attendees aware of cold regions research and the important of the Arctic and Antarctic to the United States. The introduction to the seminar will include a summary of the geo-political and military situation by speakers from the foreign affairs schools of Tufts, Harvard, and the Naval Technical Intelligence Office. It is anticipated that there will be a field trip to the U.S. Army Cold Regions Research Laboratory at Hanover, New Hampshire and its White Mountain field station.

Seminar time has been set aside for sessions on Research Reserve matters.

New Polymer Materials May Solve Fuel Tank Sealant Problem

A long-range research program conducted by the Olin Mathison Corp. with the support of the Office of Naval Research has produced in the past few years new types of polymers resistant to high heat. Called Dexsil, this family of materials that contain carborane has now been found to promise a solution to the problem of a sealant for the fuel tanks on the F-14, the first naval aircraft designed to cruise at supersonic speeds. The present material used as a sealant will deteriorate under the heat stress generated at those speeds, permitting leakage of fuel vapor into the wing interior. The escaping fuel vapor would not only be highly corrosive but also present a severe combat hazard.

A new fluorinated version of the Dexsil polymers has both the high strength and fluid resistance capabilities to be used as a sealant while maintaining high thermal stability. This has been achieved through the discovery of an effective condensation catalyst, which has made possible a significant increase in the molecular weights of several types of Dexsil polymers and the production of large chain molecules. Currently work is underway to develop satisfactory curing and fabrication procedures. The Naval Air Systems Command is providing guidance on further testing and evaluation.

Editor's Request

In the April issue there will be a questionnaire. Please return the card with the questions answered. This is the only way we have of periodically checking our distribution list.

Research Notes

High Altitude Aircraft Ocean Surveillance System

The Navy is assigned the responsibility for maintaining an ocean traffic information system capable of total and continuous ocean surveillance. The results of earlier Navy-sponsored studies indicated that high-altitude reconnaissance aircraft collect sea-traffic data at a better rate than any other observation system. This prompted ONR to sponsor a technical feasibility study at Boeing of an ocean surveillance system consisting of an airplane capable of very-high-altitude flight, carrying appropriate lightweight observation sensors, recording devices and communication equipment. The general objectives of the study defined an all-weather day-and-night system with appropriate sensors and a crew of two to operate for a period of four to eight hours at an altitude approaching 100,000 feet for possible use in the 1980 period. In the course of this original study by Boeing, five subsonic and three supersonic point-design airplane configurations of very-high-altitude capability were defined. It was concluded from this study that the very-high-altitude aircraft surveillance system and the mission concept are technically feasible, and that the subsonic airplane performs sufficiently well to warrant complete system evaluation studies in detail.

Based on results of this initial investigation a follow-on study was instituted in late 1968 to define a high-altitude subsonic configuration, that while not necessarily optimized, would satisfy the ocean surveillance system requirements. The resulting baseline aircraft has a maximum design gross weight of 60,000 pounds, a wing span of 200 feet, a wing aspect ratio of 20 and a body length of 82.5 feet. Two turbojets of over 35,000 pounds of thrust each will provide the thrust required at high altitude. This baseline airplane was designed to achieve a balance between a high-altitude capability and endurance. The airplane operates at an extremely high lift coefficient and has a slotted airfoil. To preclude having an excessively large vertical tail, which would be required for engine-out control during takeoff at full power, the airplane would use partial power for takeoff. However, takeoff distance to clear a 50-foot obstacle would be approximately 3,000 feet when using only one-seventh of available thrust.

New Computer Programming Technique for Hand-Drawn Symbols

A computer programming technique that permits the on-line input of hand-drawn patterns and the generation and analysis of these patterns in real time has been developed by Dr. Herbert Freeman at New York University under an Office of Naval Research contract. The key to the technique is the development of a pattern analyzer that allows hand-drawn symbols to be recognized by a computer. Dr. Freeman has also created a special symbol language which can be reliably and immediately recognized by the computer. Initially he has designed a series of symbols that stand for major electronic components, such as a transformer. The language is flexible enough to permit it to be expanded to include a wide variety of symbols.

The user makes his input to the computer by drawing the symbols on a two-dimensional writing surface, such as a RAND or Sylvania tablet, with a pressure-sensitive pen. The symbol, after being analyzed and recognized, is displayed on a CRT. It can appear either at the same location where the symbol was drawn on the tablet or where a cursor had been previously positioned by the user. This permits the correction of errors due to misidentification. The inputted program can also be printed out by conventional means.

The symbol recognition system can be used by a designer, for example, to make a drawing of novel or experimental electronic network or a circuit segment and test its operation on the computer without fabricating the circuit with actual hardware. Earlier schemes for accomplishing this have had disadvantages, such as the fact that the input of even a small segment of program or a circuit diagram was a monotonous and slow process. The NYU system also provides for a flexible and close man-machine interaction.

SKYLAB Planning

Apollo 7 Astronaut Walter Cunningham (center) and Captain Earle W. Sapp, USN, Director of the Naval Research Laboratory, Washington, D.C., discuss flight aspects of NASA's forthcoming SKYLAB program, for which NRL is providing extensive technological support. On their left is Dr. Maurice M. Shapiro, NRL's chief scientist for cosmic ray physics, and principal investigator of NRL's S009 Experiment, in support of SKYLAB. Cunningham, who visited NRL this week, has now been assigned to the SKYLAB program in which astronauts will live for several weeks at a time in an eight-room orbiting laboratory.

NRL Research Leads to New Navy Dosimeter

The Naval Electronic Systems Command has recently awarded a contract to the Harshaw Chemical Company of Solon, Ohio, for production of thermoluminescent (TL) dosimeters and readout equipment to be used at submarine repair facilities. The Naval Research Laboratory played the central role in the research and development leading to this procurement.

Dr. J. H. Schulman (now Associate Director of Research for the Materials and General Sciences Area of NRL) and his co-workers began the basic research on luminescence and radiation effects in dielectric solids in 1946, and made the first practical application to

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the measurement of ionizing radiation in 1949 with the invention of the silver-activated phosphate glass dosimeter, which was adopted by the Navy in the form of the DT-60 "dog tag" for measuring atomic-weapon exposures to personnel. In 1956, R. J. Ginther (now Head of the Central Materials Research Activity at NRL) developed the TL phosphor (CaF_2:Mn) which is now being employed in the new dosimeters. Although this phosphor was found to have ample sensitivity to detect a few milliroentgens (mR) of γ-radiation, and thus to be potentially useful for routine personnel monitoring, its further development was held back by the presence of undesirable spurious TL signals until Dr. Schulman invented the glass-sealed, internally-heated TL dosimeter in 1960. This step allowed radiation measurements to be extended down to less than 1 mR without interference. Mr. F. H. Attix (now Consultant in the Nuclear Sciences Division at NRL) played a key role in perfecting the device and pursuing its applications to Navy and general dosimetry problems.

The possibilities of this system were brought to the attention of BuShips, which let a contract to Edgerton, Germeshausen & Grier, Incorporated, of Goleta, California, to develop TL dosimeters and readers suitable for Navy personnel monitoring. Upon completion of that contract NRL carried out extensive tests of this dosimeter, and later extended the tests to include commercial TL dosimetry systems that had also been stimulated into being by the research at NRL. These tests included field trials on board a nuclear submarine and at three submarine repair facilities, as well as laboratory studies of response characteristics under a variety of conditions. The present procurement contract makes full use of all the information thus gained, to provide the Navy with a TL dosimetry system that truly represents the state-of-the-art, with performance characteristics significantly improved over those of the photographic film badge it is intended to replace.

NAVAL RESEARCH REVIEWS publishes highlights of research conducted by Navy laboratories and contractors and describes important naval experimental facilities. Manuscripts submitted for publication, correspondence concerning prospective articles, and changes of address, should be directed to Code 109, Office of Naval Research, Arlington, Va. 22217. Requests for subscriptions should be directed to the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., 20402. Subscription price: $1.75 per year in the U.S. and Canada; $2.25 per year, foreign; $0.20 per individual copy. The issuance of this periodical approved in accordance with Dept. of the Navy publications and printing regulations.

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