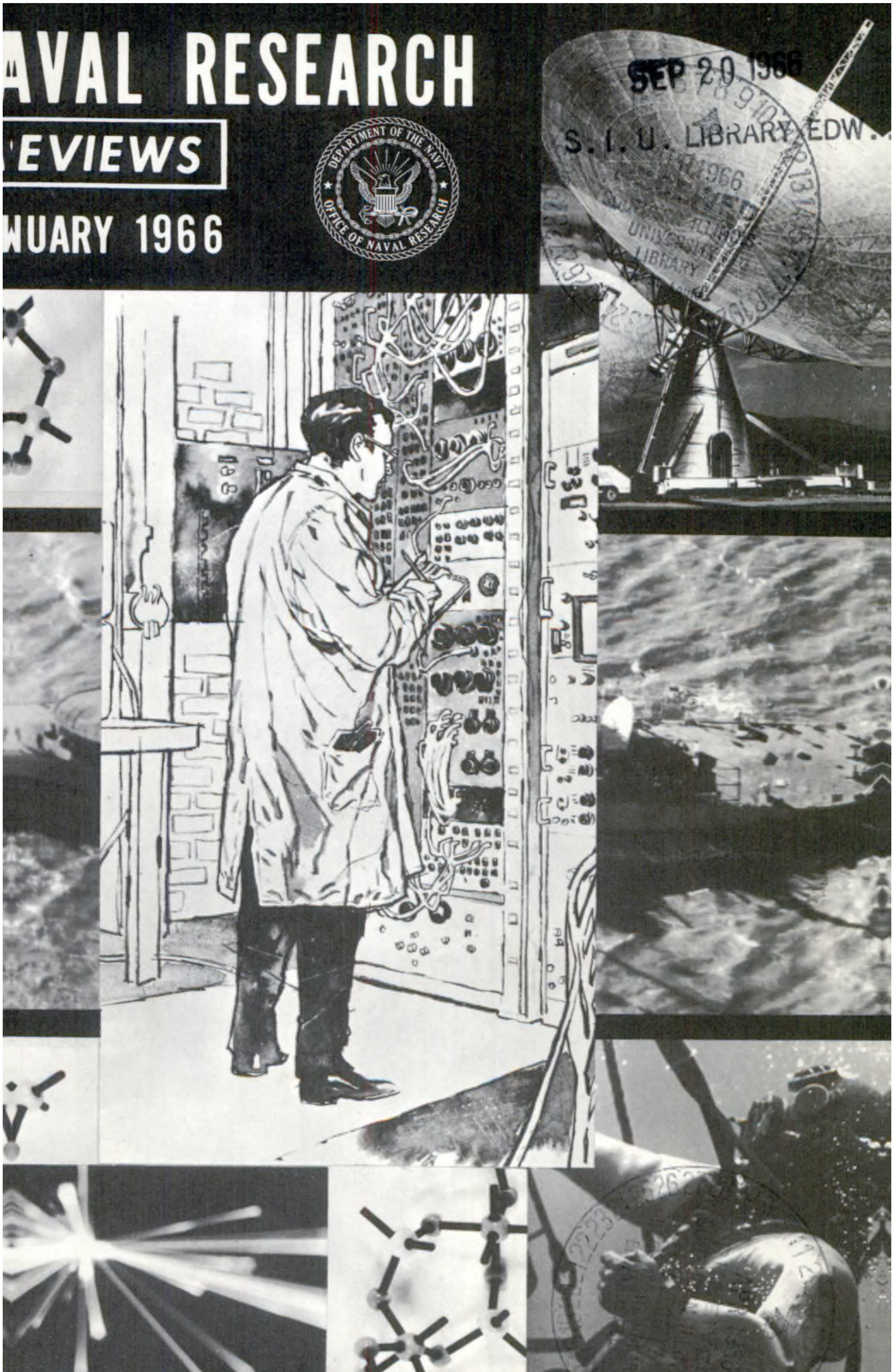
# AVAL RESEARCH
## EVIEWS

WUARY 1966







20th Year on the Frontier of Science

20th Year on

# OFFICE OF NAVAL RESEARCH VICENNIAL YEAR

## A Message from the Chief of Naval Research

*The calendar year 1966 has been designated by the Secretary of the Navy as the Office of Naval Research Vicennial Year. This action does not constitute merely the recognition of an historical fact, memorable as we believe it to be. Its significance lies rather in the encouragement that it offers to look more deeply and foresightedly at the flow of events—from a few decades back to a few decades hence—which the Office of Naval Research was created to channel and shape.*

*In the form of special events arranged for the occasion, as well as through its regular activities, serving the interpretation and dissemination of Navy-relevant scientific information, the Office of Naval Research is set to emphasize the effort of developing appropriately broad perspectives on the relation of the Navy to science. This relation is rooted deeply in history and tradition through such events as the early establishment of the Naval Observatory, the Navy's assistance in the creation of the National Academy of Sciences, and the emergence from its ranks of A. A. Michelson, the first American Noble Laureate in science. It has always been based on the clear recognition that the role played by science in furthering the Navy's capabilities is inextricably interwoven with the role which the Navy plays in science.*

*The establishment of the Office of Naval Research has been among the most forceful expressions of the Navy's firmness on this principle. Whether foreseen at the time or not, it was to turn* *out that no other arrangement could have provided the Navy with comparable flexibility in meeting the sweeping changes which the post-war years wrought in the interplay of science and military practice. This is the story we must tell and study—for the sake of whatever light it may throw on the road ahead in this endeavor.*

NAVAL RESEARCH REVIEWS *will take up in its 1966 issues an important facet of this story. It will publish a series of featured Vicennial articles, authored by distinguished members of the ONR family, which will show the ramified consequences of a few key scientific discoveries on science and technology, describe the span and depth of the research work that accounts for pivotal technological inventions, and illuminate the impact of personalities, both individual and corporate, on the evolution of science. By looking at concrete instances and observable facts, we shall approach these things as we do the development of our professional disciplines—in the scientific spirit. In the end, this series of articles may teach us more about what takes place, as the Navy makes science and science remakes the Navy, than any philosophical introspection on the principles of the thing.*

*I earnestly hope that this effort and all the other special observances which will take place during the Office of Naval Research Vicennial Year will make all of us—members of ONR as well as friends of the Office everywhere—raise our eyes to the horizon.*

JK Leydon

REAR ADMIRAL JOHN K. LEYDON, USN
CHIEF OF NAVAL RESEARCH

# A View of Science and Technology Sprung from Cryogenics

*Vicennial Article*

**Lawson M. McKenzie**
*Research Planning Associate*
*Ford Scientific Laboratory*

The striking success of the Office of Scientific Research and Development in mobilizing science for World War II and of the Office of Naval Research in establishing peacetime ties with university scientists are stories too well known to be restated, except as a reminder of *their method*. The contract method utilized by these organizations for conducting research programs followed two definite patterns: That of the *omnibus contract*, which supported a large laboratory that was virtually a government "out-of-house" enterprise; and that of the *project system*, by which a number of small contracts contributed to an "in-house" agency program.

Under both contract methods, applications of atomistic physics by basic research scientists revolutionized weapons within the short span of the War years: the bomb and radar were the unexpected fruits of basic research in atomic physics of the years just prior to the War. As the ONR launched the Navy's peacetime effort, emulating the OSRD, atomistic physics was a logical package to include on the first "grocery" list.

This is the story of one of several intensive programs in atomistic physics undertaken by ONR using the project system. It is the story of cryogenics, the science of phenomena at extremely low temperatures—temperatures of nearly 459 degrees below zero Fahrenheit. It is a story primarily of scientists working in scattered places under different regulations—some as administrators, most as research men, yet all working in complete harmony with mutual respect and with unusual freedom to get the job done.

One recalls that a number of mysterious phenomena openly challenged scientists in 1946, the most spectacular being that of superconductivity of electricity in certain metals and of the superfluidity of liquid helium. At these low temperatures, less spectacular thermal and magnetic behavior was giving new evidence for deeper understanding of the physics of solids. In every direction, challenge and promise of new discoveries prompted scientists of stature to undertake investigations of a most basic character.

Coupled with this favorable condition was the social climate of the era. The pace of war had relaxed, and the initial tremors of the technological upheaval we see today were yet to be felt. Competition for funds, competition for publication credit, exploitation of the slightest gains in the name of "breakthrough," overhead allowances, conflicts of interest, manpower stockpiling, information processing needs, and escalation of lines of authority were to appear shortly as problems, but not until the Korean emergency signalled the initial big change. Most importantly, there was a source of support – a residue of money available from retrenched wartime spending.

In fact, "normalcy" in 1946 meant a return to prewar conditions to many scientists. Some academicians had to be convinced that the funds available to ONR were for real. Few believed that they would be available for very long. Possibly the expense of the apparatus required for low-temperature investigations eased the conscience of the first ONR (then the Office of Research and Inventions) contractors. But mainly these early investigators foresaw the times to come with unusual vision and without fear. They were not afraid of military control of their destiny. They were not afraid of being over-extended or over-committed. They were eager to face the uncertainty of the outcome of their investigations. And they were eager to share their knowledge and to cooperate with others. They found in ONR the opportunity to do basic research rather than to go into engineering, full-time teaching, or other professions in the prewar pattern.

## The Program Emerges

Several laboratories were supported by ONR by the time of its first anniversary, and two conferences of cryogenics contractors had been convened to discuss their aims, goals, and methods – the first in the ONR Washington headquarters on June 7, 1946, and the second at Johns Hopkins University on December 9, 1946. The records of these initial meetings are fragmentary, but, as a minimum, the conferences represented the concerted effort of the Physics and Nuclear Physics Branch of ONR to bind the separate research projects into a viable program. This kind of ONR-sponsored research conference was not unique; for example, a like effort in spectroscopy was proceeding on a parallel course. Such efforts reflected in part the conscious attempt to create National scientific programs of significance to the Navy through contract, as had been pioneered by the wartime Office of Scientific Research and Development. The ONR scientist administrators sought to remain part of a mobilized scientific community in a real working sense and not merely in an aloof managerial way.

The effort was successful and, in fact, the U.S. community of scientist doing research at very low temperatures responded to a general offer for promotion of interchange of information and ideas being generated, whether or not they were ONR contractors. By the end of the 1940's, the ONR program became the focus of all cryogenics effort in the

Nation; that is, it was indeed a National program. National boundaries also were passed, with the help of the ONR London Branch Office; and material assistance, particularly the "loan" of helium gas by the Navy, promoted this cooperation on an international scale.

Some have attributed part of the success of the program to its close coupling with the budding solid-state program at the Naval Research Laboratory. The ONR scientist administrators were more than frequent visitors to the in-house laboratory of ONR. They had desks there and participated in the staff scientific seminars. Direct personal participation in the research work at NRL was an ambition not to be realized fully though, because of the time and effort required to administer properly the contract program.

A great measure of the success of the program was due to the close ties not only with NRL but the other great Federal laboratories in Washington, especially the National Bureau of Standards, the Johns Hopkins Applied Physics Laboratory, and the new Naval Ordnance Laboratory. Washington as a scientific community was a grand positive factor, and frequent were the business days that were concluded in a seminar at one or another of these laboratories or at meetings of the illustrious and venerable Philosophical Society of Washington.

The scientific discipline was right, the era was right, motivations of both research and administrative scientists were right, and the intellectual climate of the center of the activity was right to assure that the program would "go." There was another important factor: Wartime engineering advances placed new tools in the hands of scientists; *viz.*, microwave apparatus, or new designs of old apparatus, *viz.*, cryostats.

The war-born Collins' cryostat, developed in 1946 under Army Air Force and OSRD sponsorship, was emerging as a commercially available facility during these years. At the time, Professor S. C. Collins of MIT was giving personal assistance to a few laboratories who were building their own cryostats, supplying them with drawings as well as counsel. Professor C. F. Squire took one of the original machines with him to Rice Institute. This was presented in December 1963 to the Smithsonian Institution, having been replaced by a commercial version.

The commercial version of the cryostat became available as a result of Dr. H. O. McMahon's fine work at A. D. Little, Inc., in 1947. The second production machine was purchased by NRL. It is important to realize that these A. D. Little machines were at first bought by contractors with university funds. The discussions between university and ONR men then centered upon cooperative or stimulative support, rather than outright equipment purchase, with ONR funds going "to things that disappeared," such as investigators' summer salaries, graduate-student support, and purchase of expendable items. After all, ONR contracts then amounted to tens of thousands of dollars, and few tens at that.

The award of an ONR contract did not end the attention that the ONR scientific officer gave to the work proposed until time of contract renewal. The associations noted above were not consultative only in order to make proper judgments when examining research proposals, although this was an important factor. The ONR program administrator was continuously involved in the workaday affairs of each project. He was on the road a considerable fraction of his time to assess, to aid, to carry information, and otherwise to be part of the projects.

It was no accident, then, that Dr. F. G. Brickwedde invited ONR to hold the Third Cryogenics Conference at the National Bureau of Standards in April 1947; nor that a fourth conference was sponsored at Ohio State University at Professor H. L. Johnston's laboratory in the fall. Work in these laboratories involved improvements in thermometry, calorimetry, and other instrumentation; superconductivity at microwave frequencies; and phenomena peculiar to liquid helium—second sound and other thermal effects.

During these years, the technological benefits seemed to be in a practical (*i.e.*, high-temperature) superconductor and a sensitive radiometer. Professor Andrews' group at Johns Hopkins invented a superconducting niobium-nitride bolometer which rectified r.f. signals and could detect a single alpha particle as well as infrared radiation. Professor Ogg's work at Stanford on alkali metal ammonia solutions gave some hope that superconductivity might occur at nearly room temperatures. These solutions displayed an anamalous diamagnetism, which Professor Ogg attributed to Bose condensation of mobile electron pairs, and offered promise of superconductivity at temperatures near $-40°C$.

An attempt was made to apply these findings in a practical way, but further investigation proved disappointing—the solutions were not superconductors, and technology was not ready to pay the penalty to work at the very low temperatures of liquid helium. Applied research, which was undertaken to overcome this debility, concerned in general the behavior of materials at low temperatures. For example, Professor Collins constructed a large cryostat in which metallurgical tests were performed to extend knowledge of the properties of materials at very low temperatures. Such data would benefit future technology. The immediate payoff, of course, was in the increase of scientific knowledge and in the trained minds and hands of the graduate students who contributed. The contract with Professor W. T. Ziegler at Georgia School of Technology enabled that institution to offer the Ph.D. for the first time through the program on superconductivity of rare earths.

The way for future technology also was being opened by encouraging theoretical investigations, such as those of Professor F. London at

Duke University, which included preparation of a comprehensive treatise on "superfluids." The ONR science administrators were on the alert for possible Naval application of research findings, but the long-range effect of the program was a preparation of the intellectual soil so that seeds of ideas would ultimately sprout roots to sustain a viable Naval technology. "Superfluids," in two volumes, was such a work set to cultivate the soil. The first volume, which appeared as London's fifth technical report, reviewed the state of the macroscopic theory of superconductivity. The second volume, on superfluid helium, was not to appear until after his death in 1954. Their impact has been profound.

The nature of superfluid liquid helium below its so-called lambda point was a subject of intensive investigation by many – both theoretical, by L. Tisza at MIT and Lars Onsager at Yale; and experimental, by T. Sollar at Amherst and J. Aston at Penn State. The phenomenon of second sound, predicted by Tisza, was a main issue. The nature of mixtures of the normal and superfluid phases separated by the lambda point and the mechanism of transport by helium films were as keenly studied by C. T. Lane at Yale and J. G. Daunt at Ohio State.

The Yale group was concerned equally with the notion of quantization of magnetic flux and other magnetic properties peculiar to superconductors. Professors H. Boorse and M. Zemansky constituted another team at Columbia that was studying the properties of the superconductors of highest transition temperatures – niobium and niobium nitride. The usefulness of superconducting electronic elements in technology was an obvious spur to the ONR staff, backing their basic research. Similarly, the properties of germanium at cryogenic temperatures were being studied by Professor I. Estermann at Carnegie Institute of Technology, in extension of his wartime researches on these solid-state electronic elements.

Considerable stress has been laid on the role of the semiannual ONR conferences in communicating promptly the findings of the various projects by providing a forum of discussion. Perhaps sufficient stress has not been put on the consultative value of the projects' leaders in molding the ONR program. Their constant interest in the program and advice was in fact so deep that Professor Estermann spent a full year as a consultant to the Physics Branch and ultimately accepted the position of Director of Material Sciences of the Office.

Following the Fifth and Sixth ONR Cryogenics Conferences on April 5 and 6, 1948, at Professor Lane's laboratory at Yale University, and in February 1949, in Professor W. F. Giauque's laboratory at the University of California, a fall conference for 1949 was subsumed by the First International Congress of the Low-Temperature Commission of the International Union of Pure and Applied Physcis and held at MIT on September 6-10. This commission on very low temperatures, with C. J. Gorter as President, was organized at the first Assembly of the IUPAP following the war. This Assembly was held in Amsterdam in the summer of 1948, and the U.S. was represented by Drs. Lane and Brickwedde on the Commission on Very Low Temperatures.

The Congress was organized by Professor J. C. Slater, a Vice President of IUPAP. His introductory remarks to the Proceedings of the Congress are in the vein of this paper, although they were written from the point of view of the objectives of the newly formed Union. The hundred or so papers ranged over the properties of liquid helium, low-temperature paramagnetism, superconductivity, low-temperature electric and diamagnetic effects, and instrumentation.

The 1949 MIT meeting was a conclusion of an era—the close of the first half of the 20th Century, which saw Onnes' first liquefication of helium in 1908, his discovery of superconductivity in 1911, and the discovery of the two different phases of liquid helium in 1927 by Keesom and Wolfke. By far the most pleasant concluding note in the ONR halls, however, was the year-end news item announcing that Professor Giauque had won the 1949 Nobel Prize in Chemistry for his work in approaching the absolute zero of temperature by adiabatic demagnetization of paramagnetic salts. This event would assure the favorable action of the University of California to erect a high magnetic field laboratory, a facility of considerable promise that ONR was trying to promote for its obvious implications in low-temperature physics and atomic structure generally.

As the program entered the 1950's, it was perhaps appropriate that disclosure of the discovery of the isotope effect in superconductors was made at the Seventh ONR Cryogenics Conference at Georgia Tech in March 1950. The discovery by Dr. E. Maxwell at the National Bureau of Standards and by Professors Reynolds, Serin, Wright, and Nesbitt independently, at Rutgers University, which indicated that superconductivity arises from interactions of electrons and lattice vibrations, provided the insight needed to clarify the mystery of the nature of the phenomena. The topic was a main theme of the Bureau's Low Temperature Symposium, which was held in celebration of its semicentennial in March of 1951, taking the place of an ONR conference. The "isotope effect" remained in the spotlight until the 1957 publication by Bardeen, Cooper, and Schrieffer of their theory of the superconducting state.

The second IUPAP Congress at Oxford in August 1951 drew most ONR contractors to England *via* MATS. Perhaps this massive tour was as much a harbinger of things to come "scientifically" during the 50's as was the discovery of the isotope effect. Heretofore, ONR contractors had been enabled to visit their foreign colleagues singly, as had F. London when he was preparing Volume I of "Superfluids."

The commercial availability of the Collins' cryostat gave important impetus in ensuing years for creation of more scientific programs, and within the decade following World War II (and a generation of students) the "program" was an order of magnitude greater. By then the Atomic Energy Commission, the Office of Ordnance Research, the National Science Foundation, the International Union of Pure and Applied Physics, and other organizations were its multiple sources of support. Furthermore, communication of low-temperature science was settling on a learned-society base.

## Cryogenic Engineering Emerges

Cryogenic engineering achieved status at the turn of the 1950's. In 1949, S. C. Collins was appointed Professor of Cryogenics Engineering in the Department of Mechanical Engineering at MIT: nearly ten years later he was to receive the Kammerlingh-Onnes Gold Medal. A cryogenic engineering firm, Herrick L. Johnston, Inc., was opened in Columbus in 1952 by another ONR-supported professor: It became one of many. The profitability of cryogenic engineering at Arthur D. Little, Inc., under the strong hand of Dr. H. O. McMahon, was undoubtedly one of the factors which led to his appointment at that time as Science Director of the firm: He is now President. The National Bureau of Standards Cryogenic Laboratory was established in 1951 to provide engineering data on the properties of materials, as well as for the manufacture of the large quantities of liquid hydrogen needed for the first nuclear-fusion experiments using tritium. It became a division of the Bureau's Boulder, Colorado, Laboratories in 1954. The cryogenic center, now the Nation's largest, is the focus of cryogenic engineering and research, which supports a bustling business.

The NBS Cryogenic Laboratory started as an AEC-supported project at the Bureau in Washington in 1950. It was directed by Dr. F. G. Brickwedde, Chief of the Heat Division. In 1950, the Laboratory was moved to Boulder in accordance with the original plans, with Russel B. Scott in charge. The AEC-built NBS Laboratory was the first facility to be constructed on the Boulder site. The hydrogen liquefier erected there had a capacity of 325 litres per hour, which in those days was five times the capacity of any other hydrogen liquefier.

The Boulder Laboratory inaugurated the first Cryogenic Engineering Conference in 1954 to improve the interchange of information among the practitioners of the newly recognized engineering profession. More than 200 U.S. scientists and engineers attended the three-day meeting to hear 57 papers. A second conference was held two years later which attracted 400 people to hear 49 papers. These conferences have since been held annually at various locations around the country and have grown in size and importance. Registration recently exceeded 1000 for the meetings. A blend of science and technology continues to mark the nature of the papers presented at these conferences. In 1960, the decision was made to publish the proceedings of the first conference as well as of the subsequent ones, so that today a shelf of volumes provides an important working record for the practitioners of the new profession.

In 1961, an award for a paper of particular merit was established by the conference and, appropriately, was given for a paper coauthored by men of the Boulder Laboratory. It was a testimonial to the intellectual leadership exercised by the men at Boulder. Their leadership through service to the cryogenic engineering community has been pointed up particularly by their staff work for the annual conferences.

In 1965, Professor Collins was honored further, not only by being selected to receive the first Cryogenic Engineering Conference Award for distinguished service to the cryogenic community at the Rice Institute conference, but by the decision to name the award, to be given in future years, the "Samuel C. Collins Award."

## Cryogenic Science Diffuses

The advent of the First Cryogenic Engineering Conference at Boulder in 1954 was preceded, a year earlier, by a relaxation on the part of ONR in its support of an intensive program of basic research in cryogenics. The Schenectady Conference of October 1952 was sponsored jointly by the National Science Foundation and ONR in anticipation of the Foundation's ability and willingness to act as mentor of the many university contractors of ONR. With such a possibility under discussion, this was a time of summarizing and restating research administration principles and practice. A paper entitled "After Six Years – A Study of the Impact of the Physics Branch Program" was distributed at the conference and published subsequently in *Science.** It explained:

> *With rising costs, an enlarging scientific community, and a fixed budget (the budget of the Physics Branch has remained at substantially a constant level for 5 years), such diffusion is the only mechanism to meet the new demands for necessary researches in physics. The Physics Branch welcomes the new sponsoring agencies as an aid in removing the dilemma, although the problem of multiple sponsorship of the various programs raises new problems of scientific administration.*

The hopeful outlook in the direction of the Foundation, which was occasioned by a previously successful "transfer" to the Office of Ordnance Research of the ONR program in molecular spectroscopy, proved

*Science *118*, p. 227, August 28, 1953.

disappointing. This was because the referee approach of the Foundation was time-consuming and also because its orientation toward a traditional university departmental breakdown of activity did not fit the interdisciplinary character of the field. There was no loss of financial support of the cryogenics work, but there was a loss of cohesiveness because of the slacking of effort to provide interdependence of projects. This loss of momentum was momentary, for natural professional forces were overtaking the catalytic work which marked early ONR efforts, and the self-coordination natural to an established science was relaxing any serious requirement for assistance by a mentor.

The third IUPAP Conference was held at the Rice Institute in 1953 under NSF sponsorship. Two hundred scientists from all over the world attended. The fourth IUPAP Conference was held in Paris in September 1955 and the fifth at the University of Wisconsin at Madison in 1957. The latter was attended by 440 scientists and featured over 200 papers by 340 authors. The first Fritz London award was presented to Nicholas Kurti at the Madison meeting—another mark of the complete synthesis of this field of science. Three conferences later, in 1960, 430 scientists were in attendance at Toronto to hear 192 papers. The ninth IUPAP Conference was held at Ohio State in 1964. Lately, the basis for such large meetings has become somewhat uncertain. At each meeting since 1960, size and specialty have been a source of annoyance, and a great deal of feeling has been generated urging a breakup of the meeting into smaller, more coherent groups. For example, the IBM-sponsored meeting on superconductivity in 1961, which drew 138 members, seemed about right in size and in detailed topical programing. Perhaps the best way to spell this out is to quote* from the introduction to the Proceedings of the International Conference on the Science of Superconductivity held at Colgate University in August 1963:

> *This Conference follows at approximately two year intervals ... similar conferences held at Cambridge University (1959) and at the Thomas J. Watson Research Laboratory of the International Business Machines Corporation (1961). It is not intended in any way, however, to set a pattern or precedent for future conferences. It is believed by the organizers that topical conferences such as this one should be held only when warranted by current scientific interest.*

## Cryogenic Technology

The Cryogenic Engineering Conference now draws about a thousand scientists and engineers to its annual meeting, which is sponsored by more than 50 industrial firms and government agencies. It must hold multiple sessions to accommodate the flood of papers presented

*Rev. Mod. Phys. *36*, 1964, Part 1, pp. 1-331.

(at the 1965 meeting in Houston, eleven sessions were held in three days). One might wonder if cryogenic engineering is now at the stage of maturity where the NBS Boulder Laboratory mentorship relation will soon relax. This is probably to be expected of a cryogenics industry which today is nearly a $750 million per year business. Although 95 percent of these funds go to the liquefication and separation of gases, the 5 percent remaining is a respectable figure, and the ratio will undoubtedly change in a few more years. The high demand for gases results from their new application to a variety of old uses. For example, the basic oxygen process of steelmaking now uses 1000 cubic feet of oxygen per ton of steel to more than double the output rate obtained previously by the conventional open-hearth process. A new but expected reason for the growing use of liquid oxygen is tipped off by the liquid's nickname, LOX – a dramatic eponym in the exotic aerospace game.

Helium, the gas of particular importance to cryogenics, has been produced recently in astonishing quantities – over 2 billion cubic feet in 1963. Under control of the U.S. Bureau of Mines, helium is separated by liquefication of natural gas of our southwestern fields. Only 12-1/2 percent is used in cryogenics research and applications, the bulk being used in industry and commerce for pressurizing and purging, welding, controlled atmospheres, balloons, *etc.* (U.S. Bureau of Mines Yearbook for 1963). Half is taken in connection with America's space program. Giant liquefiers, one of which has a liquefication rate of over 500 litres per hour, are required for such tonnage quantities. In turn, the transport of helium requires efficient Dewars, for economy dictates shipping as a liquid rather than as a gas under thousands of atmospheres pressure. Tankers of 10,000-gallon capacity are used in such distribution. As a result, liquid helium is available at a few dollars per litre.

The profitability of applications of cryogenics in technology will cause business to seek other new opportunities as familiarity leads to further uses. Aerospace applications, in addition to those relating to fuel, already include cryopumping and the cooling of walls of space simulation chambers. Some of these chambers are basically spheres that are 90 feet in diameter. These giants remind one of the liquid-oxygen facilities at large steel plants. The trapping of free radicals opens up possibilities for new chemical processes. Cryosorption pumping extends cryopumping as a technique for ultra high vacuum technology. Cryobiology already has seen exciting medical applications – the storage of human blood and other parts of the body are typical of the "banks" now possible. Cryosurgery is helping many people who suffer from Parkinson's disease, cataracts, and other ailments.

In addition to these applications are some which are totally new and generally unfamiliar in technology. Superconducting magnets have become commonplace in the laboratory as a result of the discovery in 1961 that a niobium-tin compound could carry very large currents in high fields. There are now about 200 in use, providing intense magnetic fields of the order of 100,000 gauss, powered by only a few lead-acid storage batteries. Lqiuid helium is used as a refrigerant in connection with these magnets. There are now 300 Collins-A. D. Little cryostats* that are busily making this unique liquid or that are being used in closed-cycle refrigerating of low-temperature apparatus. The maser detectors for satellite communications are cooled in this way. The latter scheme is not particularly new; for example, deuterium was recondensed in transit from Boulder to Eniwetok for the initial hydrogen bomb experiments.

Within the foreseeable future, the quantum nature of liquid helium and of superconductors will be exploited further, for scientists are now beginning to put to practical use these substances, which are in the "fourth state" of aggregation, by means which depend on their macroscopic quantum properties. A few years ago, McMahon's group at Arthur D. Little hoped to exploit a device named "the cryotron," which though not strictly a quantum-effect device, seemed a hopeful candidate for computer-memory applications. It proved disappointing because it was essentially a switch acting between the normal, or non-superconducting, state and the "fourth state" of superconductivity which London was explaining during the 1940's. In fact, engineers are working with scientists on a variety of applications of the giant quantum effect in superconductors. Several developments are under way—one exploits a magnetometer of ultimate sensitivity. It is interesting that London's universal unit for the so-called "fluxoid" ($hc/2e = 2.10^{-7}$ gauss $cm^2$) is the calibration unit of the new magnetometer and a principle he wrote down in Volume I of "Superfluids."

The "fourth," or quantum, state of matter thus is just beginning to appear as a thing of macroscopic usefulness to engineers and not just as a fascinating "kind of quantum condition." There is a possibility that when the development of superconducting magnets reaches the point at which reliable magnets that generate fields in excess of 100 kilogauss in volumes of one to a few cubic meters can be produced, a very important application for the controlled thermonuclear project of the AEC (Sherwood) will be found, resulting conceivably in a breakthrough in this effort. A cryogenic gyroscope offers a possibility for a truly minimum drift instrument: One version involves the perfect diamagnetism of a superconducting rotor; in other concepts for a gyroscope, liquid helium provides the perfect lubricant needed. A magnetometer which measures in quantized flux units has been mentioned already. Amplifiers, oscillators, accelerometers, seismometers,

*The 300th engine was installed at St. Andrews University (Scotland) in August 1965. Dr. Collins attended the ceremonial event.

and other instruments are being developed also, making use of the giant quantum in superconductors. There is a moral in this story, however, which is best given in the words of Professor A. B. Pippard, quoted from the last paragraph of the Proceedings of the Colgate Conference:

> *Here we have one of the most striking antitheses one could imagine between the pure scientist and the engineer. The engineer is already attempting to apply something which, as yet, is incompletely worked out from the physical point of view, and it is a real responsibility to try to resolve this antithesis. One of our most urgent tasks, which I class among the unsolved problems, is to make superconductivity intelligible to the ordinarily trained scientist, and in particular to the man who wants to use superconductivity for technical purposes and cannot be expected merely to rely on his mathematician or physicist to tell him the next step he should be taking. I promised you an inspirational sermon, and I cannot do better than to finish at this point with a clear indication of our duty to our neighbor.*

The issues are joined. They depend upon people respecting the ambitions and contributions of each other. Some issues have been traced in this story, but by no means has the story been told fully, nor is it complete. In fact, this story has been mainly one of the interrelation of people, particularly the investigator and administrator working together, each considered by the other to be involved equally in forwarding science and engineering.

## A Final Word

As the picture unfolds and the generations of investigators, their students, and their students' students leave behind the 1946-52 period of the ONR cryogenics program, the happenings of that time become dim. It was a period of genesis. The personal associations between research and administrative scientists as fixed by the conferences of this recital, by the material as well as financial support channeled into the area, and by logistic aid continue now through memory to constitute firm bonds of friendship. They give rise to stories of the good old days, highlighting cryogenics as one of the summits of support of science by the United States Navy. Supplies of helium, MATS transportation, the conferences, advice (often unsolicited), and loan of equipment are as well remembered as the financial support. It should not be forgotten that the budget for cryogenics had to be won within the ONR in competition with other important areas of scientific promise and usefulness. There were arguments and "politics" involved, but they were part of the game which is now clothed with the respectable title "Science Administration." But most importantly – probably the key point – the budget then was mainly for support of graduate students, many of whom are now leaders of the vast science and technology sprung from cryogenics.

# Prospects in Oceanography—Central Science of the Navy*

**Rear Admiral John K. Leydon, USN**
*Chief of Naval Research*

In discussing the Navy's research program in ocean sciences there are certain difficulties. The Office of Naval Research is a dynamic institution whose objectives, perspectives, and method of operating change continually. The present time is one in which changes under consideration may alter the nature of ONR's support to oceanography.

No matter how it has been stated for various bureaucratic purposes, the prime objective of ONR's program historically has been "to build up a national competence in oceanographic research such that, as needs arise within the Navy, we will have the basic knowledge, trained personnel, and technical proficiency to meet these needs." Within the scope of this broad objective, we have had many, more restrictive goals which orient our programs to emphasize those scientific areas of known relevance to the Navy.

We operate in, on, and over the ocean; therefore, all ocean science is important to us. There is, however, a distinct difference between our broad approach of supporting basic research in the oceans and the more narrow scope of a bureau laboratory, for example, of stressing all factors that concern underwater sound and thus bear on detection or weapon systems. In general, our ocean-science program is oriented to provide for a more complete basic understanding of the oceans. It must be noted, however, that as time progresses, we are shifting a larger fraction of support to areas of direct Navy relevance. This shift in emphasis is influenced by three separate considerations. First, the growth of support for oceanography by the National Science Foundation has removed much of the burden that the Office of Naval Research has carried in fostering and maintaining the nation's oceanographic capabilities at private laboratories. Second, the Congress has stated specifically its desire that the Department of Defense reduce its support of basic research, especially where it could be supported by the civilian agencies. Third, the technology for research at sea has now advanced to the point where truly significant experiments can be conducted on the oceans. Such experiments will require careful planning, large support, and continuity. The Office of Naval Research can and will support these kinds of studies.

*An address given by Admiral Leydon at the Underwater Acoustics Symposium banquet on December 1, 1965, in Washington, D.C.

To attain its objective of providing knowledge, personnel, and technical competence in oceanography to meet Navy needs, ONR has encouraged the establishment of oceanographic laboratories and educational facilities throughout the country. Specifically, ONR has been largely responsible for the establishment of the oceanographic programs at The Johns Hopkins University, Texas A&M, Oregon State University, Massachusetts Institute of Technology, Hudson Laboratories, as well as for the expanded efforts at the University of Rhode Island and the University of Miami. All of these laboratories contribute directly to both basic research and education of oceanographic personnel. In addition to the above, which have grown through direct encouragement from ONR, we have assisted appreciably in building up the capabilities of Scripps Institution of Oceanography, Woods Hole Oceanographic Institution, Lamont Geological Observatory, New York University, the University of Washington, and other institutions.

In addition to providing financial support, we have enhanced the laboratories by providing a number of ships either through new construction or conversion. Of 24 major ships operated by private laboratories and which are funded jointly by Federal agencies, over 50 percent of the support comes from ONR. Many specialized facilities, such as FLIP, ALVIN, Arctic drift stations, four-engine research aircraft, telemetering buoys, and stationary towers, have been developed by, or made available to, the personnel of these private laboratories for research. All of these factors combined with the personnel we support represent ONR's capabilities in oceanography. These capabilities are significant when compared on any scale with other oceanographic capabilities of the United States or with the capabilities of other nations.

Our criteria for support of research are the following: (1) the research proposed must be good, (2) the investigators must be well qualified, (3) the institution must have the necessary facilities, and (4) the program should be relevant to Navy needs. In addition to satisfying these criteria, we have long maintained a policy of continuity of support; that is, we have attempted to provide stability in a field of science where capital and operating costs for research are higher than normal.

A commonly used approach has been to place funds at the disposal of the directors of institutions having programs conforming to our criteria. Therefore, the programs at these laboratories develop largely along the lines determined by the directors and their staffs. Around these centers, students have been attracted, facilities developed, and research programs prosecuted.

As the objectives of ONR change, namely, from the broad concept of building up and maintaining an oceanographic capability to the more restricted idea of utilizing this capability to increase systematically our knowledge of ocean phenomena (especially where there is recognizable direct relevance to the Navy), we find it more and more difficult to continue using the approach of institutional support. In this connection, we find our policy changing, although our four basic criteria remain the same. To us, it is clear we must put more emphasis on specific problems and leave the concept of broad, stable, institutional support to the National Science Foundation.

This represents a significant change which has been evolving for several years. Unfortunately, although the necessity for this change is well recognized in Washington, many of the laboratories have found it difficult to accept or conform to. As a result, ONR does not have the desired strong research program directed toward the solution of well-defined scientific problems. Instead, its program still consists primarily of a collection of broad institutionally supported studies. Because of this fact, it has been difficult within both the Congress and Navy Department to muster financial support for an expanding Navy oceanographic program.

Oceanography has fared relatively well, however, among the total ONR programs. Since 1962, the total ONR budget for its contract research program has increased 27 percent. During this same time, the funds available for oceanography, within ONR, have increased 67 percent. This is a dramatic re-emphasis within ONR's total program.

Because of the change in basic philosophy in ONR along the lines just mentioned specifically for oceanography, it can be anticipated that this trend toward a stronger oceanographic program will continue. It is obviously easier for ONR to justify support of research in oceanography because of its relevance to the Navy than in many other scientific areas. The degree of this trend will depend, of course, on the ability of the oceanographic program to focus its efforts as has been suggested previously.

Within the oceanographic program, certain areas have received more attention than others. Naturally, with the importance of underwater sound to many aspects of naval operations, it is not surprising to see areas such as marine geophysics, distribution of physical and chemical properties, and marine biology all well supported. Similarly, engineering aspects that provide new tools or new ways to examine the sea are also well supported, as are wave studies and ocean dynamics. This reasoning holds to a lesser degree for marine geology. Areas which may be quite exciting from a scientific point of view, such as geochemistry, have not fared as well. In part, this is because the interest of scientists was aroused at a time when the overall complexion of the program was shifting from the broad to a narrower concept.

What have been our major accomplishments? ONR feels justifiably proud in having played a major role in building up the competence of the country's oceanographic program at various laboratories.

Many other achievements of a very different nature can be mentioned; these include, for example, the initiation within the U.S. of programs in deep submergence—first the work with the TRIESTE in the Mediterranean and later the transfer of that vehicle to the U.S. for use. Along these same lines, we have supported the design, construction, and research work of ALVIN at Woods Hole. These programs have opened a whole new era in the study of the ocean. Similarly, our support of research and development utilizing moored sensors in the deep ocean has reached a point where again we have provided a radically new opportunity for investigating the oceans. Much of the equipment that is in routine use aboard survey and research ships has resulted from our programs. Gravity meters, magnetometers, and sparkers are a few of the common examples.

While perhaps not considered a major accomplishment by some, ONR, through the National Academy of Sciences Committee on Oceanography (NASCO) and by working closely with the Bureau of Ships, provided the impetus that led to the design and acquisition of the first new ships for oceanographic research since 1930. These new ships have been the opening wedge of an expanding oceanographic program.

In addition to these material accomplishments, the scientific achievements of ONR in the field of oceanography have been significant. Recently, we compiled a summary of accomplishments over a five-year period which has been used as a basis for a chapter in NASCO's forthcoming report on "Achievements and Opportunities in Oceanography." They are much too voluminous to cover in a discussion such as this. It is on the long-term accomplishments that ONR has focused, and on these its success should be judged.

Although many examples could be given, only one will be mentioned as a "for instance." That one involves the study of the nature of the ocean's bottom. Prior to ONR's support of several marine geophysical programs, little, if anything, was known concerning the structure of the ocean bottom. Our programs have provided seismic, geomagnetic, geothermal, and gravimetric evidence that is now comparable to what is available in continental areas. We have learned that the crust is thinner beneath the oceans than under the continents; that the sedimentation is thinner and more complicated than had been predicted; and we now have theories concerning the evolution of the earth which appear valid. Not only has this program provided major scientific advances in our understanding of the earth, but the "spin offs" for Naval purposes have been equally rewarding. Much of our present-day weapons effectiveness and detection systems for submarines has evolved directly from these programs. When the Navy lost the submarine THRESHER, the personnel and technology from these programs enabled the Navy to find and photograph the sunken hull.

What would we know about the ocean's bottom if it had not been for the Ewings, Hersey, Revelle, Raitt, Vacquier, Shor, Worzel, Bullard, Menard, Drake, Spiess, Heezen, Hill, and many others who have received a major portion of their research support from ONR? Perhaps a simpler way to discuss achievements is to try and name any major oceanographic advancement that cannot be attributed to ONR support either directly or indirectly. It is hard to find one.

What are the opportunities? Within the scope of the reorientation of ONR's philosophy for supporting oceanography, many opportunities exist. There are significant scientific programs that have Navy relevance and which require the kind of long-term stable support ONR is able to provide. In fact, the opportunities are so numerous, the difficulty will lie in selecting which ones appear to be the most rewarding both from the scientific and Navy points of view.

Among the most obvious opportunities are programs that will utilize new technology to understand the dynamics and variability of the oceans through the application of time series measurements. The necessity that some of these measurements must be made over periods of several years and over relatively large areas suggests that they will be inherently expensive. This requires careful planning and well thought-out experiments before any decisions are made to proceed. We have stimulated thinking in this area through a two-week discussion held in Woods Hole last summer. As a result, we have high hopes that within a month we will have at least three alternative programs documented in sufficient detail so they can be reviewed critically.

A second area of new opportunity lies in the utilization of the many deep-submergence vehicles that are becoming available. As yet, the research potential of these vehicles is not being exploited fully. Most of the effort has gone into reconnaissance dives which have allowed the scientist to see some of his problems first hand. The more sophisticated operations involving the use of proper measuring devices are still in the future. Since such efforts will be expensive, they must be well conceived and planned in detail before proceeding.

New technology will play a major role in the future of oceanography. Packaged equipment placed aboard "ships of opportunity," high-precision navigation, data telemetry, and real-time analysis by means of computers will change the ways of the oceanographer. We must be alert for such changes and be ready to accept them where they promise real gains. Caution must be exercised lest we find ourselves basing tomorrow's plans on yesterday's thinking only because large capital expenditures and long lead times were required to attain the capabilities which are now available to us. A substantial program in ocean engineering, combining the capabilities of academic institutions and industry, will be useful in this connection.

While plans for funding levels, ship construction, and facilities construction are relatively easy to formulate, plans for future scientific programs are a different matter. The necessity for planning ahead is accepted, but while plans must be based on existing knowledge, flexibility must be maintained to take advantage of changing situations. We expect that the next five years will see a complete alteration of our posture from that detailed in the original TENOC document. TENOC projected an orderly increase in support at leading institutions for their broad-based programs. This remains an essential for healthy growth of the national competence, but with the multi-agency support now available to private laboratories, it is logical that the Navy relinquish at least part of its past responsibility for institutional support to some other agency or agencies.

At this time, a number of scientists under ONR contract are documenting critical experiments in physical oceanography which are feasible and which promise knowledge that would speed up our attainment of understanding of the ocean. ONR intends to marshal its resources behind the most attractive of these. We expect this will involve the operation of large arrays of sophisticated instruments, the collection and processing of vast quantities of data, and the dissemination of the digested results to the research community for analysis.

In the field of marine geophysics, we feel that the approach to date has been largely an exploratory one and that the point of diminishing returns is being approached. We should now be in a position to ask important questions and, with the courage to focus our attention on one at a time, mount efforts to obtain the answers. It is not yet clear that the geophysicists are ready to use this approach, but we intend to encourage it by giving preferential support to investigations of this nature over continuation of piecemeal general studies.

The situation is less clear in the fields of biological and chemical oceanography, but here again it seems that we must be approaching the point where important basic questions can be formulated.

In our plans, we look forward to 1970, when our basic-research program in oceanography will be involved mainly in systematic attack upon well-defined problems.

Our plan is to encourage the interested people to define further the objectives and design of experiments. These will be submitted to others for review, criticism, and refinement. Hopefully, other as yet unidentified experiments also will be forthcoming for consideration. As soon as there is reasonable agreement, engineering advice will be obtained to provide a realistic cost figure, and negotiation for funding will be started. When the prospect of being able to embark on one of the projects becomes real, the designers of the program will be convened to discuss mutually acceptable operating arrangements.

What does this all mean? It means that a new dynamic force is being applied to the Navy's ocean-sciences program. The Assistant Secretary of the Navy (R&D), the Oceanographer of the Navy, and I have had many sessions of late on these subjects. My group is being strengthened — ocean engineering, oceanography, and related disciplines are today being pulled together to a more cohesive, visible focal point. The Oceanographer of the Navy is strengthening significantly his technical group.

To those who compare our efforts in science in the oceans with our efforts in space, the comparison is apparently odious. The fact remains that the Navy tries hard to do the most it can with the financial and other resources it gets by permission of your representatives and mine. You need not fear that our approach to ocean sciences will be less than it could be; in fact, it will be all that the law allows. The law allows enough for a dynamic program; and that is what we intend to have — period.

---

## Project LEX

The creation of a technical thesaurus for use in connection with the communication of information among Department of Defense activities has been initiated by Dr. John S. Foster, Jr., Director of Defense Research and Engineering. The undertaking, known as Project LEX, is a major phase of DOD's current program to broaden the effective exchange of technical information.

The selection of words and terms that express concepts or units of information is essential to the growth of automation. Important also to this growth is the preparation of a guide to these words and terms. Project LEX is seeking to fill this need with the thesaurus approach.

Scientific and technical terms are being gathered from all phases of DOD activities, such as research, development, engineering, requirements studies, program planning, intelligence estimates, budget analysis, operations, supply, maintenance, and the related professional groups, industries, and educational institutions.

The Office of Naval Research is responsible for preparation of the thesaurus. It will be aided by a 14-man project task force that will include representatives of the three military departments, the Defense Documentation Center, the National Security Agency, and the Defense Intelligence Agency.

Publication of the thesaurus by the Government Printing Office is anticipated before the close of fiscal year 1967.

---

**No one could predict** in 1947 that the Navy would need a long-range ballistic missile powered by solid chemical fuel. Nevertheless, ONR, at that time, instituted a broad program of research in synthetic solid rocket propellants; we were confident that this would result in a whole family of high-energy propellants having a wide range of physical and chemical properties. Initial study showed that a self-combustible plastic was needed, and basic chemical knowledge developed after three years of research resulted in nitropolymers. The advent of a practical POLARIS missile came out of this research, which started in 1947. *From a speech by CDR H. D. Moore, SC, USN, Director, Procurement Services, ONR, given at the Northeastern States Navy R&D Clinic, Philadelphia, Nov. 19, 1964.*

# Operation Cherry Blossom

Under the sponsorship of the Department of Defense, three United States students represented the Army, Navy, and Air Force at the Japanese Science Awards ceremony, which was held in Tokyo during the first week of November. This representation program, known informally as "Operation Cherry Blossom," has been sponsored by the Department of Defense for the past three years. Each branch of the military services selects a student winner at the U.S. International Science Fair as its representative at the Japanese Science Awards. Management of the program is rotated annually among the Army, Navy, and Air Force. The 1965 program was under the direction of the Department of the Navy, and the Chief of Naval Research was assigned responsibility for it.

Students selected for representation in 1965 were Mr. Richard Gott of Louisville, Kentucky, for the Navy; Mr. William Voekle of Houston, Texas, for the Air Force; and Miss Barbara Bennett of Terre Haute, Indiana, for the Army. The U.S. students were among 40 foreign students who received honorary medals as representatives of five participating foreign nations at the ceremony. Two hundred seventy-five Japanese students received the coveted winners' medals. An honorary medal also was accepted by a U.S. Naval official on behalf of the Department of the Navy.

The background of this unique award ceremony lies in the world-wide surge of interest in science which occurred after World War II. Japan realized fully the implications of scientific research, as did the West, and many of its leading citizens became exponents of furthering scientific education. One of these citizens, Mr. Matsutaro Shoriki, former State Minister of Science and the publisher of the *Yomiuri Shimbun*, a leading Japanese newspaper, directed the cultural staff of the newspaper to sponsor a student science fair and awards. In 1956, with the aid of Science Service, Incorporated, of Washington, D.C., which sponsors the U.S. National Science Fair, the *Yomiuri Shimbun* inaugurated its annual science competition.

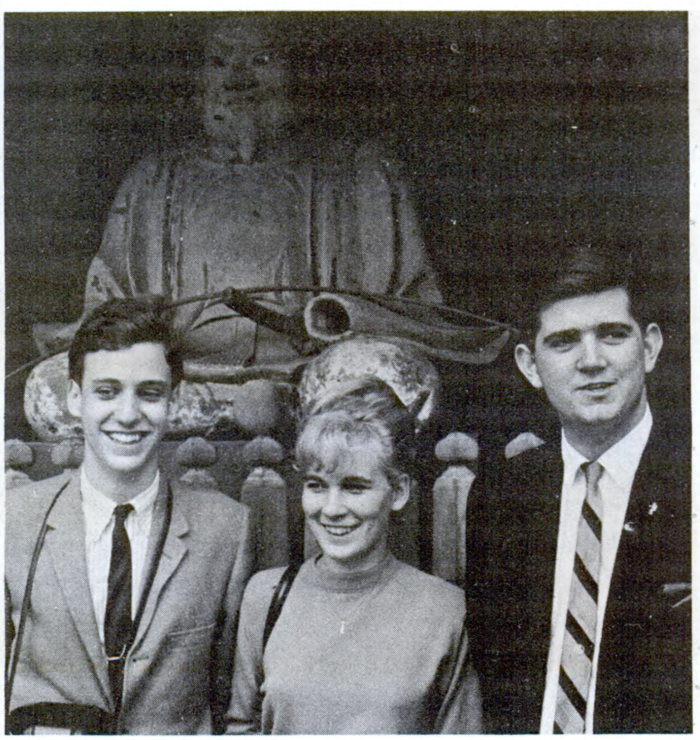
The purpose of such fairs, of course, is to promote an interest in science among young people of high-school age. Science fairs, honorary awards, and scholarships often stimulate students to enter scientific fields as career endeavors. In these efforts the *Yomiuri Shimbun* has had the full support of the Japanese government and the Japanese scientific community through the National Council for the Advancement of Scientific Education.

Tradionally, competition in the fair has been limited to Japanese students, although students from foreign lands have been invited to exhibit their science projects in Japan and to participate in the award ceremony.

In this regard, the Asia Foundation has been instrumental in sponsoring the participation of many Asian countries, including the Republic of China, Malaya, the Republic of Korea, Okinawa, Pakistan, Hong Kong, and the Philippines. The Japanese Science Awards Committee had long been hopeful that the United States also would send participating students, particularly inasmuch as Japanese students compete in the annual U.S. Science Fair International. However, financial difficulties prevented U.S. student participation until 1963, when the Department of Defense approved sponsorship of the program and "Operation Cherry Blossom" was born.

The Department of Defense sponsors the program as a reward for scientific excellence achieved by American students. In Japan, the three American students exhibited their projects along with the other students in the new and modern Museum of Science and Technology, thereby fostering greater international scientific understanding as well as cementing Japanese-American relations.

The students were selected for their work in mathematics, physics, and biology. The Navy winner, Richard Gott, was singled out for his efforts in developing a new class of geometric figures, called "pseudo polyhedrons." The Air Force winner, William Voekle, developed a project in the area of ion rocket propulsion, and the Army winner, Barbara Bennett, was selected for her work in the biological sciences. Miss Bennett has developed and patented a new method for producing mushrooms in a tissue culture.



Student science-award sentatives of the U.S. Richard Gott (left), the Barbara Bennett, and th Force, William Voekle, themselves during sight tour in Tokyo.

Among the highlights of the students' trip, in addition to the highly ceremonial award presentation, was the opportunity given them to hear Russia's most famous team of astronauts, Colonel and Mrs. Andrian Nikolayev, speak on the importance of science to all nations. The students also were greeted by representatives of the Japanese Prime Minister, the State Minister of Science and Technology, and representatives of the Japanese scientific community.

The Department of Defense was represented at the ceremony by COL Chester B. Wine, Director of Training and Personnel, Headquarters Fifth Air Force, and COL C. W. Cook, Commander of U.S. Army Research and Development, Far East.

Other activities in Japan included a visit with the American Ambassador, a two-day visit with Japanese families, a visit to a Japanese high school, tours of historic sites of interest in the Tokyo area, and tours of U.S. military facilities in Japan.

On its return to the United States, the official party of "Cherry Blossom" stopped in Hawaii as the guests of Admiral Roy Johnson, Commander-in-Chief of the Pacific Fleet. Admiral Johnson met with the students briefly and congratulated them for their scientific achievements.

As the trip drew to a close, Mrs. Dorothy Schriver, Associate Director of Science Service, Incorporated, who was among the group that accompanied the students, noted that "the students had created good will not only for science but also for the United States by projecting a very favorable image of American youth."


Richard Gott, student science-award representative of the U.S. Navy, discusses his exhibit during Japanese Science Awards program.

# Psychological Aspects of Antarctic Living*

**LT Paul D. Nelson, MSC, USN**
*Navy Medical Neuropsychiatric Research Unit*
*San Diego, California*

Guided by the heroic feats of such great polar explorers as Amundsen, Scott, and our own late Admiral Byrd, the United States has constructed and maintained several permanent research stations on the Antarctic continent. In support of the scientific mission of the Office of Antarctic Programs, the Navy has contributed logistic services in the form of supply, transportation, and personnel. Since 1956 the Navy's Bureau of Medicine and Surgery has provided assistance by conducting annual physical and psychiatric screening of Antarctic duty volunteers and, during the past five years, by sponsoring a continuous program of research concerned with man's adaptation to the rigors of Antarctic living. The present paper is a survey of the research on psychological problems which the Navy has conducted. Although there are many hundreds of men who participate in various types of Antarctic efforts, it should be mentioned that the study of psychological problems has been focused upon those who actually live at the research stations for a continuous twelve-month period.

In the study of ecology, one should have some understanding of the more salient attributes of both the environment and the organism. A few remarks should therefore be made about the Antarctic station setting and similarly about the population of men who inhabit these stations.

Climatic conditions surrounding the stations vary according to time of year and location of station. Temperatures have been below −100°F (−73.2°C) and seldom warmer than 40°F above zero. Altitudes range from approximately sea level to the 9,600 feet above sea level found at the South Pole station. During the six summer months of nearly continuous daylight, activities are carried on out of doors; at this time even the relatively moderate climate makes difficult the heavy work entailed in construction projects and in the receiving and storing of supplies. Once the darkness of winter sets in, the activities at most stations are confined almost exclusively to the indoors as supplies cease coming in, and, except for occasional radio communication, the

*Delivered at the 71st Annual Meeting of the Association of Military Surgeons of the United States, Washington, D.C., October 20-22, 1964. Reprinted from *Military Medicine,* Vol. 130, No. 5, May 1965.

men are isolated from the outside world for approximately six months. The stations, being small communities of quonset huts and located under ground at two of the interior sites, provide a physically and socially restricted environment for the men who winter-over.

There is one relatively large station, McMurdo Base, which is composed roughly of 200 men. This station is structured similarly to other commands of comparable size, having a complete staff and departments. The smaller outlying stations, which during the past year included Byrd, Eights, and Palmer in addition to South Pole, have varied in membership size over recent years from 8 to 35 men. It has been upon these smaller stations that most of our research efforts have been focused.

Navy enlisted personnel generally comprise about 60 percent of the small station membership; there are usually several Seabees having different construction skills, two radiomen, an electronics technician, a hospital corpsman, and a cook. A Navy medical officer has been assigned to several of the stations during recent years; in addition to carrying out his professional responsibilities, he has served as officer in charge. Completing the station membership are civilian research personnel, including a meteorology crew which continuously monitors weather conditions and several students of the earth and atmospheric sciences. The median age for both military and civilian personnel has been about 27 in recent years. The men have ranged in age from 18 to 45. Somewhat less than 40 percent of the men who winter-over are married. While the military personnel, who have an average of eight years of job experience, tend to have more field experience than the civilian members of the station, the latter have higher levels of formal education. The civilian personnel, in terms of background characteristics, are more likely to have come from urban communities and to have been raised in smaller families and in families that have higher socioeconomic status.

In summarizing to this point, it can be said that the small station groups are culturally heterogeneous. In addition to having diverse backgrounds and purposes for being in the Antarctic, most of the members of these groups have had little, if any, previous work experience on a prolonged basis with persons trained in other occupational fields. Even within the military complement of the stations, for which the Navy serves as a common referent organization, many of the traditional organizational relationships are confused by the unique combinations of specialists who comprise the stations. The group composition, therefore, along with the physical conditions of station life, constitute the major environmental parameters within which individual adaptation must occur.

Of greatest importance in our consideration of human adaptation is the physical and emotional health of each individual. Certainly the heroic and unprecedented mid-winter evacuation of a physical casualty from McMurdo Base last year is witness to this concern. Fortunately, survival has not been an adequate criterion on which to differentiate adaptation abilities of small-station personnel. The men do make it through the winter. While many instances have been reported of individual difficulties and of great emotional stress, no documented psychiatric breakdowns of psychotic proportions have occurred among the wintering-over station personnel since the onset of psychiatric screening. Consequently, the criteria of adaptation have been of a relative nature such that men are compared with one another, and with themselves over time, on various facets of behavior or cognitive functioning. A few of the questions raised in our research on adaptation are the following: What seem to be the most meaningful criteria of psychological adaptation to station life? Once such criteria are defined, what types of persons appear to be most or least effective in such an environment? Are there any general patterns of emotional or attitudinal change among men confined to small stations? And finally, what are some of the problems and behavioral phenomena of group life among these men?

On the basis of interviews and psychometric methods by which the men evaluate one another, there appear to be three major dimensions of adaptation — the man's work performance, his social compatibility, and his emotional composure. Since interdependence is so great at the small station, it is important that each man have the ability to proficiently execute his tasks; this requirement is perhaps more critical for some of the occupational specialties than it is for others. Beyond this, however, is the attitude with which a man approaches his work and any other duties around the station for which he may be called upon to contribute his time and effort. A man's industriousness is highly important, therefore. Furthermore, the close living conditions obviously make it mandatory that individuals be able to get along well with one another. In some instances, through varying one's work schedule or work site, a few people have been able to remain apart from others in the group over short periods of time. But such is the exception rather than the rule. Compatibility refers to the capacity to be tolerant and sensitive to the idiosyncrasies of others while, at the same time, not being overly sensitive about one's self. It seems to matter little whether a man is essentially outgoing or withdrawn in relation to others so long as he does not irritate, annoy, or cause dissention among others *when* he is in their presence. The third dimension of emotional composure seems to be related to both work and social competence. Here we are concerned with the man's ability to control emotions which might have disruptive effects upon others, his capacity to accept authority, and his ability to maintain a reasonably stable and positive disposition.

To obtain individual performance and adjustment data, the station members and formal leaders provide ratings of one another in the three forementioned criterion areas. These evaluations have been adequately reliable both in the sense of being stable over time and in terms of agreement among members at any one time. In order to identify characteristics of the most and least effective men, background variables have been studied subsequently in relation to these evaluations of actual performance. Among Naval personnel, age and years of job experience are correlated positively with performance, while past history of delinquent-truant type behavior is correlated negatively with performance. Among the civilian station members there are slight differences between the weather and physics research personnel. In the former group, age and years of experience are correlated positively with performance, while in the latter group, education appears more important. Thus, the characteristics on the basis of which these men are most likely to be selected initially for their jobs – namely, experience and education – appear most relevant also for performance. Suggested by each of these findings is the importance of a personal history of successful accomplishments in previous work and educational settings.

In contrasting the results of small-station with large-station adaptation, a rather interesting result has appeared. At the small station, particularly among military personnel, the individual who needs to have many avocational pursuits, such as hobbies, reading, and belonging to clubs, tends to do less well than the one without such needs; the reverse appears to be true for the larger station. What is suggested is that at the smaller stations, where facilities are perhaps less adequate and environment more compact, the man who can be at ease with idleness in his spare time wears well. At the larger stations, on the other hand, there are more opportunities for avocational pursuits and to move about both physically and socially to provide variations in stimulation. This seems of some significance in view of recent awareness among students of sensory-deprivation phenomena that the concept of activity level may be a critical dimension of human behavior.

Individual differences exist as much within the realm of attitudinal and emotional symptoms as they do in the realm of performance evaluations. If there is any trend, however, it is for complaints of insomnia, feeling mildly depressed, and feeling irritable to increase with the onset of winter and then to decline towards the end of the year. Pre-Antarctic baseline data on emotional reactions of individuals have been missing, so it is difficult to know the extent to which many of these symptoms are peculiar to the setting. There is speculation, however, that the increase incidence of symptoms coincides with a period of reduced physical effort, increased enclosure within the station, and with the "leaving of the last plane." Attitudinally, the men tend to become more bored and to feel less useful over time. There are variations among occupational sub-groups suggesting that the men whose time is filled most continuously with work-demands maintain a greater feeling of usefulness and experience less boredom.

Attitudes which change most markedly over the winter months among all personnel are those related to the group. These are feelings that the group becomes less compatible, less productive, and works together less harmoniously toward the latter half of the year. The demands imposed by the close social grouping are emphasized furthermore by the frequently reported desire for more privacy. Thus, we have the antithesis of the person in isolation; he is likely to desire more isolation from those about him as time goes on. The differences among persons fulfilling different roles would certainly be worthy of more intensive study. The cook, for example, is probably more continuously in contact with someone from the station because of the location of his galley. The meteorology crew tends to work in teams of two or three men over periods of several hours at a time. An atmospheric physicist, on the other hand, may find that his work requires him to be in a dome above the station for hours at a time in relative isolation from all others at the station. What effect each of these situations has on the particular persons fulfilling the roles is unknown.

Work is a primary orientation at the small station: It is the reason for the man being there, and it is thus his sense of pride, his sense of contribution, and the domain in which he perhaps has his closest interactions with others. There are a few individuals, such as the cook, who tend to work alone—although others may be present in his work area—but most of the station members work in sub-groups of occupationally related specialists. These sub-groups furthermore tend to remain fairly much intact over the year. Since there is such prolonged work association among various sub-groups of personnel, our research has focused recently upon the differential compatibility among work associates. Work groups composed of men of comparable age, rank, and family background tend to be more compatible over the winter than work associates who are more heterogeneous with respect to these characteristics. This finding did not appear for the early months of the year but only for the winter months of most intense confinement. Friendships formed among persons off-duty who have no work association tend to be relatively few and unstable over time. There is almost an absence of specific friendship structure other than that which exists among work associates. This appears to be true particularly for the smaller of the stations.

A major facet of any group's structure is the network of channels through which members communicate about administrative matters. At the small stations these channels are formed in the triangular hierarchy traditional of formal organizations, with the formal leaders being the major sources of information. Informal networks of communication do exist, but they are more often observed in larger groups, perhaps facilitating the effectiveness of the formal structure. Among the informal leaders – those not officially designated but to whom others go for leadership – the men who demonstrate greatest concern about being part of an effective group as well as being task-oriented and aggressive are most popular. On the level of the designated leader, considerateness of the individual is again a primary behavioral attribute associated with esteem.

An interesting problem about small-group leadership, particulary within a formal organization, such as the Navy, pertains to the distance a leader must maintain in order to insure greatest impartiality and efficiency. In most situations it is probably safe to say that the social-emotional distance of a leader from his men must in some way be proportional to the tolerances of the setting in which he is a leader. In the small stations, physical and interpersonal distances are short. Furthermore, there are certain basic tasks related to everyday survival which call for the help of all station members, an example being the chipping of ice for water. This can lead to a general feeling of status leveling among group members. In such a situation it is difficult for a leader to remain formally distant and aloof from his men as individuals. He must engage them directly but with such skill as to maintain his status among them. Since the leader's power is basically put to the test in matters of decision-making, we might look at the types of decisions small-station leaders are likely to make and the way in which they might be made. One decision concerns general station policy – matters which affect all men. Another concerns technical matters. A third concerns the emergency – which differs from the first two mainly in terms of the time dimension. It is hypothesized that different styles of leadership are appropriate for these three types of decisions and that, if properly carried out, the leader can in fact remain close to his men without loss of esteem or status. In matters pertaining to general policy, such as schedules for work detail or movies, group members should be consulted as a body in the democratic sense before the leader makes a decision. In matters of a technical nature, the relevant individual specialists at the station should be consulted as a staff for their opinions prior to the formal leader's making a decision. In each case the decision rests with the leader but follows the advice of his men. In the emergency – that situation which can be disastrous for any leader or group – a quick decision is called for and generally must be of an autocratic nature. But the emergency decision is less common than the other two, and thus the leader can gain the confidence of his men through the more common everyday decisions and consequently have their cooperation in times of stress. *– Continued on back cover (inside)*

# On the Naval Research Reserve

## NRRC 11-5 Wins National Competition

This year's winner of the Research Reserve *Award for General Excellence* — Naval Reserve Research Company 11-5, San Diego, California — was announced by RADM J. K. Leydon, USN, Chief of Naval Research, on December 14, 1965. NRRC 11-5 was the first West Coast company to win the award since 1961, when the initial winner was designated as NRRC 13-6, Idaho Falls, Idaho.

Nominations for the award, which is given to the most outstanding Research Reserve company, were submitted by commandants for the Naval Districts. During the period to which the award applied, LT Edward H. Anderson, USNR, was in command of NRRC 11-5. Presentation of the award is planned for some time early in 1966.

Among the accomplishments of the 29-member Research Reserve company for fiscal year 1965 were the following:

| | |
|---|---|
| *Inspection grade* | *3.89* |
| *Ready Reserve status* | *86.4* |
| *ACDUTRA participation* | *72.9* |
| *Correspondence course completion or current in promotion points* | *100%* |
| *Satisfactory Federal Years earned* | *97.1* |
| *Training grade* | *4.0* |
| *Membership includes largest number of junior officers* | |
| *Presentation of Twelfth Annual Research Reserve Seminar in New Research Horizons* | |

A panel established to review the records, inspection marks, and other criteria, on which the award is based, and to recommend the winning company was composed of the following officers: CAPT L. B. Melson, USN, Assistant Chief for Research, Office of Naval Research; CDR R. J. Stankowski, USNR, Assistant for Training and Mobilization, Office of the Assistant Chief of Naval Operations (Naval Reserve); and CDR J. E. Kennedy, USNR, Head, Specialist Programs Branch, Bureau of Naval Personnel.

Members of the panel which convened to designate the winner of the *Award for General Excellence* commented very favorably on the records of the other companies entered in the competition. These companies and their commanding officers for fiscal year 1965 are as follows:

| | | |
|---|---|---|
| NRRC 1-2 | Providence, Rhode Island | LCDR Pierrre F. Smith, USNR |
| NRRC 3-9 | Upton, Long Island, New York | LCDR Silvio J. Tassinari, USNR |
| NRRC 4-13 | Philadelphia, Pennsylvania | CAPT John J. Horan, USNR |
| NRRC 5-3 | Frederick, Maryland | CDR Henry T. Eigelsbach, USNR |
| NRRC 6-18 | Nashville, Tennessee | CDR Ned L. Warren, USNR |
| NRRC 8-1 | New Orleans, Louisiana | CDR E. P. Johnson, Jr., USNR |
| NRRC 9-7 | Lafayette, Indiana | CDR Ralph L. Davis, USNR |
| NRRC 12-8 | Monterey, California | CAPT George J. Haltiner, USNR |
| NRRC 13-1 | Seattle, Washington | CAPT John H. Avery, USNR |

To Naval Reserve Research Company 11-5, as well as to the other companies listed in nomination for the award, a hearty "Well Done."

# Captain Selections

Three members of Naval Reserve Research Company 1-2, Providence, Rhode Island, were selected for captain in fiscal year 1965. They are Heber W. Youngken, Jr., Robert W. Harrison, and Peter F. Merenda.

CAPT Youngken

CAPT Heber W. Youngken, Jr., USNR, Dean and Professor, College of Pharmacy, University of Rhode Island, began his Naval career as communications officer with CTF-24 and later became an instructor at the Naval Hospital Corps School, Naval Training Center, Farragut, Idaho. He was a member of NRRC 13-1, Seattle, Washington, and since 1957 has been a member of NRRC 1-2. He has authored two textbooks in his field of pharmacology and written many articles in the field of pharmaceutical education and research. He also has been a principal investigator on several research grants from the National Institutes of Health.

CAPT Harrison

CAPT Robert W. Harrison, USNR, Professor of Zoology at the University of Rhode Island and former commanding officer of NRRC 1-2, is a distinguished physiologist. NRRC 1-2 has been particularly fortunate in being able to attend his drill lectures on survival techniques, the physiology of exercise, and deep-sea diving physiology. He is a recognized authority on aviation physiology and has authored several papers on the subject. He is listed in "Who's Who in the East." His current research is on the effect of exercise on blood cholesterol and on arteriosclerosis. During his wartime duty at the School of Aviation Medicine at Pensacola, he authored one of the first texts on emergency survival techniques.

CAPT Merenda

CAPT Peter F. Merenda, USNR, Associate Dean of the Graduate School and Professor of Psychology at the University of Rhode Island, was an NROTC graduate and began his Navy career as a communications officer and personnel and training officer in various staffs of the Atlantic Fleet Training Command. In 1958, he was a charter member of Educational Specialist Unit 1-25 (Boston), and since 1957 he has been a member of NRRC 1-2. From 1958 to 1961, he served as NRRC 1-2's commanding officer, during which period the unit was honored by winning its first Specialist Unit Award. Captain Merenda is an active member of the American Psychological Association and Psychometric Society and has authored more than 40 scientific articles in professional journals in his field. He has also made an outstanding contribution to the Navy in conducting about 30 technical research projects, some of which have been in the field of officer performance evaluation and fitness reports. In addition to his primary duties at the University of Rhode Island, he also holds the post of research consultant in an outstanding industrial psychology firm.

# FIRST NAVAL DISTRICT REPORTS

## Recipient of Metawampe Award

The commanding officer of NRRC 1-3 has been awarded the Metawampe Award for 1965 at the University of Massachusetts. LCDR Joseph S. Marcus, USNR, Assistant Dean of Engineering and Professor of Civil Engineering, was voted the award by the graduating class of 1965. The award carries with it a $1,000 stipend and lectureship as well as the distinction of being voted the outstanding teacher of the year on the basis of election by students.

The Metawampe Award commemorates an ancient New England legend that describes the benevolent actions of an Indian spirit, called Metawampe, who practiced the golden rule and performed acts of good will among his fellow tribesmen. The award, which is voted each year by the graduating class, matches a similar award that is voted by the faculty to its choice of distinquished teacher of the year. The latter award also went to a faculty member of the School of Engineering, which made it two in a row for the school.

## Oceanographers of NRRC 1-2

Among new members of Naval Reserve Research Company 1-2 are MAJ Johnes K. Moore, USMCR, and LT Ellsworth H. Wheeler, USNR. MAJ Moore, who is drilling with the unit under orders from Headquarters, First Marine Corps District, and LT Wheeler, a recent transfer from the Air Force, are both doctoral candidates at the University of Rhode Island Graduate School of Oceanography. The careers of these two members – both in the service and in research – are particularly interesting.

MAJ Moore's oceanographic interests are in estuarine ecology, especially the interrelationships between benthos and plankton in shallow-water environments. In 1961, he spent six weeks on Eniwetok Atoll studying the biological concentration of suspended materials on the coral reef. The topic of his doctoral dissertation is "Biodeposition by the bay scallop and its role in the ecology of the epibenthos." He is doing his research in the Niantic estuary in Connecticut. MAJ Moore, who is the son and brother of naval officers, is a 1953 graduate of Bowdoin College. He served with the Third Marine Division in Japan as a tank officer and was until recently the commanding officer of 9th 105mm. Howitzer Battery, USMCR. MAJ Moore's presentation to NRRC 1-2 on the marine life and growth in Eniwetok Atoll, illustrated with colored slides, was one of the most interesting of the past year.

LT Wheeler's oceanographic studies emphasize zooplankton ecology in the deep ocean, especially of those forms living at a depth of 4000 meters. He returned recently from a three-month cruise to the South Atlantic aboard TRIDENT, the 180-foot research vessel of the University of Rhode Island. TRIDENT carried out a program of biological study that extended from the Bermuda area across the Mid-Atlantic Ridge and the equator into the South Atlantic as far as 23°S. LT Wheeler's responsibilities included supervision of the mid-water trawl program, which involved sampling the relatively unknown populations of fish and crustacea of the 1000-meter level. His own program, a quantitative sampling of deep-sea zooplankton between depths of 2000 and 4000 meters, will provide data for his doctoral dissertation.

LT Wheeler, a graduate of Dartmouth, was originally commissioned through the Air Force ROTC. Subsequently, he served with the Air Defense Command in Korea. He is a SCUBA diver, has had arctic survival training, and reads Russian and French scientific literature. His oceanographic career has also included time as a research assistant at Woods Hole Oceanographic Institute.

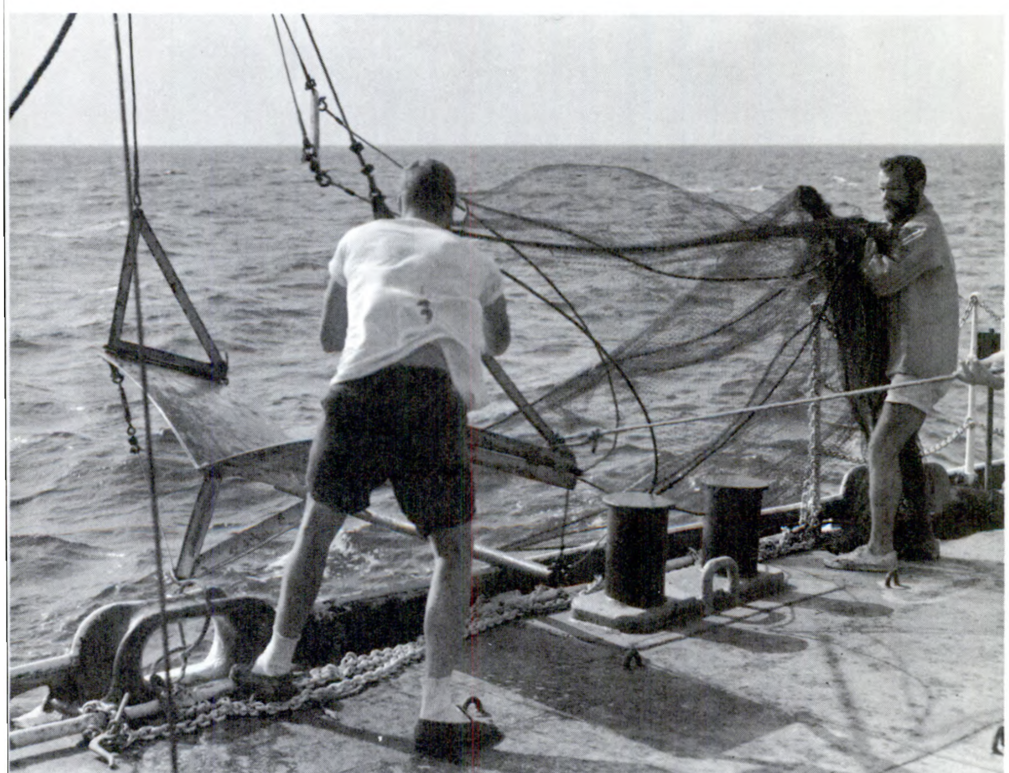


U.S. GOVERNMENT PRINTING OFFICE : 1966 O—799-149

*Psychological Aspects of Antarctic Living – Continued from page 29*

In summary, it seems safe to say that once the uniqueness of being in a strange environment wears off, which it surely seems to do, the greatest problems facing man in Antarctic stations are similar to those with which he must cope elsewhere – his work and his fellow men. Certainly it is difficult to work under the physical circumstances of such a setting. But the men do accomplish their jobs admirably well. In addition to simply adapting, however, the men contribute to their surroundings. Sometimes it is in the form of a new building, a newly decorated living space, or a new movie film derived from several films already seen many times. Each group attempts to build a little of "home" into the Antarctic, be it in the form of a local Lion's Club or in the form of Burma Shave signs along a snow path outside the station. Such ingenuity of the men to provide that which seems to be missing is perhaps important for successful adaptation – adjustment with high morale and productivity. Were our own ingenuity in research half so successful, perhaps many of the issues which remain unknown or questionable to us would be clarified.

---



LT Wheeler, at right, and assistant prepare to lower an Issaacs-Kidd mid-water trawl from the TRIDENT.

# IN THIS ISSUE

VOL. XIX NO. 1



**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 740, Office of Naval Research, Washington, D.C., 20390. The magazine is listed for sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., 20402. Subscription price: $1.50 per year in the U.S. and Canada; $2.00 per year, foreign; $0.15 per individual copy. The issuance of this periodical approved in accordance with Dept. of the Navy publications and printing regulations.

NAVSO P-510

EDITOR: Richard D. Olson

*The past two decades of Naval research encompass such variety and range of interest and accomplishment that a representation of them by way of a few photographs is doomed to fall short of the mark. In this cover representation, the Navy scientist is depicted in association with the undersea, ocean surface, and atmospheric and space realms with which he deals.*