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RESEARCH REVIEWS

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Frederick E. Charlton orients loop antenna over penguin nest as Carl Eklund places egg containing telemeter under bird. Temperature signals picked up by the antenna are carried by a transmission line to a receiver located nearby.

easuring the emperatures f Incubating enguin Eggs

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lar Research Division
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earch and Development

rederick E. Charlton
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Charlton, left, displays temperature telemeter which has been prepared for insertion in pengiun egg shell held by Eklund.

In an article entitled "Radio Thermometer That Fits in a Penguin Egg," published in Research Reviews for June 1957, the authors, John H. Busser and Marion Mayer of American Electronic Laboratories, Inc., discuss a tiny transmitting unit which they designed for the Office of Naval Research. In the article appearing on these pages, Carl R. Eklund and Frederick E. Charlton carry the story one step farther, telling how they applied the instrument to studies of penguin-egg temperatures and giving some of the results of their work. At the time the studies were made, the senior author was with the U. S. National Committee for the International Geophysical Year, serving as Wilkes Station Scientific Leader.

Ever since the Emperor Penguin (Aptenodytes forsteri) was first found incubating its eggs in the antarctic winter at temperatures as low as -77°F., students of animal physiology have wondered how it was possible for the embryos to develop. Until 1957, these men could do little more than continue to ponder the question, because of the inaccessibility of the Emperor's breeding rookeries and the lack of a suitable instrument to study the phenomenon. At that time, however, with the establishment of various stations in Antarctica by the United States for the International Geophysical Year, a rare opportunity was presented for carrying out an investigation which might shed light on this question.

Of course, there was still the matter of instrumentation. As a first step toward obtaining the device needed, the senior author, then with the National Research Council, discussed the problem with Dr. Orr Reynolds, then Head of the Biological Sciences Division of the Office of Naval Research. It was pointed out that the instrument would have to be small enough to be placed within a penguin egg, and so designed that it did not need to be linked by wires with an antenna located outside the egg, as would be necessary if a thermocouple were used. The reason for this requirement was that the Emperor has no fixed nest, often moving many times while incubating its egg. This is possible because it carries its egg on the webs of its feet, and thus can move or "sit" at will.

At the time the request was made, ONR was considering plans for a miniature telemetering instrument which could be used in human physiology studies. In fact, a contract for the design and construction of this instrument was then in the process of being drawn up with the American Electronic Laboratories of Philadelphia. Fortunately, several of the instruments were completed in time to be used in our work. These were flown to New Zealand just before our departure for Antarctica in December 1956.

The authors were stationed at Wilkes Station, which is located among the Windmill Islands of Vincennes Bay on the Budd Coast of Wilkes Land at latitude 66°15' S., Longitude 110°31' E. Although this area is very rich zoologically, no Emperor Penguins were nesting there during our visit. Consequently, we decided to carry out the temperature experiment simultaneously on two summer-nesting species— the Adelie Penguin (Pygoscelis adeliae) and the South Polar Skua (Catharacta maccormicki). The studies were conducted over a nine-day period from December 11 to 19, 1957, on Clark Peninsula, one-quarter mile from Wilkes Station.

The temperature telemetering system consisted of a transmitter small enough to permit insertion in an egg, a receiving loop antenna placed over the nest, a low-frequency radio receiver, and an audio-frequency pulse-counting device.

The transmitter included a transister oscillator, which was placed, together with a temperature-sensitive element and three mercury-cell batteries (life, about 100 hours), within a multi-turn single-plane directional loop antenna. Of an elliptical shape, and only about 1 by 1-1/2 by 2 inches in size, it fitted snugly within a large skua or penguin egg. The unit was made waterproof by sealing it in plastic.

To prepare the eggs for insertion of the transmitter unit, they were first cut in half lengthwise and emptied. The transmitter was then placed between the two halves of the eggshell and the edges cemented together. After the cement had dried, a glass syringe was filled with the appropriate albumen, and the substance injected through a 1/16-inch hole at the top of the egg. The hole was then sealed with cement.

To provide comparative data, transmitters were placed in both an Adelie Penguin egg and a skua egg. As the normal clutch of eggs for these birds is two, only one telemeter egg was placed in each nest, this being substituted for one genuine egg. It was desirable that one normal egg remain in the nest to serve as a control, since, if it hatched, it might indicate that the experimental egg had received a normal temperature. It was also felt that the bird should at all times sit on two eggs—the normal clutch size. It should be noted that upon completion of the study the normal egg hatched in each instance.

When the telemeter egg was returned to the nest, a two-foot diameter loop antenna was placed over it. The antenna was mounted on a six-foot pole held upright by a wooden stand seven feet high. The pole could be turned within the stand, the purpose being that if the setting bird rotated the telemeter egg into a no-signal position (the egg was placed in the nest with its internal loop horizontal) the loop antenna could be rotated so as to pick up the signal again.

The radio thermometer and empty penguin egg shell are readied for use. Left, the telemeter is placed in shell. Right, albumen is injected into sealed shell.

A transmission line connected the loop antenna and the antenna tuner, which was located along with the receiving instruments in an 8 by 10 foot shelter, or "wannigan," mounted on a sled. This was located 180 feet from a skua nest and 130 feet from a penguin nest in which the telemetering eggs were placed. A window in one side of the shelter enabled observers to see both nests. Twenty-four-hour watches were maintained at 8- to 10-hour intervals by the co-authors, aided occasionally by several men from the station.

The system functioned in this way: The telemeter egg radiated a modulated electromagnetic signal, the number of pulses per second being determined by the temperature inside the egg. This signal was intercepted by the loop antenna placed over the nest, relayed by a transmission line to the low-frequency radio receiver located in the "wannigan," and there amplified, detected, and sent to the counter, which recorded the number of pulses. Even though the signals were continuous, a count was taken for each bird only every 15 minutes on a 24-hour basis, alternately on the skua and the penguin. The pulses transmitted by each experimental egg were carefully calibrated against a standard thermometer before the egg was placed in the nest, and they were recalibrated on completion of the study.

As stated previously, studies were conducted over a nine-day period. However, due to technical difficulties, some of the records obtained during the period of observation were discounted. The temperatures shown below are from those sections of the continuous record in which it was felt the instruments were operating normally. The skua records extend only from 2:30 p.m., December 15 to 11:30 p.m., December 17. The penguin temperatures represent a longer period.

Results of the study show that the average temperature of the incubating skua egg was 96.6°F., with a maximum of 103.5°F. and a minimum of 87°F.* As determined in a published study made previously by the senior author, the average body temperature of this species is 106.1°F., ranging from a maximum of 108.4°F. to a minimum of 103.4°F. The average temperature of the incubating egg was thus 9.5°F. less than the average body temperature.

The average temperature of the incubating Adelie Penguin egg was 92.7°F., with a maximum of 98.2°F. and a minimum of 84.5°F.* The average body temperature of the Adelie is 103.8°F., ranging from a maximum of 106.4°F. to a minimum of 100.3°F. Thus the average temperature of the incubating egg of the Adelie was 11.1°F. less than its average body temperature, and 3.9°F. less than the average temperature of the incubating skua egg.

The greater range in the incubating temperatures of the skua egg is explained by the number of times the parent bird changes incubation duties with its mate. One of the pair of skuas under study was sprayed with green paint to provide easy differentiation of both birds on the nest. A continuous 132-hour record of the nest-changing was kept, and during this period the pair relieved each other on the nest 13 times, or an average of 2.36 times every 24 hours. The Adelie Penguin, on the other hand, may not be relieved by its mate for as long as two weeks, as in the case of the male when it first starts the incubation after the egg is laid. This probably accounts for the greater fluctuations in temperatures of the skua egg.

On the basis of studies made of the temperatures of chicken embryos, it has been found that a rise in body temperature of the embryo

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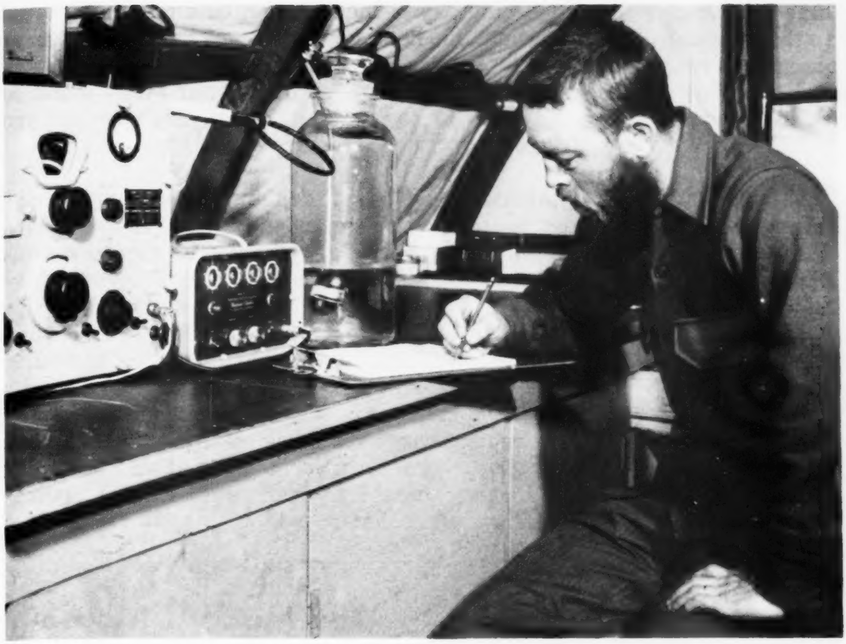
*These data are part of a Ph.D thesis being prepared by the senior author for the University of Maryland.

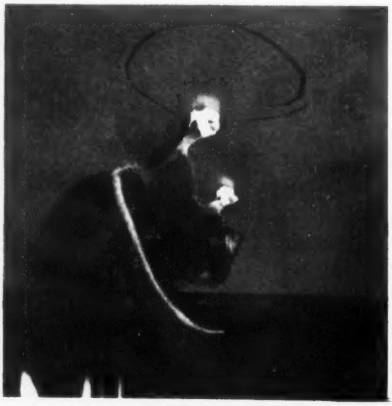


Charlton calibrates temperature telemeter. Instruments shown, from left to right, are receiver, counter, and telemeter (in bottle).

Eklund removes one genuine egg from penguin nest and replaces it with egg containing telemeter.

may be expected after the tenth day of incubation (the incubation period is then about half over), when the heat production of the chick embryo increases rapidly. If similar action takes place in the eggs of the skua and the penguin, the temperatures recorded during our study would be valid only up to about the first 10 to 15 days, after which the embyro would affect the temperatures.

The theory of application and basic design of the temperature telemeter were excellent for the work as carried out, and it is believed the instrument can be used in physiological studies to measure temperatures remotely. Unfortunately, we did not answer the question we had uppermost in mind when we undertook the study—determining the incubation temperatures of eggs of the winter-nesting Emperor Penguin. It is hoped, however, that such research will be carried out in the future. Through it, we will be able to determine if eggs of the Emperor actually do hatch at lower temperatures than those of other birds. If it is found that they do, we will then want to know what there is in the physiolocigal makeup of the bird which allows this to happen. It is at this point that the work may take a turn that will directly benefit man, for the findings could have important medical applications.

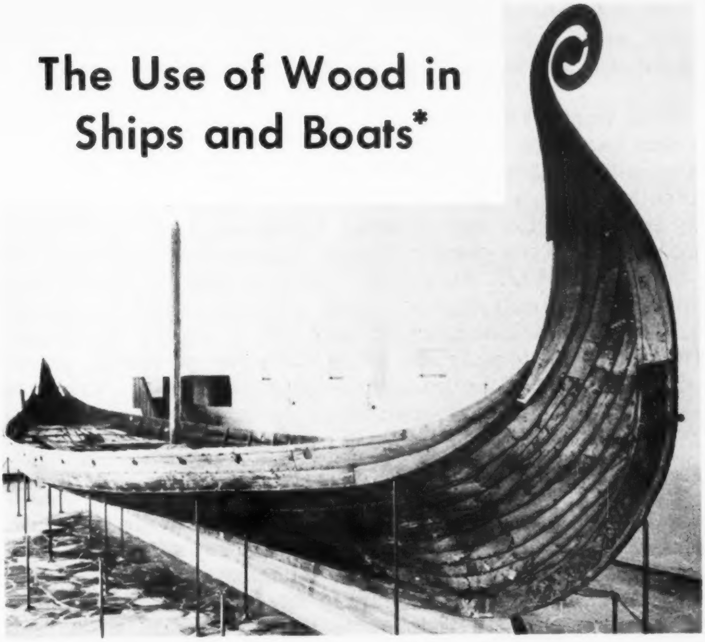


The Modern Mouse

Considering the many important assignments now being given the lowly mouse in the conquest of space, one wonders how we could get along without him. Two examples of mice contributing their efforts to space research are shown at left. Above, a black laboratory mouse serves as a subject for a study of limb reaction under simulated high and zero gravity conditions in the ultra centrifuge at the Navy School of Aviation Medicine, Pensacola, Florida. No, the picture is not upside down, the mouse is. Magnets attached to his feet keep him in this unnatural position. Below, a white mouse "inspects" a cutaway model of a Minneapolis-Honeywell rate gyroscope, heart of the stabilizing system of giant IRBM and ICBM missiles. Just what he makes of the many miniature parts, we don't know, but he does serve to indicate the size of the device.

Yes, the mouse is rapidly proving himself to be the rodent of the future. This does not mean, however, that he has given up his old ways. He'll still raid a cupboard or tear up an old mattress if given half a chance.

The Use of Wood in Ships and Boats*



Viking ship of 9th Century. Length, 71 ft. Hull planking and keel cut from Norway oak; mast, from Norway pine.

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For over 4,000 years ships and boats of wood traversing the world's waterways have played a key role in man's quest for wider horizons of truth and freedom. The many historic deeds of exploration and conquest that have occurred during this period would obviously not have been possible had it not been for a well developed skill in the building of ships. Shipbuilding is, in fact, one of our oldest organized industries. Spurred on by the endless struggle of maritime powers for dominance of the seas, the art and craft of shipbuilding was brought to a high state of development. Knowledge and skills were passed from father to son—each new generation and century adding its small bit of progress.

WOOD AS AN ENGINEERING MATERIAL FOR SHIPS

The most rapid growth of scientific shipbuilding came with the advent of iron and steel as the principal material of construction. This was made possible by the phenomenal advances in the metallurgical sciences and technologies. In the case of wooden ships and boats, which

*Shortened version of an article appearing in the August 1958 issue of the Journal of Forestry (Society of American Foresters).

continued to be built for many purposes, the construction methods which persisted were those of the craftsman, not the engineer, because the wood sciences and technologies had not yet emerged as engineering tools.

Until World War II practically all construction of wooden ships and boats was based on time-honored traditions. The pressures of war, however, stirred things up. For the first time wood was put to use in unconventional ways. The plywood torpedo boat and landing craft and the cleanly framed motor minesweeper represented great strides forward in wood design. Even greater breaks with tradition followed during and after the Korean War. An entire family of specialized minesweepers was designed and built in which wood was chosen as the principal material. This choice was made on the basis of wood's structural merits and availability in comparison with other non-magnetic materials, as evaluated by the naval architect and design engineer. Structural capabilities of wood laminates were recognized and accepted in ships of this size for the first time.

Wood was able to meet this challenge because of the basic fund of performance data which could be made available to the designer. It was convincingly shown that wood materials and techniques are compatible with such modern industrial factors as mass production, engineering, and economy. It was also necessary to overcome the native prejudice of most naval architects and engineers toward natural materials. To the average engineer the unlimited variability which nature bestows upon wood is something which cannot be coped with in a closely engineered structure.

However, greater knowledge of wood's properties and the availability of this knowledge in conventional engineering form is serving to break down the general reluctance to accept wood as a modern engineering material.

The necessity for the engineering approach in our rapidly changing world is evident. Time no longer permits us to develop better products by cut-and-try methods. Applications of materials must often be projected far beyond any previous experience. As in the case of other basic materials used in engineered products, wood must be adapted to the expected performance level.

The real successes in using wood as an engineering material in the Bureau of Ships have come from taking the "if" out of wood for the engineer. There are several ways of achieving this.

First, by empirical tests, the characteristics of typical pieces of wood falling within some loosely defined classification can be determined, then by applying liberal factors of safety it can be reasonably assured that the performance will not drop below some acceptable minimum. In shipbuilding this approach is generally not desirable, since a large part of the ship structure is in effect overdesigned. Overdesigning in ships takes away valuable space and adds weight. Both space and weight are always critical on a warship.

Second, by meticulous selection wood can be chosen which is so uniform in character that its performance can be predicted without allowance for variability. This approach while acceptable to the engineer is costly and meets stiff opposition from the lumber industry. Furthermore, rigid selectivity, which has always been a hardship, is becoming more and more difficult as the quality of the harvestable timber in our forests drops.

A third approach is to reduce wood to relatively small basic components of easily controlled uniformity, which are then combined to provide a more desirable distribution of properties. This is the approach that has earned wood a continued place in the design of naval craft and in many other engineered structures. It strikes a responsive chord among design engineers, who are most familiar with synthetic materials, that is, materials which are formulated, rather than selected for desired characteristics. Furthermore, techniques which have developed out of this approach have greatly extended the potential of wood as a structural material, particularly where the size and shape of wood as it occurs in nature have been limiting factors.

WOOD RESEARCH FOR SHIPBUILDING

In order to pursue the last mentioned approach to engineered use of wood it is necessary to maintain a supporting program of research and development and to establish adequate specifications and standards. It is also essential to develop reliable quality-assurance procedures if the engineered product is to fulfill its expectations. In the Bureau of Ships, as in all engineering organizations which successfully use wood, these supporting functions are considered an integral part of the design effort. They are managed by wood specialists who can translate the background of wood science and technology into usable data for the engineer.

The scale of the Bureau of Ships' program, when compared to the private and public effort devoted to the development of other basic structural materials, is quite modest. Within the field of wood alone, however, the Bureau's program is one of the largest—amounting to about $250,000 per year in terms of dollars and involving at present the services of two private and five government laboratories.

The work is divided into three task areas, embracing fabricated products, basic lumber products, and materials and techniques for prevention of wood deterioration.

About 35 individual projects are presently underway. In scope, they range from quick tests supplying urgently needed information on immediate Fleet problems to comprehensive long range development of products and attendant engineering data. The following examples are indicative of the type of pioneering research and development which are needed to support the Navy's operations.

- <u>Wood laminates</u>. The Navy, with much outside assistance, has adapted the principle of wood laminating to marine use with outstanding success. Current research and development is designed to expand the species which may be utilized, to develop further economical shipboard uses of laminates, to provide more complete design information, and to impart greater durability.

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● <u>Plywood</u>. Especially durable and strong types of plywood are required for ships and boats. Current research and development on plywood is concerned with devising a material which is completely immune to marine-borer and fungus attack and highly resistant to fire.

● <u>Fastenings</u>. Traditional methods of mechanically fastening wood are being scrutinized to determine if improved fastening systems can be developed which will take better advantage of the inherent strength of wood.

● <u>Fundamental properties</u>. The basic physical and mechanical properties of little known woods (mostly from the tropics) are being explored to determine their applicability to shipbuilding.

● <u>Wood preservatives</u>. Techniques are being developed which will make complete decay protection in wood ships and boats practicable. Also, means of decreasing the flammability of petroleum solvents for preservatives are under investigation.

● <u>Adhesives</u>. The present adhesives used for marine wood products provide excellent durability; however, the conditions under which they can be satisfactorily used are very exacting. Although the Bureau undertakes no development of new adhesives, it encourages such development and evaluates newly introduced products for potential improvement of marine applications. A continual effort is also made to improve adhesive testing methods.

WOOD SHIPS

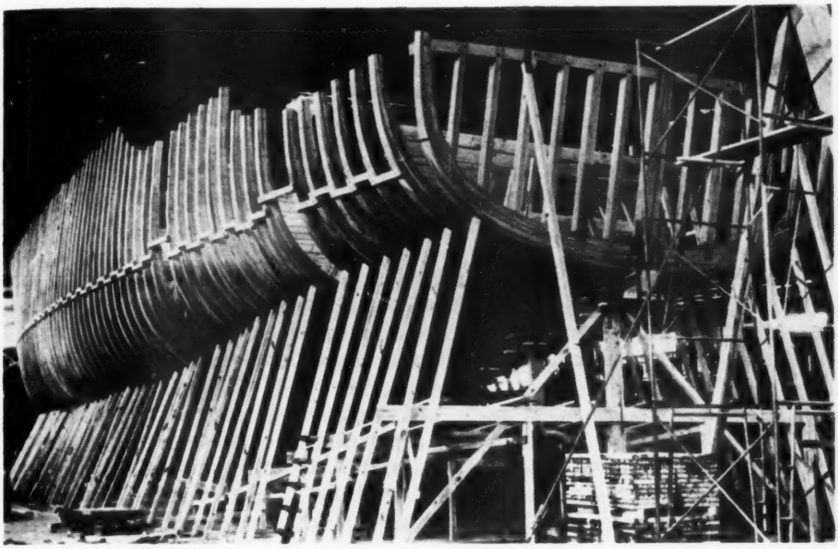
The translation of research and development findings into action comes about in many different ways in the Bureau of Ships. In all cases, however, it reflects itself in the design, construction, or maintenance of a ship, a small craft, or a component thereof. An idea of the effect this has on the end product can best be obtained by a look at developments in the Navy's wooden ships.

The hull characteristics of wooden ships during the past ten centuries are illustrated on the front cover, inside back cover, and on page 7. The major structural changes taking place during the past ten years in adapting wood as an engineering material for the hulls of ships are illustrated on page 11.

The United States Navy found itself with only a small number of wooden minesweepers available when the Korean War began and was also faced with the inability to use steel ships due to the powerful magnetic field they created. A heavy sowing of magnetic influence mines resulted in the loss of several ships in Korean waters.

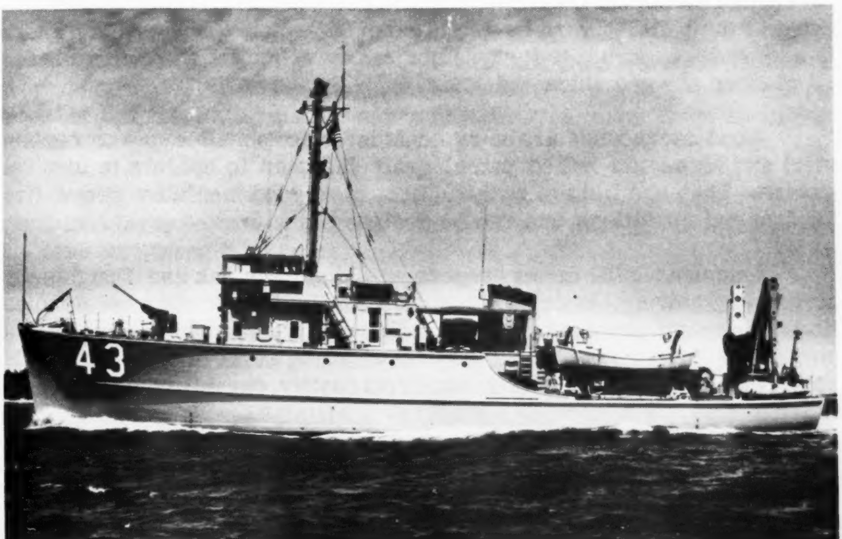
A crash program was initiated to develop and build a family of effective nonmagnetic minecraft. Wood was chosen for the hulls as the only practical structural material available with the desired nonmagnetic properties.

Bureau ship designers studied wooden hulls as far bask as Viking ships to learn the principles of construction. The World War II YMS was a take off point, and the end product was a completely new ship—the 165-foot MSO 421 class of ocean minesweeper. Contract awards began in 1951, and during the intervening years an impressive number of wood



MSO minesweeper, 1953. Length, 165 feet. Transom and hull frames are built of oak laminates.

USS BITTERN, minehunter, 1957. Length 144 feet. This ship has the first all-pressure preservative-treated laminated red-oak hull.



hull ships have been added to the navies of the free countries of the world. These have included MSO, MSC, MSI for ocean, coastal, and inshore minesweeping service; the MHC, a new prototype coastal minehunter; the MSL, a 36-foot minesweeping launch; the YP, a training and district patrol craft; the SC or 110-foot subchaser; and the PGM or 110-foot patrol gunboat. Over 300 such wood craft are serving as American built wood ships in both the United States Navy and the navies of other free countries throughout the world.

In minecraft construction the selection of sound, durable, high grade woods, plywoods, and laminates is a particularly important consideration as this assures ability to withstand rugged service. Shock and underwater explosion tests on recently constructed craft of this type have shown that wood hulls perform well in comparison with hulls of any other shipbuilding material.

There is a trend toward use of more and more wood laminates. Although the specifications for MSC coastal minesweepers still permit the use of either steam-bent or laminated frames, only a few of the builders now elect to use steam-bent frames in preference to laminates.

A major advance has been in improving the durability of wooden ships. This has been accomplished by such practices as using resistant hardwood and preservative-treated wood and avoiding untreated sapwood. Designers have also carefully considered the elimination of fresh water leaks and other decay-producing hazards. Ships have been made marine borer proof through the use of effectively treated materials.

Another growing development in wood shipbuilding is prefabrication. The deckhouses on the ocean minesweepers MSO 423 and 424 were prefabricated. The minehunter MHC 43 included prefabricated frames which were laminated and bevelled to final shape at a plant a thousand miles from the shipyard. A three-foot section was cut from the ends of the frames to permit rail shipment in standard cars. These were then glued at the building yard by use of a portable heat curing box. There is a splendid opportunity for prefabrication of watertight bulkheads for all classes of wood ships and boats.

Wood deckhouses are being considered for possible use on certain steel and aluminum hulled patrol craft designed to operate in tropical waters. They are light in construction, have good insulation properties for tropical conditions, and can be designed to withstand severe storms.

American-built minesweepers use domestic oak and Douglas-fir almost exclusively. In certain countries of the free world where choice timbers are not abundant, greater reliance is placed on the use of imported tropical woods. These tropical species, some of which are little known in the United States, offer excellent quality, durability, and strength in large size, all heartwood members.

To provide greater durability when American oak is used, specifications have been developed for gluing treated red oak and white oak laminates having unlimited sapwood. Treated red oak laminates have been used successfully in the MHC 43, and when one of the authors recently visited aboard this ship, the skipper assured him that hull performance was very good under all service conditions.

WOOD BOATS

By virtue of its long use in boats, wood has suffered every imaginable abuse as a material. There is more to a properly built boat than the average layman, or boat builder for that matter, is aware of, and quite a little engineering skill is required, not only in its fabrication, but also in its maintenance and care.

Research in ways and means of extending the service life of wood craft has emphasized the need for improving storage practices. In the past, stock boats have frequently been subjected to full weather exposure for long periods without raintight, ventilated shelters.

Based on an analysis of maintenance and repair costs of small wood craft, the Bureau has begun a program to assure adequate protection of all stock boats and proper preservation of all the component parts.

In selecting new boat building woods, several factors in addition to durability are considered as making wood boats particularly suited to naval use.

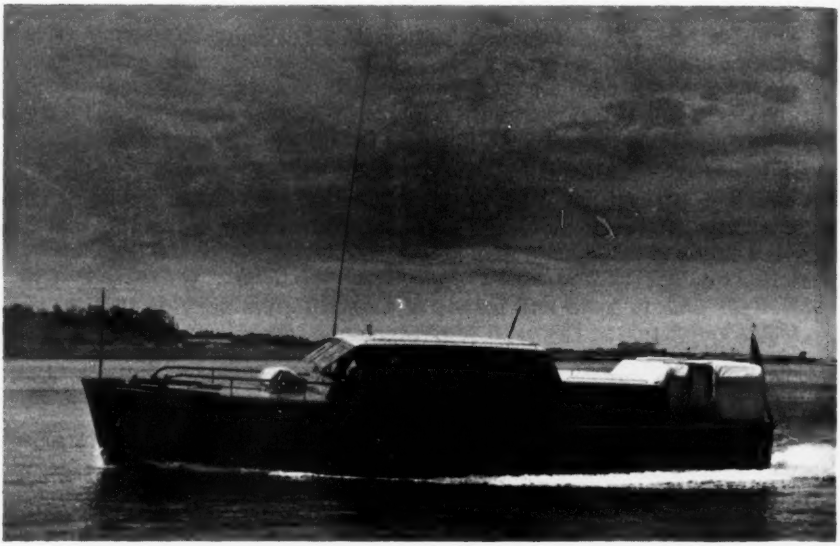
- Strength. Wood for boats and ships must have great strength in relation to its weight. The use of laminated members greatly reduces the strength loss formerly incurred by use of fastenings. Impact resistance probably is one of the more important mechanical properties which make wood desirable for boatbuilding. In wooden construction of any form, 100 percent over the working stress is allowable for short-term loading in impact. This is an important factor which makes wood hulls "bounce back" undamaged from severe contact with piers or from the shock of underwater explosions.

- Insulation. Wood has good natural insulating qualities, a factor which makes boats easier to heat in cold climates and easy to cool in tropical climates. Wood decks, because of their resiliency and excellent wearing and insulating qualities, are preferred on many ships as well as on boats.

- Corrosion-resistance. There is no corrosion problem with a wood hull fastened with silicon bronze or Monel fasteners. Wood does not lose its strength by aging.

- Adaptability. Wood boats are readily adaptable to conversion for different missions. Standard boats can be modified for specialized functions by economical measures.

- Material availability. Wood, an ever-renewing resource, is relatively available even under adverse emergency conditions. In addition to our domestic resources, potential supplies of lumber in the tropics have scarcely been touched. The use of laminated materials also greatly increases the potential supply of lumber for boat and ship members.



A 40-foot area command cutter built of Philippine woods, 1957.

The fact that lumber is so widely available makes it possible to build and repair in some very remote areas. The construction of a 40-foot area command cutter (see photo on this page) utilizing durable and strong Philippine species readily available at the Subic Bay, P. I., Boat Repair Facility, has been possible on the basis of engineering data supplied by Bureau research.

● Low cost. The cost of boatbuilding lumber averages about $0.10 a pound. Maintenance costs for wood boats are not excessive, if a small amount of judgment is exercised during active service and adequate shelter is provided during periods of inactivity.

Over the years many competitive materials have made a bid for wood's place as a boatbuilding material. Some of these materials have been used very successfully. Wood boats, however, still comprise the largest portion of naval small craft.

There are centuries of evidence in both naval and private experience that wood craft properly built and cared for are highly reliable. When boat and shipbuilders use wood in accordance with good engineering principles, the result is an assurance of quality and performance not readily equalled or surpassed by any other material. True economy dictates that only the highest quality of strong durable woods and workmanship be used. This truth holds in boat and shipbuilding more than in any other industry. The buffeting by forces in storms at sea is greater than that encountered in any other environment. In the light of these facts, well established by history, it is not surprising that in these days of atomic-powered submarines, super aircraft carriers, and guided missile ships the Navy still sends its wooden ships into all the oceans of the world on missions of crucial importance.

Cloud Modification by "Carboning"

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Cooperative investigations conducted by the Naval Research Laboratory and the Naval Weather Service led to the recent and successful qualitative experiments in which cloud formations were both created and destroyed after selected areas and levels of the atmosphere were treated with ordinary carbon black. In seven experimental runs over the Georgia-Florida coast, cloud dissipation followed within a period of 5 to 20 minutes after dry carbon black was released from the dropsonde chute of a Navy WV-3 Super-Constellation; the opposite effect—cloud formation—occurred during five experiments in which carbon black was dispensed in a clear, humid layer of the atmosphere. Quantities of carbon black employed in these experiments varied from 1.5 pounds in dry packages to 6 pounds suspended in liquid.

Although the results were both successful and encouraging, the experiments demonstrated only an effect, which has yet to be studied scientifically. Until then, the results have no immediate application to any of the announced goals of previous cloud-modification programs, such as reduction or production of rainfall and hurricane control.

It is the purpose of this article to describe briefly how an idea conceived by one of the authors (van Straten) was extended by preliminary studies to a reasonable hypothesis, tested somewhat successfully at NRL on a small scale, and found worthy of a series of tests conducted recently in selected areas and levels of the atmosphere.

FROM THE OLD TO THE NEW CLOUD-MODIFICATION THEORY

Earlier cloud-modification programs were based on the idea that the artificial changes desired could be produced by accelerating the processes which might be expected to occur naturally within a cloud. Thus the first work involved an attempt to accelerate a normal phase change (from liquid water to ice at temperatures below freezing) which had not taken place in a supercooled cloud. When particles of dry ice (solid carbon dioxide) are passed through a supercooled cloud, the temperature of a portion of the cloud, is lowered, causing some of the liquid water droplets to freeze. Once supercooled water and ice are present at the same time, ice crystals will grow at the expense of the liquid, the liquid will gradually disappear from the cloud, and precipitation will follow. Seeding supercooled clouds with silver iodide crystals, or sublimation nuclei, depends essentially upon this same mechanism. Both of these methods, however, are restricted to those portions of the clouds which are made up of liquid water droplets at temperatures less than 0°C.

For the modification of clouds warmer than 0°C., several investigators have studied the effect of introducing large water droplets to initiate the coalescence process, leading to precipitation. This method has been demonstrated in tropical areas.

A well-accepted theory of rain generation in the middle latitudes holds that with the coexistence of liquid and solid water at temperatures below freezing, sublimation takes place as a consequence of the vapor-pressure difference between the two phases of water. But what this theory does not explain is how rain forms in the tropics from clouds which never reach freezing levels.

In an attempt to explain such tropical rain, it may be noted that the vapor-pressure difference between water surfaces of slightly different temperatures is comparable in magnitude to that which exists between ice and supercooled liquid water at temperatures below freezing. And when one considers the amount of convective activity within a cloud, it is not unreasonable to assume that both warm and cool water droplets from different levels in the cloud may be carried to the same region. Thus the vapor-pressure difference resulting from the temperature difference of the droplets could induce distillation and growth of the cooler droplets at the expense of the warmer. The coalescence process could follow this activity. With this line of reasoning, only one further step was needed to form a hypothesis concerning a method for modifying clouds artifically.

If a heat source were introduced into either the top or base of a cloud, certain effects might be expected. First, there could result a sufficient temperature difference between droplets to induce a distillation process. Second, the cloud could become stabilized, or it might become more active. For instance, if the heat source were introduced into the region above a cumulus cloud, the natural growth of the cloud might be inhibited. Further, according to this hypothesis, the local temperature difference should result in the growth of large droplets which, in falling, would coalesce. On the other hand, if the heat source were introduced near the base of an existing cloud or near the convective condensation level in the absence of a cloud, an increasing degree of instability should result. An existing cloud might well grow and become more active; and in a clear, humid region, a cloud might well be generated. The introduction of a heat sink should, under most conditions, have the opposite effect.

Depending upon the areal distribution, intensity, and duration of the heat source or sink, any of several effects can be envisioned. Single convective clouds might be generated or disintegrated, or fog and stratus clouds might be created or dissipated.

In essence, then, this hypothesis states that if the heat balance in limited portions of the atmosphere can be changed, some degree of cloud modification should occur. On the basis of pure speculation, the consequence of introducing a heat source or heat sink appears to be unlimited. In practice, of course, the effectiveness of the technique depends upon the availability of an appropriate heat source or heat sink.

CARBON BLACK AS A HEAT SOURCE OR SINK

A common substance which is an efficient absorber of radiant energy is carbon black. In the presence of solar radiation, carbon black should absorb heat and act effectively as a heat source. At night, in the absence of solar radiation, it should radiate more effectively than its surroundings. Thus, since it would be colder than its surroundings, it should have many of the characteristics of an appropriate heat sink.

Carbon black can be obtained commercially in a range of particle sizes on the order of 10 to 100 millimicrons. If one assumes that all the particles are discrete upon release into the atmosphere, a surface area is obtained having the order of acres per pound. Conceivably, then, only small quantities would be required to change the heat balance in a portion of the atmosphere. The small particle size also indicates a negligible rate of fall. Although it is unlikely that all of the particles are discrete and that no clumping will take place, the efficacy of small quantities of carbon black is indicated.

This small particle size may prove advantageous or disadvantageous. While the surface area in a pound of carbon black is tremendous and the rate of fall may be negligible, the convective activity which the substance would probably cause might so disperse the particles that concentrated heating or cooling would not occur. To this extent, the carbon black falls short of the requirements of the hypothesis which demands introduction of a heat source or sink at a given level in the atmosphere. On the other hand, dispersal by convective activity may enhance some of the ability of carbon black to modify clouds. Still unknown is to what extent this dispersal will influence the effectiveness of carbon black as the agent for producing the effects postulated by the hypothesis.

Some of the answers to this problem were sought in a simple exploratory experiment conduced in a modified altitude chamber at NRL to determine whether or not the dissipation rate of artificially formed fog is affected by the introduction of carbon black. The results appeared to justify the ensuing experiments, which were carried out in the atmosphere on naturally formed clouds and in selected clear areas of the atmosphere.

TYPICAL EXPERIMENTS AND RESULTS

A series of flights was made from the Naval Air Station, Jacksonville, Florida, during the last of July 1958, in an attempt to determine if the hypothesis proposed has any validity and if carbon black can serve to some degree as a heating agent. The quantity of carbon used, the level of flight, and the atmospheric conditions for each of 14 runs are given in the table on page 18.

Experimental Conditions Under Which "Carboning" Flights Were Performed

Run No.	Condition of Atmosphere	Amount of Carbon Used (pounds)	Carboning Height (feet)	Remarks
1	Cloud Base: 5,000 feet Top: 9,000 feet	1.5	8,000	Cloud dissipated in about 20 minutes.
2	Cloud Base: 7,000 feet Top: 8,900 feet	1.5	8,400	Cloud dissipated in 5 minutes.
3	Cloud Base: 4,000 feet Top: 10,000 feet	1.5	8,000	Cloud dissipated in 18 minutes.
4	Cloud Base: 4,200 feet Top: 11,000 feet	1.5	8,300	Not observed.
5	Clear air	1.5	3,500	Small cloud formed.
6	Clear air	1.5	3,600	Small cloud formed.
7	Clear air	1.5	3,600	Static line broke; package may not have opened. No cloud.
8	Clear air	1.5	3,600	Small cloud formed.
9	Clear air	1.5	4,000	Small cloud formed.
10	Clear air. Carbon dropped over one-mile track.	6.0*	4,000	Clouds formed along entire track. Bases: 3,000 feet. Tops: 6,000 feet.
11	Cloud Base: 3,800 feet Top: 10,000 feet	1.5	8,000	Cloud dissipated in 24 minutes.
12	Cloud Base: 4,000 feet Top: 10,000 feet	1.5	8,000	Cloud top dissipated and bottom became wispy in 15 minutes.
13	Cloud Base: 4,000 feet Top: 13,500 feet	3.0	8,000	Cloud dissipated in 13 minutes.
14	Cloud Base: 4,800 feet Top: 12,000 feet Carbon dropped over one-mile track.	6.0*	8,000	Cloud dissipated in 8 minutes.

*In liquid suspension

A Super-Consellation from the Airborne Early Warning Squadron was used as the dispensing plane, and an AJ-Savage attack aircraft and an SNB Beachcraft, from Heavy Photographic Squadron VAP-62, were used to observe and photograph the effects of the "carboning" (Figure 1). Voice communications by radio permitted the exchange of oral descriptions, which were recorded in part, and post-flight debriefing sessions were recorded to summarize the results. Photographic records completed the data-gathering efforts of the experiments.

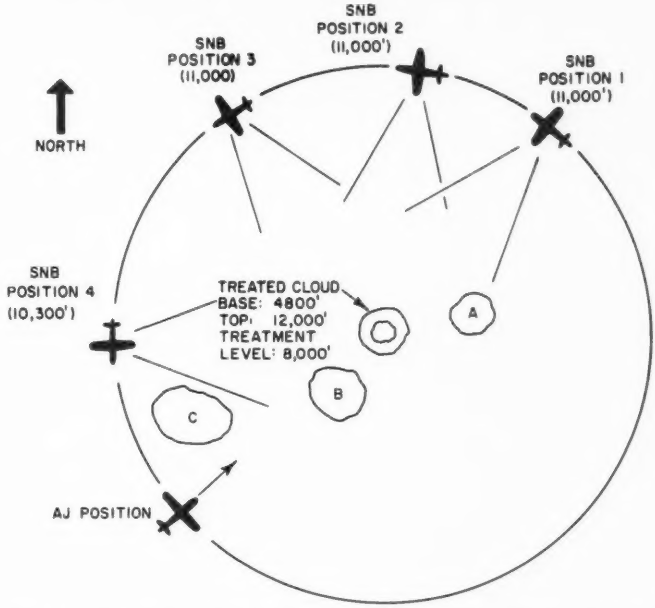
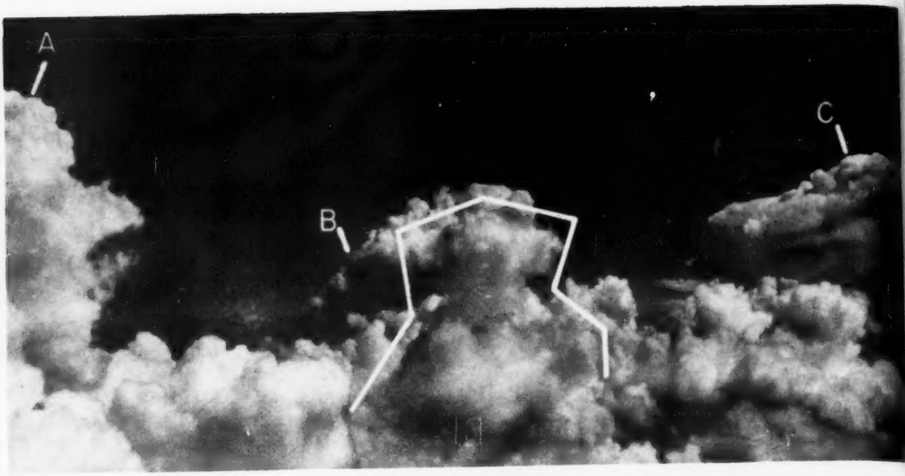


Figure 1-- Orientation diagram, showing relative positions of the photo-reconnaissance aircraft, treated cloud, and reference clouds (A, B, C) for the photographic sequences of Run 14. (See Figure 2.)

Two types of runs were made. In one type, packages containing 1.5 pounds of dry carbon black were thrown through the dropsonde chute of the plane. The packages were opened in the slipstream by means of a static line, which ripped off the plastic adhesive tape used to seal them. In the other type of run, 6 pounds of carbon black were suspended in 5 gallons of water and poured through the chute from a drum.

Cloud dissipation flights were made along the Florida-Georgia coast during the period from 11:00 A.M. to 3:00 P.M. local time, when the cumulus cloud build-up was most active, usually culminating in a thunderstorm around 4:30 P.M. A cloud along the coast between Jacksonville and Brunswick was selected, and carbon was dropped while the Constellation was flying through the cloud. Eight clouds were carboned. Only seven were observed, but all of these were dissipated. Since no positive controls were possible, it cannot be stated definitively that the carbon treatment caused the dissipation. The following evidence, however, can be adduced:



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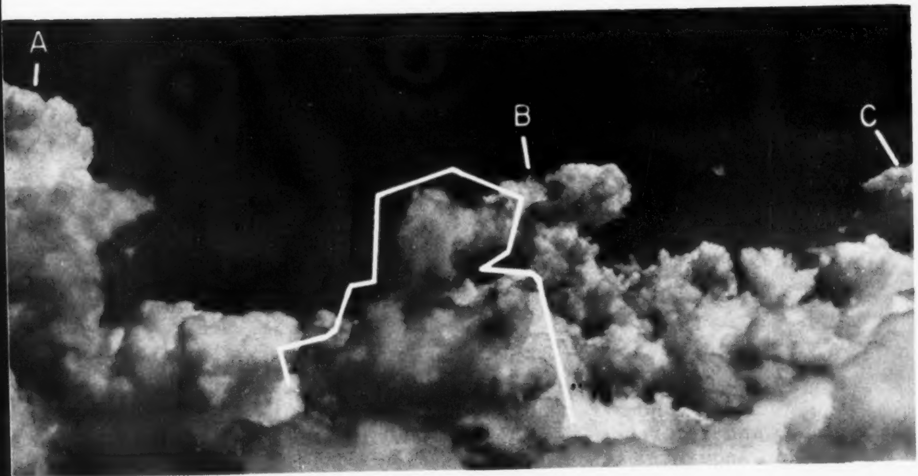

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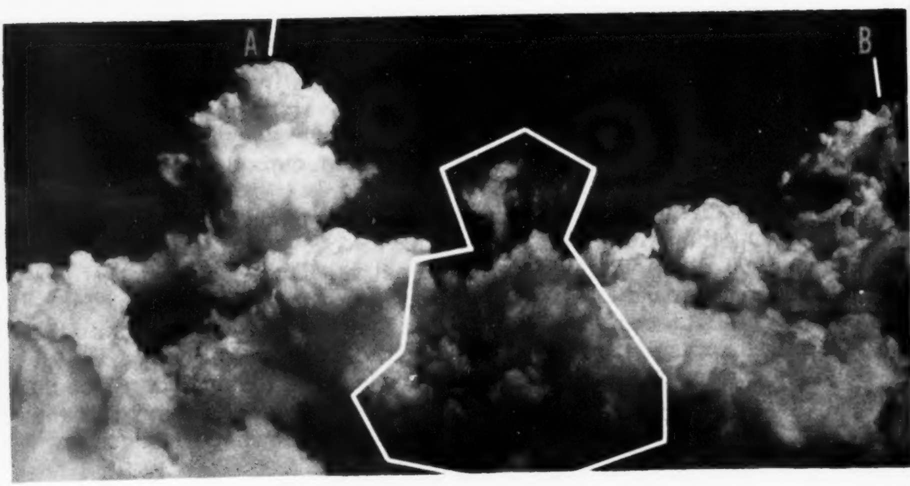

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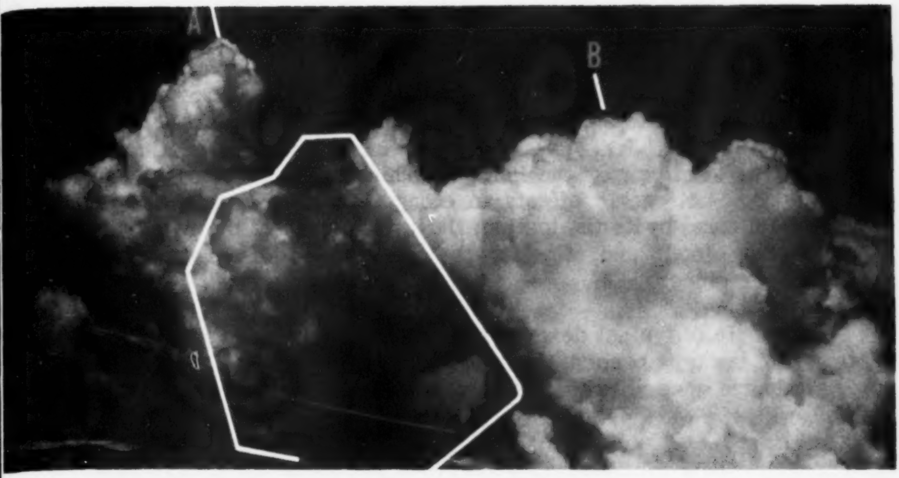

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Figure 2--Cloud dissipation (Run 14).

A. Beginning of separation and dissipation of top portion of cloud. SNB at position 1 of Figure 1, one minute after treatment.
B. Separation and dissipation of top of cloud is more advanced. SNB at position 2 of Figure 1, three minutes after treatment.
C. Dissipation of top is nearly complete; dissipation of lower half has reachedan advanced stage, with the cloud appearing gray and wispy. SNB at position 3 of Figure 1, five minutes after treatment.
D. Dissipation is nearly complete, with only fragmentary gray wisps remaining. SNB at position 4 of Figure 1, eight minutes after treatment.

Figure 3--Cloud formation(Run 10).

Enlarged 35-millimeter movie frame taken by VW-3 plane three to five minutes after it dropped 6 pounds of carbon black in clear air. Carbon in water suspension was distributed over a mile track from right to left in the photo.

- The record of seven dissipations out of seven clouds carboned and observed.
- The direct relationship between the amount of carbon used and the rate of dissipation for about equal-sized clouds.
- The similarity of the dissipation history of each cloud: a period of no noticeable effect; an elongation of the top of the cloud, followed by its dissipation; the turning gray of the remainder of the cloud; and, finally, the very rapid dissipation of that remainder.

A couple of typical descriptions of the order of events have been taken from the tape recordings of the debriefing sessions. The meteorologist aboard described the last run (Figure 2), as seen from the SNB, as follows:

> "This . . . drop was made at 1416 Romeo [local standard time] into a cu [cumulus] cloud, the top around 12,000 feet and its base around 4,800 feet. Three minutes later, at 1419, the top of the seeded cloud started narrowing and dissipating. At 1420, the top 1,000 feet of the cloud had broken off in a separate wispy cloud from the cloud underneath, and the cloud underneath started dissipating at 1422, six minutes after the drop. At 1423 the entire cloud had almost disappeared, having become gray in color, similar to the others. At 1424, eight minutes after the drop, the entire seeded cloud had disappeared. Around that cloud we have other cu--five-eighths cu--with tops of 11,000, and they are still around the area. That is about all I have. At 1425 we left that area for NAS, Jacksonville, and other clouds were building up to about 13,000 feet in the area. Within an area of about 50 miles, I could see three cumulo-nimbus clouds building up to 25,000 feet."

This same run was described by the pilot of the AJ photo plane as follows:

> "On this particular run I noticed that [the cloud] was dissipating much faster than the previous three. I shot the cloud just as the Connie went into it and made a 360° [turn] approximately three minutes after he made the drop, and already I could see it dissipating. And as Mr. Giles [quoted above] said, the top 1,000 feet was already beginning to separate itself, elongate, and squeeze itself off. By the time I made my second turn, why, it had turned this sort of darker grayish color, and I only got about three turns around and I couldn't find the cloud. It had gone. It was dissipating--more or less in the same general way as the first clouds did; however, much faster and much more thoroughly."

In addition to that part of the demonstration devoted to the effort of dissipating clouds, an attempt was made to generate clouds by using carbon black to produce the necessary convective activity in a column of humid air. For this purpose, a nearly circular cloud-free area about 25 miles in diameter, was found. The clear area was ringed by cumulus clouds with bases at 3,000 feet and tops at 5,000 to 6,000 feet. On five separate runs, a 1.5-pound package of carbon black was dropped in the center of the clear area at altitudes of from 3,500 to 4,000 feet. As the plane circled about each of the drop areas, a single wispy cloud could be observed developing at the sites of all drops except one. As the static line broke during that one drop, it was uncertain whether or not the pack opened.

The final effort in the cloud-free area involved pouring a suspension of 6 pounds of carbon in 5 gallons of water along a track about one mile in length at an altitude of 4,000 feet. When the plane flew back parallel to this track, a mile length of cumulus clouds with bases at 3,000 feet and tops at 6,000 feet was observed (Figure 3). This line of clouds was identical in texture and appearance to those which formed the boundary of the clear area 10 to 15 miles away.

LOOKING AHEAD

The results presented in this article are qualitative and are based on subjective observations in flight and subsequent interpretations of photographs. Measurements of meteorological parameters, control conditions for comparison with the treated areas, and objective measurements of the cloud modifications are lacking. Also, the flights were made in an area where cumulo-form clouds are dominant during the summer season. It is well known that generation and dissipation can occur rapidly as a natural process in such cloud formations. Yet it is believed that the consistent reports of the pilots and weather officers, the consistent pattern of the dissipation history of each cloud, and careful case history studies of the photographs (movies and stills), together with logs of all runs taken in flight, provide evidence that the carbon treatment produced real effects in dissipating and forming clouds. No evidence was obtained that would enable us to determine if precipitation was formed.

Results of these experiments indicate need for further experiments of a quantitative and objective nature. At the present time, dispersion of the carbon black, temperature effects, growth of water droplets in treated clouds of various types, and other fundamental questions are being studied. If these scientific studies provide satisfactory answers, the next step should be devoted to applications of the method to a variety of weather situations.

NRL Physicist Heads IGY Committee

Dr. Maurice M. Shapiro, Superintendent of the Nucleonics Division, Naval Research Laboratory, has been appointed Chairman of the U. S. IGY Committee on Interdisciplinary Research. This Committee is concerned with the utilization of IGY data for advancing our theoretical understanding of geophysical phenomena, especially those in borderline research areas.

Responses of the Australian Aborigine to Cold

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School of Medicine
University of Pennsylvania

The Australian aborigine is a member of a racially distinct group of men which has been isolated on the island continent of Australia for 30,000 to 40,000 years. As a result of his lack of intercourse with other humans for so long a time, his culture is widely different from our own. One peculiar feature is that he does not wear protective garments, in spite of the fact that he lives in an environment in which the air temperature goes down to or even below the freezing point of water. To the physiologist, this is an important characteristic, because it may indicate that he differs in his response to cold from other humans, many of whom are accustomed to avoiding air temperatures below 85°F. in the environment immediately surrounding their bodies. Thus, the question arises, what are the metabolic and thermal responses of the Australian aborigine to moderate cold exposure, and how do they differ from our own?

To answer this question, an international group of physiologists recently arranged for two expeditions to go to Australia to study the aborigine. Both were supported in part by the Office of Naval Research. The first team of investigators arrived in Areyonga on July 24, 1957, to undertake a month-long series of measurements of the metabolic and thermal responses of the aborigine to moderate cold exposure during sleep. It consisted of P. F. Scholander (leader), University of Oslo, H. T. Hammel, University of Pennsylvania; J. S. Hart, National Research Council of Canada; D. H. Le Messurier, University of Adelaide; and J. Steen, University of Oslo.

Areyonga, a native term meaning "valley of echo," lies in the northeastern part of the tribal territory of the Pitjandjara people. It is the westernmost settlement maintained by the Welfare Department of the Northern Territory. The Pitjandjara people were chosen for our study because they have had less contact with the European culture than tribes at the other settlements. They come and go freely from the settlement to their tribal lands, yet still retain the "know how" for sustaining themselves by the ancient methods of their culture. Around the settlement they wear clothing during the day, but they often remove it at night when they lie down to sleep. As their ancestors have done for generations, they lie between two small fires, the bare ground beneath them and the open sky above them. When away from the settlement, they leave their clothing behind and revert entirely to their ancient custom of "dress."

Our experimental plan was to measure the oxygen consumption and the rectal and skin temperatures of the natives while they slept according to their primitive habit, then compare their responses with those of white subjects utilized for control purposes, sleeping in the same way. We soon learned, however, that it was impossible to maintain a sleeping environment of comparable cold exposure for both groups, because the radiant heat fluxes from the fire to the body and from the body to the sky were large and highly variable compared with the metabolic heat production. To achieve a standard cold exposure, the fires were removed and the subjects were shielded from the clear cold sky and exposed only to the air between 0°C. and 5°C. The heat

A windbreak and three small fires provide the only shelter an aborigine family needs for a night.

A more permanent shelter, the wurlie, is prepared when the aborigine wishes to remain in one location for a few days.

loss from a naked body in this environment is greater than can be withstood for several hours. Therefore, all subjects lay on canvas cots in sleeping bags that consisted of a single-layer woolen blanket covered by a thin wind-resistant material. In this micro-environment, the white subjects achieved thermal balance by shivering, thereby increasing their heat production by about 30 percent. In the same environment, the bodies of the natives cooled a little more than those of the white subjects, and they did not shiver or otherwise increase their heat production.

Two subjects lie with heads in respiratory hoods while skin temperatures are measured with thermocouples and radiometer.

Laboratory tent beside native sleeping quarters.

Refrigerated meat van is towed across the Finke River. A bulkhead divides the van into a forward sleeping chamber and a small laboratory aft.

Having found a distinct and easily determined difference between the natives and the control subjects when measured in the winter months, another series of studies was undertaken to learn whether the response of the Areyonga aborigine to cold is the same in the summer as in the winter. The physiologists making up this team consisted of H. T. Hammel; R. W. Elsner, University of Washington; H. T. Andersen, University of Pennsylvania; D. H. Le Messurier; and F. A. Milan, Arctic Aeromedical Laboratory. This group returned to Areyonga in December 1957 to repeat the measurements made previously. To simulate winter night temperatures in the summertime, a refrigerated meat van was converted to a sleeping chamber in which the air temperature was maintained at about 5°C. All other details of the experimental plan were unchanged.

As was the case for the winter experiments, the natives exposed to cold in the summer responded by greater body cooling than the white subjects, and they did not shiver. The absence of a seasonal variation in the aborigine's response to moderate cold indicates either that the cold to which he is exposed during summer nights is sufficient to maintain his hypothermic response or else that his response stems from some peculiar racial characteristic.

To determine which of these explanations is the correct one, the expedition moved up to Darwin and spent the month of January studying the response to cold of aborigines who live in the tropical zone along the northern coast of Australia. From an examination of the climatic data accumulated over the past five years by the weather station at Darwin, we could be certain that the coastal natives had not been exposed to cold for at least several months. Although it is possible that natives who continue to sleep in the ancestral way would be exposed to cold during the winter nights of July and August, it is likely that most of our tropical subjects had not experienced chronic cold exposure even in the winter, since they have acquired many of the sleeping habits of the European culture.

The response to cold of the tropical aborigine was intermediate between that of the white subjects and that of the aborigines living near Areyonga. From these comparisons it is concluded that the Australian aborigine has an inborn ability to tolerate a greater body cooling before balancing heat loss by increased heat production. The extent to which he can tolerate body cooling without metabolic compensation can be increased by prolonged exposure to cold.

Toward what end do these findings contribute? Biologists have always been excited about studying isolated systems because of the possibility of discovering unique responses to different sets or even the same set of environmental components. The aborigine constitutes one such system. But there are many others. Perhaps before too long, biologists will even be studying such systems on other planets, where, if life exists, it will undoubtedly have evolved in entirely different environments than we know on earth. These studies are bound to have important practical applications. But the chief motivation for pursuing them will be to gather information that will help solve the greatest of all mysteries—that of life itself.

On the Naval Research Reserve

Seminar in Submarine and Diving Medicine

The first annual Research Reserve Seminar in Submarine and Diving Medicine was held at the U. S. Naval Submarine Base, New London, Connecticut, from October 26 to November 8. Twenty-one reserve officers of the research, medical, and submarine programs were formally enrolled; many sessions were also attended by student officers from the Submarine School and reservists whose periods of on-the-job training duty overlapped the Seminar.

Taking the broad view of "medicine" as encompassing all aspects of human health and efficiency, the Seminar undertook to explore the physiological, psychological, and environmental problems encountered in conventional submarine operations, in prolonged submerged cruises on nuclear-powered ships, in submarine escape and rescue operations, in deep-sea, skin, and SCUBA diving, and in the selection of personnel. Orientation was also provided in the history and military application of these techniques.

Much of the program was presented by the Staff of the Medical Research Laboratory, which served as host to the Seminar, under CAPT Joseph Vogel, MC, USN, with the collaboration of the Submarine Force, Atlantic Fleet, and the Submarine School. Activities included visits to conventional and nuclear submarines, and demonstrations of deep-sea, skin, and SCUBA diving, free and buoyant escape techniques, and the use of submarine simulators for training purposes. Visits were also made to the U. S. Naval Underwater Sound Laboratory and the Electric Boat Division of General Dynamics Corporation, where pertinent research and development projects were reviewed.

Visiting speakers included CAPT A. B. Metsger, USN, Deputy and Assistant Chief of Naval Research, and CAPT J. P. Aymond, USN, Special Assistant for the Research Reserve, representing the Office of Naval Research; CAPT H. J. Alvis, MC, USN, and CAPT G. J. Duffner, MC, USN, Bureau of Medicine and Surgery; CAPT J. L. Kinsey, MC,

Seminar participants.

USN, Special Projects Office, Bureau of Ordnance; CDR G. H. Mahoney, Experimental Diving Unit, Naval Gun Factory; Mr. A. S. Gates, Bureau of Ships; CDR David Minard, MC, USN, and Dr. S. N. Stein, Naval Medical Research Institute; LCDR E. H. Lanphier, MC, USN, Underwater Demolition Team 21; Prof. C. P. Yaglou, Harvard School of Public Health; Prof. Christian J. Lambertsen, University of Pennsylvania School of Medicine; and Mr. James Dugan, author of "Man Under the Sea," and Secretary, U. S. Liaison Committee for Oceanographic Research.

The Seminar was conceived and proposed by LCDR Leon J. Greenbaum, MSC, USNR, a member of Naval Reserve Research Company 5-10, Bethesda, Maryland. CDR Herbert N. Gardner, MSC, USNR, also of NRRC 5-10, served as Chairman, with the assistance of LT L. S. Van Orden, MC, USNR, of the Medical Research Laboratory, as Coordinator.

Research Studies Completed by Research Reservists

Six research studies have been completed recently by members of the Research Reserve. In the case of four of these, letters of appreciation have been forwarded to the project officers by the Chief of Naval Research; the other two studies are currently under review in the Office of Naval Research.

Under the direction of LCDR Lucius M. Hale, USNR, Commanding Officer of NRRC 3-10, Massena, New York, members of the company completed a research study on "Cold Weather Construction Practices." The report, which was prepared to present possible solutions to certain problems related to heavy construction during cold weather, used the winter construction operations on the St. Lawrence Seaway and Power Projects as the principal source of information. In addition to review by the Geography Branch, Earth Sciences Division of ONR, copies of the study were forwarded to the Bureau of Yards and Docks.

CDR I. G. McChesney, USNR, former Commanding Officer of NRRC 3-4, Rochester, New York, directed a company study on "The Economic Status of Several Nuclear Power Reactors." Information in this report served to bring previous studies in this field up to date.

Another study, which no doubt will have a continuing value to members of the Research Reserve, was conducted by members of NRRC 4-9, Dayton, Ohio. The Study, "Recommended Procedures for Selection and Conduct of Naval Reserve Research Company Scientific or Technical Studies," was under the direction of the Commanding Officer, LCDR William E. Kremer, USNR. Copies of this study may be obtained from ONR (Code 120) by any company planning to initiate a company research study.

LCDR Anna H. Kennedy, USNR, a member of NRRC 11-2, Pasadena, California, completed an individual research study under appropriate duty orders entitled, "Auditory Annoyance." Dr. Kennedy, a leader in the field of hearing and bioacoustics, was encouraged to submit the report to a technical journal in the field of audiometry.

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[1]Articles are arranged chronologically under the ONR division or laboratory having cognizance of the research described.

[2]Written by the editorial staff of Research Reviews.

[3]Adapted from an article published in Engineering Research Institute News, University of Michigan, April 1958.

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[2] Written by the editorial staff of Research Reviews.

[4] Adapted from an article published in the IGY Bulletin, National Academy of Sciences, February 1958.

[5] Adapted from an article published in Monthly Newsletter, Bureau of Supplies and Accounts, June 1958.

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U. S. GOVERNMENT PRINTING OFFICE: 1958 O - 489585

The important role played by wooden ships in man's efforts to expand his horizons is well exemplified by the Mayflower, pictured here. See article beginning on page 7.

In This Issue

COVER PHOTO: The Flying Cloud, 1851, fastest of the California clippers. For a discussion of the use of wood in ship building see article beginning on page 7.

RESEARCH REVIEWS endeavors to report briefly highlights of technical progress in research by Navy laboratories and contractors and the development of important naval research facilities. Articles which meet these broad criteria and possess a good degree of readability are welcomed. Manuscripts and changes of address should be sent to Code 740, Office of Naval Research, Washington D. C. ... Research Reviews is listed for sale by the Superintendent of Documents, U. S. Government Printing Office, Washington, D. C. Subscription price: $1.50 per year in U. S. and Canada; $2.00 per year foreign; $0.15 per individual copy. Use of funds for printing this publication was approved by the Director of the Bureau of the Budget, February 12, 1958.

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