AVAL RESEARCH

REVIEWS

DEPARTMENT OF THE NAVY
OFFICE OF NAVAL RESEARCH

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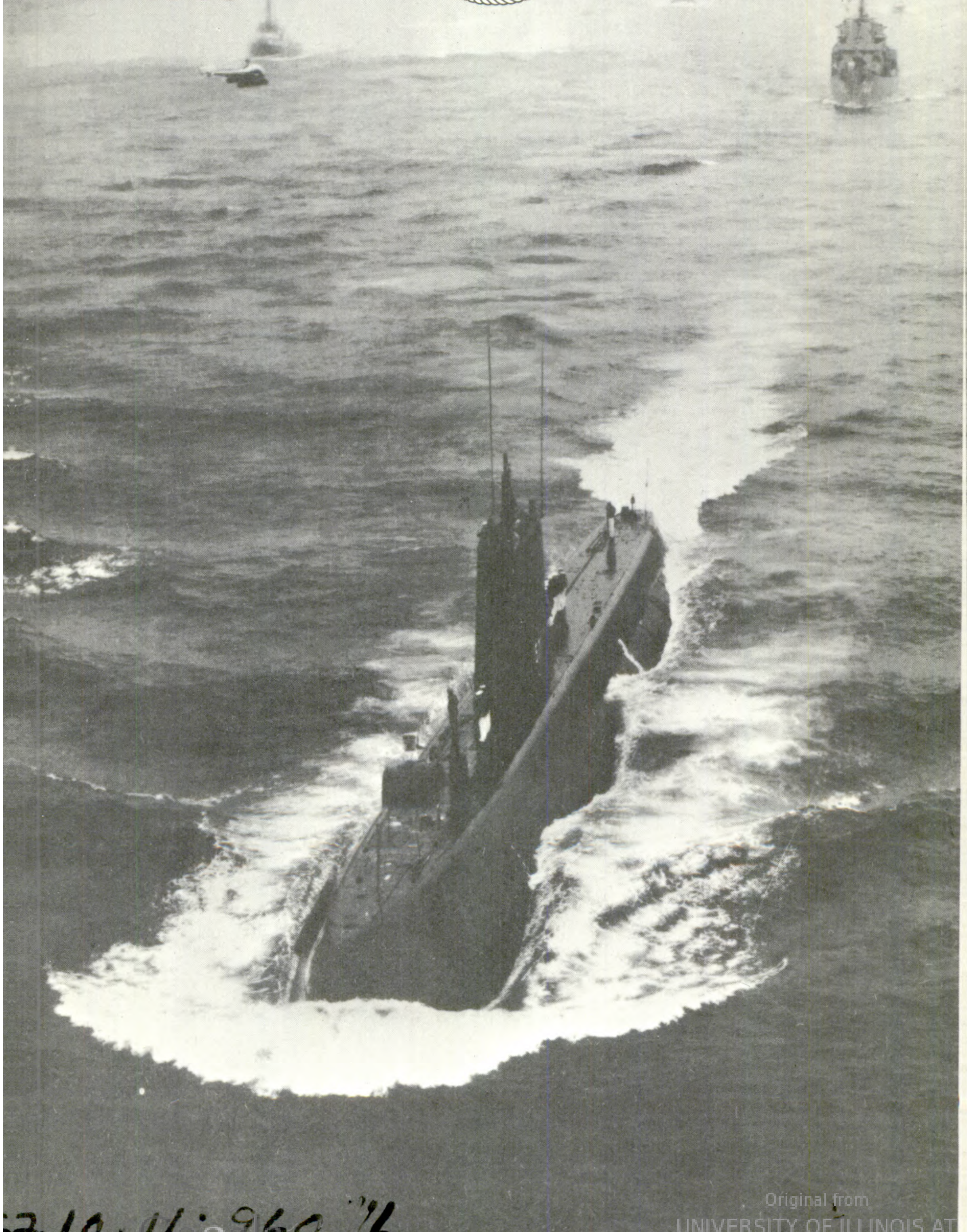

The First X-Ray Picture of the Sun

Reproduced above is the first X-ray picture of the sun, which was obtained by scientists of the Naval Research Laboratory on April 19, 1960. The photograph was made from 130 miles in space with a "pinhole" camera flown in an Aerobee-Hi rocket launched at the White Sands Missile Range in New Mexico. The image caught on the film at the back end of the camera was only 1/20 inch in diameter, and the pinhole itself was 5/1000 inch in diameter. The accompanying photograph, which is a direct enlargement of the original film, shows a bright halo of X-rays around the periphery of the solar disk and several intense spots of bright X-ray emissions distributed across the solar disk. These X-ray emissions from the sun do not penetrate the earth's atmosphere below a height of some 60 miles, but they play an important role in the formation of the ionosphere which in turn controls long-range radio communication. Dr. Herbert Friedman, Superintendent of the Atmosphere and Astrophysics Division of NRL, exhibited and explained the significance of the photograph to scientists attending a recent symposium on solar emissions, held in Washington, D.C., and sponsored by the National Academy of Sciences and the American Geophysical Union. The photograph resulted from a successful experiment prepared and executed by ENS Richard L. Blake and Mr. Arlyn Unzicker, both of the Naval Research Laboratory.

Solar Flares and What They Do

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By taking a simple telescope or even a good pair of binoculars which have been covered by a dark filter so that the sun can be looked at directly without injury to the eyes, we will sometimes see on its otherwise perfect, silvery surface, small black dots and patches. These are sunspots. If watching the sun is continued, some of these sunspots will disappear in a matter of days while others will appear, growing slowly, and then finally going behind the limb, or edge, of the sun as it rotates on its axis. Sunspots are quite long lived; some reappear several times on the visible face of the sun, and thus apparently last for a matter of months. But others will grow and become lost on the bright solar disc in only a few days.

Observing sunspots over long periods of time reveals that the number of sunspots on the face of the sun at any one moment slowly rises and falls in a definite 11-year rhythm. At times, there may be roughly 100 spots visible, while a few years later only a few can be seen. Had we been watching the sun with this simple equipment in 1957 and 1958 when it was heavily dotted with sunspots, we might have seen a pinpoint of bright light close to or over one of the spots. We would then have seen a large solar flare, an event of great importance to our planetary system. We will be mostly interested here in these large flares which occur about two or three times per month when the sun is at the peak of its activity cycle. However, astronomers using more refined means of observing the sun find that there are also smaller flares, as well, and that a couple of dozen of these may occur in a single day. The significance of a solar flare comes not from the tiny extra output of light by the sun which makes the flare for our eyes. It is of interest because a single flare sets off a great chain of events that affects our own close environment, planet earth, in extremely complex ways for days or even weeks. The understanding of these effects, the reason that flares appear on the sun, and what happens inside these flares to produce effects that reach out for millions of miles are among the great current problems of physical science.

To begin talking about any of these questions, it is necessary to be far better equipped than with just binoculars or a single telescope. So we must turn to highly developed scientific instruments and methods of using them. One of the remarkable aspects to the study of the sun's activity and its effect on the earth is that many branches of science are involved each with its own methods of approach. At work on these problems are astronomers, astrophysicists, radio astronomers, ionospheric physicists, geomagneticians, and auroral and cosmic-ray physicists. Even meteorologists are involved, since there seems to be a link between solar activity and weather--which, although fragile, is nonetheless fascinating. It is clear that the study of the sun by so many unlike minds is best done when all observations are made in a coordinated way and are followed by rapid exchange of information.

This was one of the main reasons for creating the IGY* and its follow-up, the IGC.† Here scientific cooperation is of much greater direct importance than in any other area, and this was actually achieved to a remarkable degree on national and international levels during those periods. Much of this work was accomplished under the sponsorship of ONR.

SOLAR FLARES

Let us then outline the knowledge that is now available concerning the questions "what is a solar flare" and "what does it do?"

We must actually start this story before the flare begins. For one of the most important discoveries in the study of the sun is that strong magnetic fields protrude from the sun's surface near sunspots.†† The strength of these fields may be as high as 2000 gauss, a value easily obtainable on the earth, but these solar magnetic fields cover very great areas, much larger than the entire surface of the earth. Solar flares generally occur in or near these sunspot magnetic fields and following the flare, these huge fields are considerably weakened. Since magnetism is a form of energy and since energy can be transformed but not lost, great amounts of it aare released in the flare process. This sudden release of energy in a small region of the sun's highly ionized atmosphere--just above its surface--is the ultimate cause of all the complex effects that follow the flare. One effect that would be naturally expected is intense heating of the sunspot region by means of electrical currents; and this heating produces the small but very bright flash of light we see as the solar flare.

Closely coincidental with ths visible feature, radio operators experience interference of radio communications for an hour or two on the side of the earth turned toward the sun. This type of radio blackout is called a "sudden ionospheric disturbance" (SID), or by those physicists who monitor the amount of galactic radio noise penetrating our ionosphere, a "sudden cosmic noise absorption" (SCNA). This effect is caused by ultraviolet light and soft X-rays which produce additional ionization in the earth's ionosphere. This radiation is also due to high temperatures. But while it is of the same fundamental nature as visible light, differing only in having shorter wavelength, it is quickly absorbed by the topmost layers of the earth's atmosphere, and none of it can be detected at ground level. Rockets fired at the first signs of a flare, however, directly observed these energetic radiations on several occasions.§

During the growth phase of the flare, radio astronomers, can "hear" the crisp burst of high frequency "radio noise" from their receivers. This release of radio energy takes place over a wide range of frequencies (20 to 10,000 megacycles). (We will return to an explana-

*International Geophysical Cooperation.

† International Geophysical Year.

†† For an excellent discussion of this phenomenon, see the article by H. W. Babcock in the December 1959 Scientific American.

§ Naval Research Reviews, pp. 1-6, November 1959.

tion of these radio bursts a little later). After a few minutes the bursts are no longer heard but there is now a rather steady emission of radio noise from the sun that slowly rises in strength then gradually dies away after several hours. This long-enduring radio hiss will be most prominent at the lower and intermediate frequencies. The importance of this radio emission on a quite broad band, or continuum is that during the flare the sun was able to accelerate particles up to quite high energies. These particles doubtless electrons--evidently acquire quite high individual energies; but because there still remain very strong magnetic fields even after the flare, these electrons are easily retained in the neighborhood of the sun where they move in tight corkscrew-like paths. As a result of this sharply bent (or accelerated) motion, they lose their energy in a matter of hours by emitting "radio noise." (Fundamentally the same effect is known to occur, although at a higher frequency in large man-made particle accelerators, called "synchrotrons." Electrons whirling in very strong magnetic fields emit a beam of visible light strong enough to be seen by the unaided eye. This light is called "synchrotron radiation," the term also applied to the radio waves in the case of the characteristic solar radio noise storms following large flares.) Another remarkable feature of this solar phenomenon is that the region emitting this synchrotron-type radio noise is very large--often much bigger than the sun itself. These sources of radio energy are located high in the sun's atmosphere, indicating that the electrons and magnetic field, as well, have quickly expanded away from the flare region.

SOLAR PROTONS

The next effect produced by the flare is seen at the earth about an hour or so after the flare has reached its peak development, and this effect is a much more direct and striking example of the sun's ability to produce energetic atomic particles. Streams of protons of up to a few hundred million electron volts energy begin to arrive at the earth, at first fluctuating greatly in intensity and probably reflecting the turbulent conditions in the solar atmosphere. Then after a few hours they impinge on the earth in a quite steady manner, dying slowly away in a matter of days. These protons are of too low energy to produce any effects in cosmic-ray detectors at ground level and can only be directly detected by use of high-altitude vehicles such as balloons, rockets, or satellites. They do, however, produce a large and characteristic effect on the earth's ionosphere, and this fact was of great importance in the discovery of this phenomenon.

The uncovering of this important flare effect was made only lately. It is, however, one of the best examples of the great success that marked the intensive and coordinated observational program carried out during the IGY. The rapid understanding of the solar proton phenomenon followed quite directly from the large number of solar and ionospheric observations that were available. Most of the detailed knowledge of solar particles or low-energy cosmic rays, as they can properly be called, came from particle counters and photographic emulsions carried by large plastic research balloons. Very important statistical evidence has been realized from radio physics techniques, notably cosmic radio-noise measurements in Alaska, Canada, Greenland, and Sweden.

A balloon flight, made by a group from the University of Iowa at Fort Churchill on the Hudson Bay, succeeded in showing that a stream of rather low-energy protons arrived at the top of the atmosphere shortly after the large solar flare on 22 August 1958, and was present for at least two or three days. Then the continuously recorded cosmic noise-absorption observations, along with some important data from the satellite Explorer IV, showed that many large flares do the same thing. During the period from January 1956 to July 1959, there were about 30 such instances, or approximately one per month. It became clear that the emission of energetic protons is a regular and important aspect of the solar flare phenomenon.*

The frequent emission by the sun of very intense beams of ionizing particles clearly constitutes a further radiation hazard for human space travel.† However, it should not prove to be serious for two principal reasons:

- The radiation although intense is not highly penetrating, and space vehicles will be able to carry adequate shielding.
- With the great amount of information now available on this phenomenon, it is possible to predict safe periods and danger periods for ventures out of the earth's protective atmosphere.

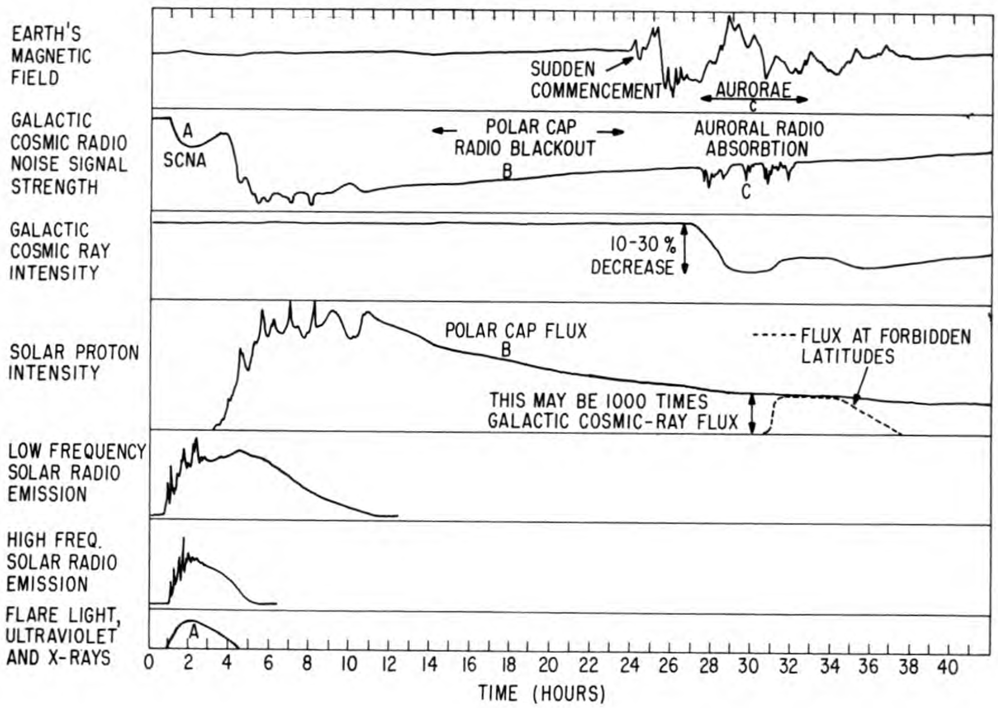
WORLD-WIDE GEOMAGNETIC STORMS

The final major effect produced by a solar flare is one which has been known for some time and one with which many people have had direct experience. These are the geomagnetic storms and accompanying bright, colorful aurorae that appear far to the south of the auroral zone. Because of the lack of important details, we can only give an account of the events which may later turn out to be wrong in rather basic ways. Much more knowledge is required about the entire magnetic storm process, a problem that will be one of the primary concerns of future satellite work.

Because of its great heating effect, the flare is believed to produce something akin to a supersonic "boom" which pushes a hot and highly ionized gas (or plasma) out through the sun's atmosphere. It is this violent motion which excites the bursts of radio noise mentioned earlier. This gas will expand as it moves across the planetary system. Its speed is quite variable, usually being between 500 and 1000 kilometers

*Previous to this discovery, it was known that on rare occasions (five times in 18 years) in connection with flares the sun emits very high energy cosmic rays for comparatively short periods of time.

†See Naval Research Reviews, inside front cover, October 1959.



Pen-recorder traces of detected radiation during solar flares that show the sequence of solar and terrestrial events and typical duration times. The pairs of letters indicate well-defined cause-and-effect relationships.

per second. Thus, if headed in the right direction, it will bump into the earth in a day or two. Since it is so highly electrical, being mainly composed of electrons and protons dissociated from one another, it will actually collide with the earth's magnetic field and the highly rarefied upper layers of the earth's ionosphere. The collision is first detected wih ground-level magnetometers as a rapid and characteristic change of the magnetic field, called the "sudden commencement." This is followed by larger changes in the magnetic field which at times amount to several percent. These changes gradually subside, and after half a day or so the field is largely undisturbed. During their presence these large magnetic-field changes have important effects upon the outer Van Allen radiation belt. Great numbers of the particles which previously were whipping back and forth from one hemisphere to the other in tightly trapped orbits are disturbed by the magnetic storm effects and are shaken out into the earth's atmosphere where they produce bright auroral lights and intense X-ray showers high in the earth's atmosphere. Surprisingly, just a few hours later during the magnetic storm, these last particles--mainly electrons and in all probability protons as well--are replaced. The source of these "replacement particles" is almost certainly the storm-producing gas cloud. There is evidence, however, that outside the earth the gas cloud does not contain any of the high-energy particles that the radiation belt is known to contain; therefore, it is believed that the interaction of the gas cloud with the earth accelerates some of the solar particles that make up the cloud.

EFFECTS OF THE STORM ON GALACTIC AND SOLAR COSMIC RAYS

The magnetic-storm-producing gas cloud has significant effects on cosmic rays during the time of its influence on the earth. A few hours after the sudden commencement of the storm, the high-energy cosmic radiation that circulates through our galaxy is partially excluded from the region of the earth. This decrease in cosmic-ray intensity (known as "Forbush decrease"), amounts to from a few percent up to 30 percent or more of the total primary intensity. It occurs in a matter of hours, but many days or even longer are required for the intensity to recover its former value. It is believed to be due to magnetic properties of the solar gas cloud or to magnetic effects produced by the cloud in the neighborhood of the earth. Because these storms occur frequently during maximum solar activity, the cosmic-ray intensity often does not fully recover before the next decrease comes along and thus is steadily driven down during these times. Then, as flares become less frequent on the sun, the cosmic rays recover in intensity. In this way, the cosmic rays coming from the galaxy are modulated in the region of the earth by solar activity to have cyclical 11-year intensity variation.

One interesting phenomenon is the aurorae which appear regularly in the auroral zones. At present, it is not clear what part solar flares play in producing them. The outer radiation belt doubtless plays a role, but some other important and as yet unknown factor must also be present to cause the daily appearance of aurorae in the absence of magnetic storms.

One important statement remains to be made concerning the effects of solar flares. There are very great differences in detail between one flare and another. In some cases one or more of the effects described in this discussion may be entirely left out. These phenomena are reflections of the enormous complexity of this problem, which will continue to demand man's best efforts and most refined techniques for some time to come.

Named to Nat'l. Academy of Sciences

Edward L. Hays, superintendent of the Safety and Survival Equipment Research and Development Division at the Naval Air Material Center's Air Crew Equipment Laboratory, has been appointed to the National Academy of Sciences. He will serve on the Academy's Panel on Closed Ecological Systems. Mr. Hays has been engaged in research in the field of aircrew safety, including the development of survival and escape equipment systems, for more than 15 years. In 1944, he was one of the original employees of the Aero Medical Department which later became the Air Crew Equipment Laboratory.

Atmosphere Control in Confined Spaces

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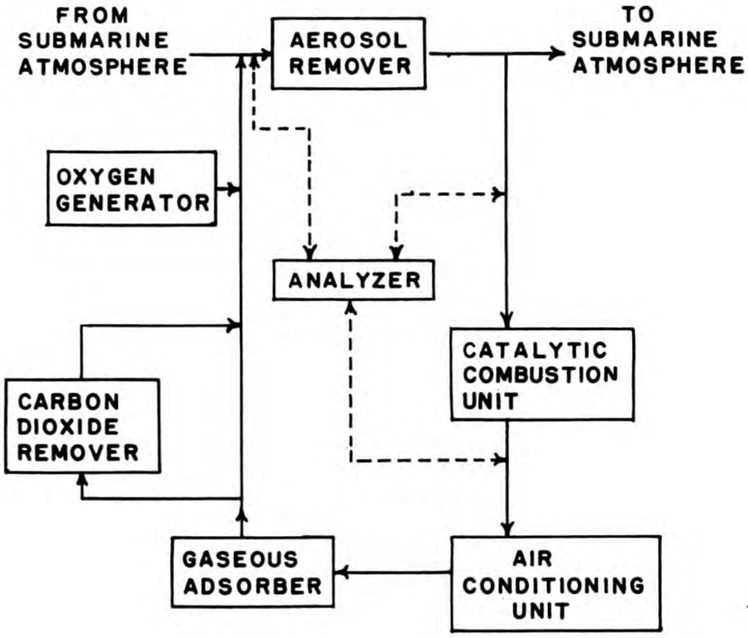
The recent voyage of the TRITON around the world was a superb demonstration that nuclear power has given the submarine an almost unlimited capability of underwater operation. The length of submergence now seems to depend mostly on the ability of men to live and work efficiently in closed spaces; this includes all factors involved in the maintenance of the health, morale, and human relations of the crew. The overall program which has brought this capability into being is generally referred to as "submarine habitability." But because the problems of maintaining life satisfactorily in a submarine, and in a space vehicle, are essentially alike, the Navy's interest extends to any type of confined space that is isolated from our material atmosphere, whether deep in the water or high in the sky. Thus, while this article deals specifically with submarines, it should be remembered that solutions arrived at in one medium may also be applicable to the other. The Naval Research Laboratory's interest in this area is concerned with the chemical and chemical-engineering problems involved in maintaining a satisfactory atmospnere that is free from harmful contaminants. (See the Cover Photo.)

For continuous submergence, it is necessary to establish an equilibrium between the respiratory metabolism of man and the various systems supplying oxygen and removing carbon dioxide. In addition, trace substances which adversely affect man must be either rigidly controlled or eliminated entirely. A continuous monitoring system must also be provided to indicate the concentration levels of the various components in the confined atmosphere.

The block diagram on the next page shows an integrated system for controlling the atmosphere in a submarine. In this cyclic system a sufficient quantity of the air from the submarine is passed continuously through an aerosol remover. A portion of this air—the amount depending upon the level below which carbon monoxide and the deleterious organic vapors must be maintained—is drawn through the catalytic combustion unit, which oxidizes the combustibles to carbon dioxide and water. The air is then passed over the cooling coils of the air conditioner to reduce the temperature of the outlet air and at the same time condense out a portion of the moisture. Traces of residual gases are removed by adsorption on a bed of adsorbent material. A bypass takes part of the air from the adsorber unit through the carbon dioxide removal unit. Oxygen is then added, either from bottles or from a generator. In going through these scrubbing and regenerative processes, the cycled air inevitably picks up aersols, so it is passed through the aersol remover before being released into the submarine. Meanwhile the atmosphere analyzer is used to monitor the system at any desired point or points in the submarine; if necessary, as indicated by the dotted lines, it could be used to control any particular process in the system.



Atmospheric control system.

We have outlined the various components of the integrated system. Now let us consider some of the items in more detail. Aerosols must be considered as contaminants. They may be either liquid or solid and result largely from smoking, cooking, cleaning, and painting. Aerosols are much more of a problem than is normally realized, particularly where long submergences are required. While there is little information on the effect of long-time exposure on humans, there is a well-recognized effect on delicate operating equipment. NRL has determined the nature and concentration of the various kinds of aerosols present in the submarine atmosphere. The specifications for high-efficiency electrostatic precipitators to reduce these contaminants to acceptable levels have been recommended and accepted. A program to install aerosol removers in new construction, and backfit in present ships, is now underway. These precipitators are high-efficiency, high-capacity units resulting from the research efforts of NRL and BUSHIPS.

Carbon monoxide and hydrogen are now being removed by a catalytic combustion method developed by NRL. This unit also removes a large majority of the known and unknown organic vapors encountered during long periods of submergence. The unit contains a heated bed of Hopcalite which converts, by oxidation, the carbon monoxide and hydrogen to carbon dioxide and water. Most organic materials also are completely oxidized.

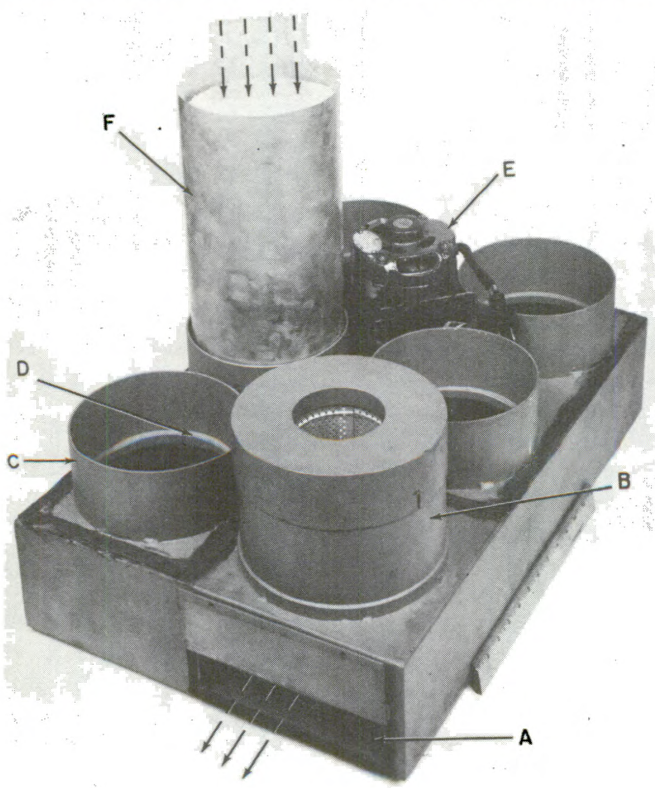
The cooling coils in the air conditioner serve to reduce the air temperature from the hot combustion unit and to condense water. As a final method of removing trace quantities of organic vapors, an activated carbon bed has been incorporated in the unit. The carbon is practicable only if the organic gas content can be maintained at a low level, because if the organic content is high, the adsorbent quickly becomes saturated. And replacement of carbon beds at sea is impractical.

At present, in the fleet-type submarines, carbon dioxide is removed by lithium hydroxide as an absorber, a method that has been modified into a more convenient form by the use of canisters. Because of the stowage problem, however, the cans would not be practical for prolonged submergences. At present, all of the nuclear submarines are equipped with a liquid scrubber containing mono ethanol amine (MEA). This material has the ability to absorb carbon dioxide at room temperature and to release it on heating. Since the amine is subject to oxidation and is considered to be somewhat toxic, NRL is studying methods of inhibiting its oxidation and is also considering nontoxic substitutes.

Another unit, being considered for carbon dioxide removal, employs the electrolysis of aqueous sodium sulphate. In this process, referred to as the sodium sulphate cycle, a caustic forms at the cathode, and oxygen is generated at the anode. After the caustic has been used to absorb the carbon dioxide, sodium sulphate is regenerated by mixing the sodium carbonate with the acid being formed at the anode. Such a system is a very appealing regenerative method because it requires only a source of power and water. A pilot model of the proposed unit is under construction at NRL and should be operating in the near future.

The possible use of algae to absorb carbon dioxide and generate oxygen is attractive if an efficient species and suitable light source can be found. A small plant built to investigate these factors, is in operation.

In all submarines, oxygen is now being supplied from cylinders, thus establishing a definite limit on submergence time. The Laboratory has developed a simple and efficient method of storing oxygen in the form of a chlorate candle. This candle is a mixture of sodium chlorate and



Lithium hydroxide unit for removing carbon dioxide: (A) bypass with door open; (B) filter assembly; (C) canister support ring; (D) rubber sealing ring; (E) 1/2-hp, a-c motor; (F) simulated canister filled with soda lime. Arrows indicate normal airflow.

powdered iron in such form that it gives off oxygen when ignited. These candles can be used either as an emergency supply or for submergences of several weeks duration without becoming too much of a storage problem.

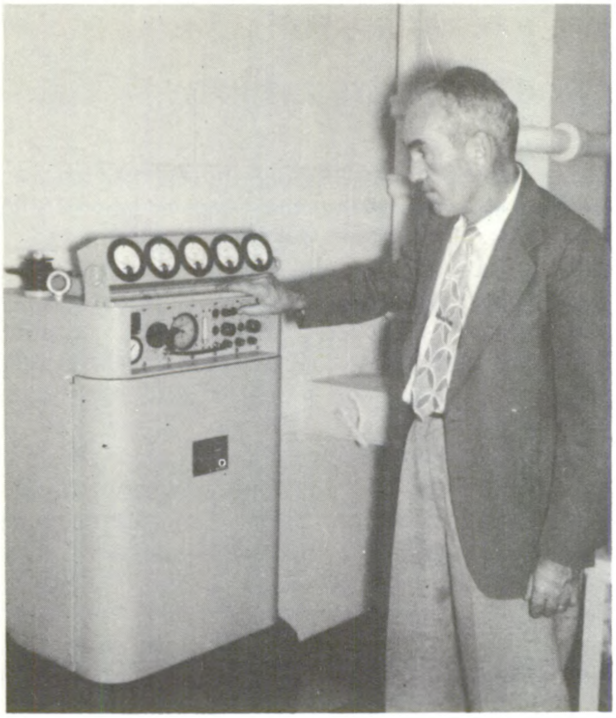
An oxygen candle with burner.

For prolonged submergence under conditions where sufficient power is available, it appears that for the present we will have to depend on the electrolysis of water for our supply of oxygen. A high-pressure electrolytic cell for this purpose has been developed by the Bureau of Ships. This cell will not only avoid the problem of storing high-pressure oxygen cylinders but at the same time provide sufficient pressure for expelling from the submarine the hydrogen evolved. This system is currently installed on the POLARIS submarine GEORGE WASHINGTON.

Still another method of oxygen generation by electrolysis is being developed. This unit employs the nickel cadmium storage battery that generates oxygen on the charge cycle. This unit would have relatively low power requirements and would not require the use of the fragile diaphragm necessary in other electrolytic equipment.

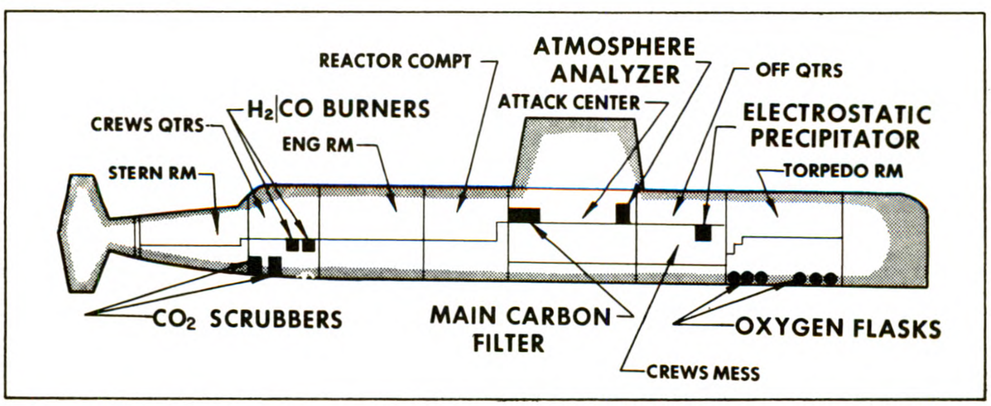
The sulphate cycle, already mentioned in connection with the problem of removing carbon dioxide, provides another electrolytic method of generating oxygen. Since it will combine both oxygen generation and carbon dioxide removal into a single unit, it is very attractive for submarine use.

The monitor for the integrated control system is the atmosphere analyzer. Each of the presently operating nuclear submarines is equipped with an analyzer developed at NRL. The detection methods employed in the unit are infrared adsorption for carbon dioxide, carbon monoxide, and Freon; paramagnetism for oxygen; and thermal conductivity for hydrogen. Until replaced recently by a production model, these analyzers were not only developed, but constructed, installed, and maintained by the Laboratory. This procedure, somewhat unusual for a research laboratory, was necessitated by the time factor in the accelerated nuclear power program. A completely new method, in which four, small, thermal conductivity cells are used in combination with a simple computer system, is now under development. This unit will be capable of analyzing for all known gases present in concentrations over 1 percent and will be considered as a replacement for the present analyzer.



The Mark III atmosphere analyzer.

The voyage of the TRITON, and the earlier exploits of NAUTILUS, SKATE, and SARGO, have provided ample evidence that the atmospheric control systems presently in use are workable and that submariners can live in their sealed environments with reasonable comfort for months at a time. It can be mentioned again that the experience gained in submarines is applicable to the manned cabins of proposed space vehicles. It should be pointed out, however, that in the submarine there are a few power and weight limitations and water is in abundant supply. These conditions simplify our present problem in comparison with that of manned space travel. However, the principles of atmospheric control in the two cases are considered identical.



Atmospheric purification equipment in a typical nuclear powered submarine.

(Courtesy of BuShips Journal.)

A New Vehicle for Exploring the Ocean's Floor

Only a few months ago, from a bathyscaph, Navy scientists viewed the ocean's floor at a depth of 35,800 feet. Now the Navy has available a new undersea vehicle which will give scientists full freedom for investigation in this environment they have just begun to penetrate. Dubbed RUM for Remote Underwater Manipulator, the vehicle is essentially a remote-controlled tank equipped with a long, jointed, manipulator arm and hand, together with specially devised underwater television cameras which serve as eyes for the operator back on shore.

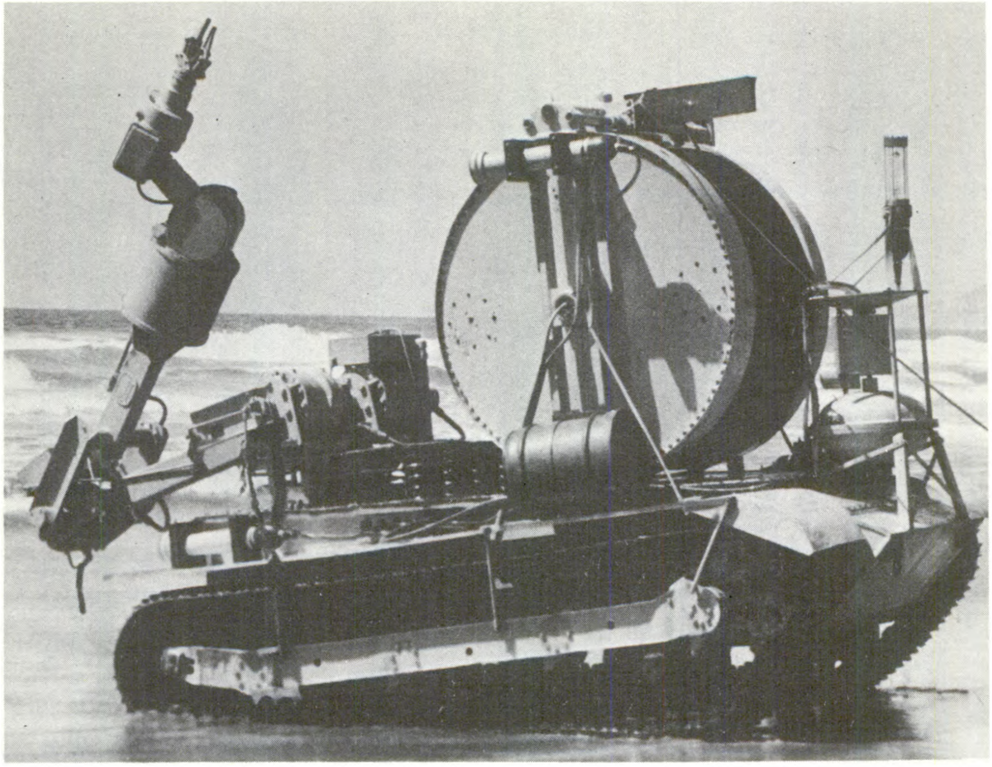
The goal of the Navy RUM development is to have available a vehicle capable of performing controlled-work functions in oceanographic research. This includes observation of the sea floor, the collection of samples and specimens, and the assembly and installation of deep bottom-mounted instrumentation in the ocean.

The first experimental vehicle was developed under the direction of Dr. Victor Anderson at the Marine Physical Laboratory of the Scripps Institution of Oceanography at La Jolla, where it is now undergoing extensive underwater tests. The basic hull and truck assembly is an Ontos tank (an operational self-propelled rifle used by the Marine Corps) upon which has been mounted the special manipulator arm. Specially adapted sonar equipment guides its progress over the ocean bottom.

RUM can operate at depths down to 20,000 feet, maintaining a speed of 3 miles per hour where level-bottom conditions permit. It can maneuver and operate on grades of 60 percent and is capable of surmounting vertical obstacles 12 inches in height. The tracked vehicle with the mechanical manipulator in place is capable of carrying a payload of 1000 pounds in the water, and without the manipulator the payload is increased to 2000 pounds. Hydraulic controls provide the normal braking action for the vehicle, while emergency braking is automatically performed by a spring-actuated friction brake.

The powerful boom-mounted mechanical manipulator, designed and built by General Mills, is a modified version of the master-slave hands used in atomic laboratories. Made of stainless steel, the arm is an electromechanical device which synthesizes the motions of the human arm. It includes a two-pronged hand that opens and closes, a wrist that rotates in either direction, an elbow that pivots, and a shoulder that both pivots and rotates. The hydraulically actuated boom supports the arm and enables it to reach out 15 feet in any direction to perform jobs requiring skill and dexterity in oceanographic research. Also, the boom has a hook for lifting tall, heavy objects, with the load capacity ranging from 170 pounds to over 5000 pounds.

A unique television system, fabricated by Orbitran Company, Inc., utilizes four underwater cameras. These are designed to monitor from



RUM on the beach. The test vehicle, RUM, returns from the Pacific ocean floor, off the coast of Southern California.

the beach the operation of the vehicle and its manipulating arm and hand. Illumination for the cameras at pitch-black ocean depths is provided by mercury vapor lights attached to the ocean rig.

A coaxial cable, long enough to permit operations out to five miles, links the undersea vehicle to a mobile van on shore. The cable carries the television signal and relays power for the operation of the vehicle, the cameras, and the mercury vapor lights and provides several remote-controlled telemetering channels.

The present experimental RUM model has been built for the Navy primarily to test the feasibility of employing such a vehicle in oceanographic research. The engineering design for a fully operational vehicle includes a lift appendage, designed by Hughes Aircraft, Inc., which will enable the undersea vehicle to swim underwater rather than just crawl along the ocean bottom as it does now. With this appendage, RUM will be able to raise or lower itself in the water, move sideways, hover, or float.

Tungsten for High-Temperature Coatings

High-purity tungsten can now be easily plated on metal surfaces by using a vapor deposition process which the National Bureau of Standards* has developed for the Navy. The method, devised by W. E. Reid and Dr. A. Brenner of the Bureau's electrodeposition group, involves reducing gaseous tungsten hexafluoride with hydrogen by passing it over the heated object to be plated. At temperatures above 300° C, tungsten is deposited on the hot surface, and the only other reaction product, hydrogen fluoride, passes out with the excess of hydrogen. By this method (Figure 1), it is possible to coat numerous simple and complex surfaces such as rocket and missile nozzles and jet engine parts. The technique also lends itself to the fabrication of tungsten articles, (Figure 2), and may be the only way that complicated shapes of tungsten can be formed. Simple tungsten shapes for use in vacuum tubes have already been fabricated.

Tungsten is one of the few metals that possess structural strength at temperatures above 2000° C. Its extremely high melting point (3140° C), hardness, and corrosion resistance make it a desirable material for high-temperature equipment. Until lately, however, the high-temperature properties of tungsten could not be effectively utilized. Its

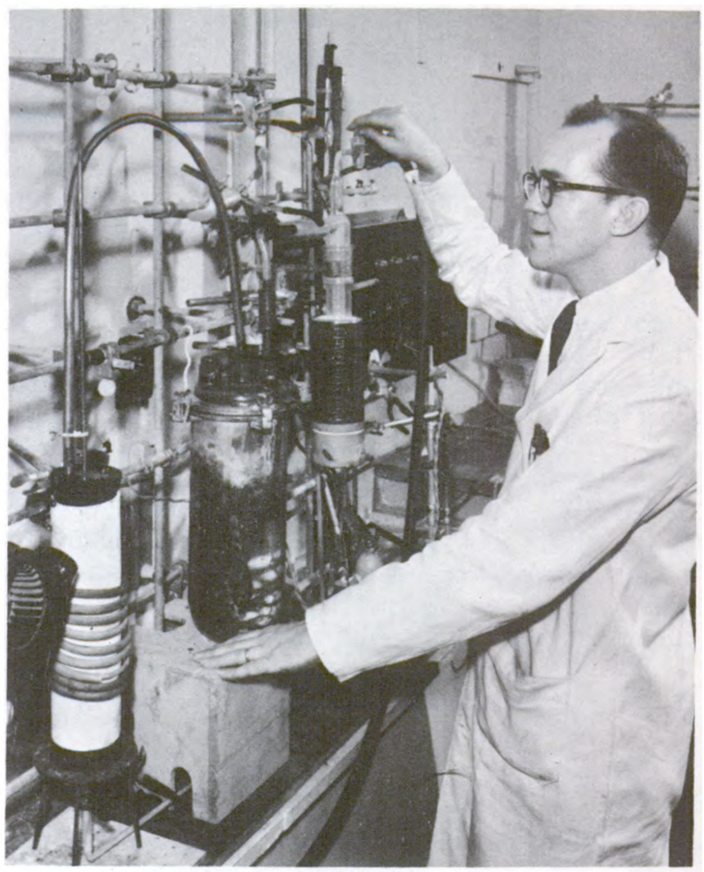


Figure 1 -- Plating high-purity tungsten on metal surface by a vapor deposition process at NBS. To produce tungsten coatings, hydrogen and tungsten hexafluoride are passed over the object to be plated (in ceramic cylinder at left). Hydrogen fluoride, the only impurity formed, is absorbed in the trap (vessel in center). W. E. Reid inspects equipment before a run.

*A similar method has been developed independently by the Bureau of Mines.

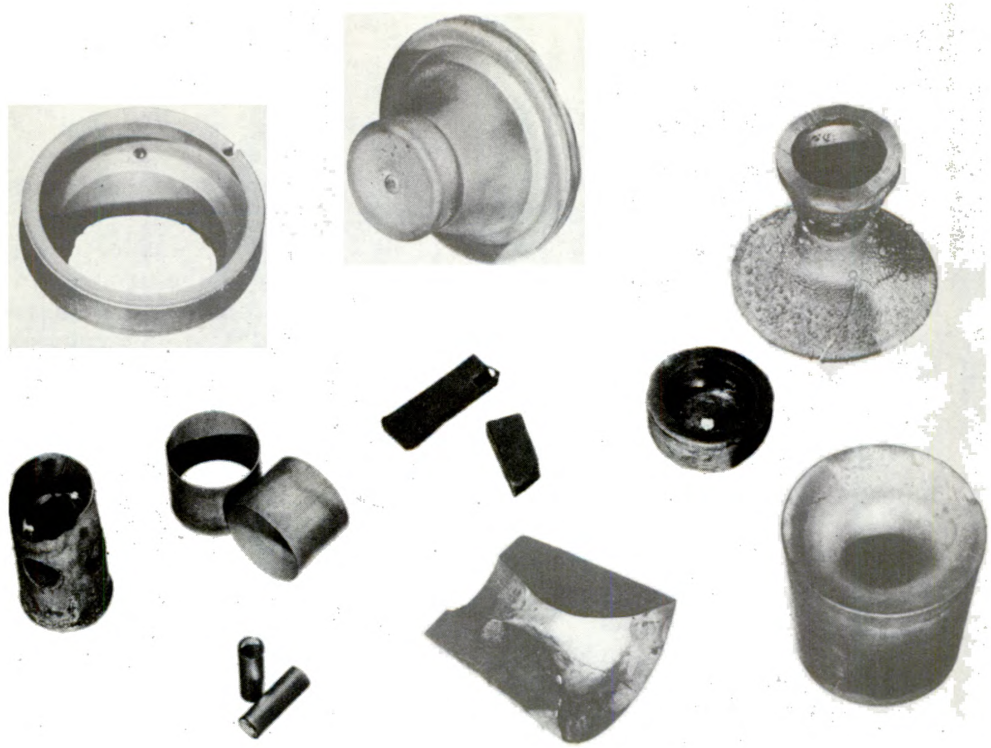


Figure 2 - Specimens of simple and complex tungsten forms and coated objects produced by vapor deposition method developed by NBS. Plated articles shown are rocket nozzle (right bottom), cross section of rocket nozzle (center bottom) and small sample rectangular pieces (third center row). By using this process, complicated forms can be fabricated entirely of tungsten as illustrated by components for an electron furnace (left and center top), thick tungsten rocket nozzle insert (right top), sample tubing (second from left center and left bottom) and "crucible" (right center). The intricate interior as well as the exterior of the object at left center is completely coated with tungsten showing the excellent covering ability of the method.

brittleness and hardness prevented it from being machined by conventional methods, and its weight restricted it from being used in aeronautical equipment. For these reasons, efforts were made to develop a practical method for depositing tungsten coatings.

Tungsten hexafluoride was selected for use in the vapor deposition process for two reasons. First, the compound is a gas at room temperatures and therefore convenient to use. Second, tungsten apparently forms only one compound with fluorine—WF_6. Thus the reactions are straightforward, uncomplicated by many products or side reactions.

The equipment required is simple. The object to be plated is placed inside a cylinder of ceramic material; the air is then pumped out and replaced by hydrogen. A controlled temperature induction furnace heats this object to about 650° C. Then the two gases, tungsten hexafluoride and hydrogen, are passed through ordinary glass flowmeters into the reaction chamber. When the gaseous mixture comes in contact with the heated object, tungsten is deposited on the hot surface. The byproduct of this reaction, hydrogen fluoride, is absorbed in a suitable trap.

Although the theoretical ratio of 3 moles of hydrogen to 1 mole of hexafluoride is needed for complete reduction, satisfactory coatings are obtained when the ratio is lower. In practice, however, smooth deposits are insured by using a hydrogen-to-hexafluoride ratio greater than 6. Wide variations in the flow rate of the gases and in the pressure in the system have no major effects on either the efficiency of the process or on the quality of the coating. Although the optimum temperature range for rapid formation of smooth deposits is 650 to 700° C, temperatures in the range from 300 to nearly 900° C are fairly effective. Definite crystal growth is observed at 900° C when the ratio of hydrogen to hexafluoride is 3 to 4.

Spectrochemical examination shows that the tungsten obtained by vapor deposition is purer than ordinary commercial tungsten. Silicon is the only impurity present in a concentration of 0.1 percent or more. Then too, the deposited metal has the theoretical density of pure tungsten—19.3 g/cm3—which is higher than that of tungsten compacts produced by powder metallurgy or by flame spraying. That is, plating eliminates the very tiny holes between tungsten particles resulting from the other two processes. The hardness of the deposits obtained at 650° C is about 475 VHN (Vickers Hardness Numbers) or about the hardness of ordinary commercial tungsten. The crystals deposited at 900° C are not as hard (410 VHN), indicating a slightly higher degree of purity.

The adhesive bond between the tungsten coating and various basic materials was investigated. Adhesion to molybdenum and to iron was good; to copper, somewhat weaker; and to iron, rather poor. The tungsten-graphite bond was about as strong as the graphite itself. Tungsten deposited on ceramics also showed good bonding.

Deposits 1/16 inch thick were obtained by vapor deposition in an hour. In this same time only 0.001 inch thickness of tungsten could be plated from fused salts melts in electrodeposition. The maximum thickness of deposit that can be obtained by the vapor method has not been determined, but would depend on the permissible roughness of the surface. Because of the rapidity of deposition, this process lends itself to the continuous production of tungsten-coated strips or wires.

Plating a metal strip or wire is simple, but the uniform distribution of tungsten over an irregularly shaped object is a problem that must be solved for each item. Deposition is more uniform over the exterior of an object if plating is conducted in a chamber much larger than the object. Since tungsten deposition occurs in greatest quantity where the gases first strike the hot object, better distribution probably can be obtained by passing hydrogen through the main opening in the chamber and leading the WF6 to various parts of the object, by a system of injector tubes. For obtaining a desired tungsten shape without the other metal underneath, the metal form is chemically dissolved after deposition. The method of separating the tungsten depends upon the other metal used.

Research Notes

Annual Iceberg Forecast

The ice patrol will have only about 100 icebergs to look after this season; this is the prediction of Mr. Irving I. Schell, Professor of Meteorology at Tufts University and Associate of the Woods Hole Oceanographic Institution.

A study of the fluctuations in the iceberg severity off Newfoundland during the past 80 years, carried on by Mr. Schell, indicates that the principal cause of the fluctuations in the number of icebergs drifting down past latitude 48° N each year off Newfoundland during April, May, and June mainly, is the strength of the northwesterly winds along the Labrador coast and the temperature during the preceding months December to March. With icebergs always in abundance to the north in Baffin Bay, the number of bergs that will cross this latitude—which was chosen by the International Ice Patrol as a "signpost"—will depend on the winds that are determined from the December to March pressure distribution and on the temperature in that general area. Although the major portion of an iceberg is below the surface, the Labrador Current in which these bergs ride is relatively slow while the wind speed can be many times greater. By acting on the exposed portion of the berg, the wind greatly affects the berg's speed and direction. Low temperatures generally mean the formation of pack ice offshore which tends to ward off the bergs from getting close to the coast. With strong northwest winds and low temperatures, the bergs which might otherwise find their way into the shallows and bays along the coast, are forced southward to enter the warmer waters to the south where they quickly melt.

The relationship between the December to March pressure distribution and temperature and the iceberg count was expressed as a formula that can give early in April the approximate berg count on a scale of 0 to 10. On this scale the average count is approximately 5 units which corresponds to some 420 bergs. For last year, the indication was for an excess of 0.8 units on this scale, or for some 530 bergs. A total of 685 bergs was counted that year. For the year before, 1958, when only a dozen icebergs, approximately, was indicated, only two were recorded past latitude 48°N. For this year the indicated count is well below the average, around 100. The formula from which this forecast was derived is based on data which ended in 1926. For the period of 33 years subsequent to 1926, there was a discrepancy between the actual count and the computed count only in the years 1929, 1944, and 1945. In the last 60 years as many as 1000 and more icebergs drifted past latitude 48° in 1904, 1909, 1912, 1929, and 1945; and fewer than 10 bergs came down past this line in 1940, 1941, 1951, and 1958. In addition to investigating the fluctuations in the iceberg count, past latitude 48°N, the study aims to develop a formula for indicating the eastward drift of some of the bergs. Although few bergs find themselves way out in the ocean those that do are particularly dangerous because they are not under surveillance and are not normally expected there. The iceberg study is part of a broader study of ocean ice-weather relationships, which concerns itself also with the pack ice covering a large portion of the Arctic Ocean and adjacent waters, that Schell began in 1938.—ONR, Boston.

WWV and Standard Frequency Comparison

How does the National Bureau of Standards check the change in frequency of WWV, the NBS time-signal station (standard frequency radio station)? Daily observations to determine WWV's change in frequency—in terms of cesium resonance—are made at NBS, Boulder, Colorado; WWV, Beltsville, Md.; and the Naval Research Laboratory, Washington, D. C. The WWV 2.5-megacycle carrier is checked at NRL against a cesium standard by a phase-comparison method in which the measurements are averaged over 54 minutes around noon (EDT) each working day. NBS personnel at Beltsville also makes the same type of determination. At Boulder readings obtained while using a time-pulse comparison method are averaged over a 30-day period. Reports are sent to WWV and NBS by NRL each week, and similar information is received by NRL from WWV and NBS.

Although it is possible to adjust carefully several cesium resonance devices so that they agree to one part in 10 billion at any one location, three such devices may differ by as much as five parts in 10 billion when located at remote points, even though the resonant frequency (9,192,631,840 cycles per second) of each cesium resonance device is the same. At distances up to 15 or 20 miles from the transmitter (the distance from NRL to WWV), the phase of the received WWV signal carrier is small enough to be compared against a precision oscillator or cesium resonance device without substantial error. At greater distances, however, where length of propagation path begins to take effect, the accuracy of comparison can best be achieved by observing the loss or gain in time of a special clock. This is no ordinary clock, but one controlled by the cesium standard at each receiver over a period of time long enough to make doppler or propagation variation effects insignificant.

The type of information NBS uses to triple check WWV's frequency follows:

Frequency Deviations of the Signals Received from Station WWV
With Reference to Cesium Standards
(Using a 9,192,631,840-cps division ratio)

1959 Jul-Aug	30-day moving average at NBS Boulder, using once-a-second pulses at 15 Mc	60-min average each day at WWV, using 2.5-Mc comparison	56-min average each day at NRL, using 2.5-Mc comparison
26	$-30\ p/10^{10}$	$-32\ p/10^{10}$	NR (no reading)
27	-29	-32	$-28\ p/10^{10}$
28	-29	-32	-28
29	-29	-32	-29
30	-29	-31	-28
31	-29	-32	-28
1	-29	-32	NR

The phase resolution at 2.5 megacycles is roughly three parts in 100 billion, although all values have been rounded to the nearest 10 billion. The possible slight difference in measured value among the three cesium resonance devices are also taken into account. At the present state of the art, the values agree within five parts in 10 billion when averaged over a 30-day period. Actually, the frequency measurements are made with continuously running, highly stable crystal oscillators. To assure that the 2.5- and 5-megacycle oscillators are disciplined, they are reset periodically to cesium standards which are generally run only for short intervals to conserve the life of the cesium tube. The NRL oscillators (built by Bell Telephone Laboratories) have stabilities of some three parts in 10 billion per day.

At distances greater than 20 miles from the WWV transmitter, where the doppler shift resulting from propagation path-length variation limits direct phase comparison at high frequencies, the station's once-per-second time pulse can be checked against a clock under atomic discipline over an interval sufficient to achieve the desired accuracy. By using a clock having only one-tenth of a microsecond resolution and driven by a BTL-type oscillator, comparison to one part in one billion per day is possible.

The information from NRL, WWV, and Boulder—regarding WWV's departure from atomic frequency—is combined by NBS and published monthly in the Proceedings of the Institute of Radio Engineers.

Living Drift Bottles

Marine creatures that look like tiny, transparent beer kegs have been used as "living drift bottles" in a study of the ocean currents off California conducted by two scientists at The University of California's Scripps Institution of Oceanography. Called Doliolum denticulatum, the animals rarely grow more than three-eights of an inch long. They are plentiful in the central oceans, and also off Baja California.

Leo D. Berner, Jr., biologist, and Joseph L. Reid, Jr., oceanographer, have discovered that when the water is as warm as it has been during the past three years, the doliolids are also found as far north as San Francisco. The creatures can swim only feebly. The trip from Point Conception, the northernmost point they have been found during cool years, to San Francisco, would be the equivalent of a baby's crawling 25,000 miles. Their presence so far north thus offers further evidence on the differences in prevailing current patterns during periods of warm and cool water.

The submarine with the "biggest ears" in the U.S. Navy's underwater nuclear fleet was launched at Groton, Conn., on April 27. She is the sonar-packed TULLIBEE, first of the nuclear hunter-killer sub-and carries a record number of tracking "ears," most of them in her "nose." Designed specifically to seek out and destroy enemy subs, the TULLIBEE will be able to make the most of her "hearing aids." Special sound-proofing construction throughout the ship will eliminate much of the sonar noise and make her the quietest sub in the fleet.

On the Naval Research Reserve

Promotions to Lieutenant Commander

Twenty Lieutenants of the Research Reserve Program were among the 912 officers of the Naval Reserve selected for promotion to the grade of Lieutenant Commander by the Fiscal 1960 line selection board, which convened on March 8, 1960. Congratulations are extended to these officers, who are listed below along with the Research Reserve companies to which they belong.

J. D. Armstrong, Jr.	3-2	M. C. McLean	5-8
H. J. Bender	6-16	D. A. Pitt	9-6
J. E. Bossoletti	11-8	E. A. Scoles	12-3
J. P. Cofer, Jr.	5-2	E. Swain	6-1
L. E. Fox	12-1	S. J. Tassinari	3-9
L. U. Jameton	9-8	G. E. Thornburgh	13-5
L. L. Kupferberg	5-3	E. N. Trickey	1-1
R. F. Lanzillotti	13-3	R. L. Van Sickle	3-3
R. K. Larson	9-5	J. Vislocky	3-14
T. D. Linton, Jr.	5-8	H. G. Wise	6-15

Some statistics have been drawn from the records of the Research Reservists selected for promotion.

Date of Rank:	Earliest	8-1-45
	Latest	7-1-55
	Median	4-1-52
Designator:	1105 - 18	
	1315 - 1	
	1355 - 1	
Date of Birth:	Earliest	1912
	Latest	1928
	Median	1923

Seminar on Science and Engineering

Polytechnic Institute of Brooklyn was host to 80 officers of the Naval Reserve Specialist Programs and various Army and Air Force Reserve components. The officers attended a two-day seminar on Modern Advances in Science and Engineering, on 6 and 7 May. The Seminar, arranged by the College at the request of Naval Reserve Research Company 3-1 in New York City, was sponsored by the Commandant of the Third Naval District. Co-chairmen were CDR F. E. Kulman, USNR, Commanding Officer, NRRC 3-1, and Dr. A. B. Giordano, Dean of the Graduate School.

The program included presentations by 12 of Polytechnic's teaching and research staff and covered advances in polymer chemistry, radioactive analytical methods, nuclear and solid state physics, particle accelerators, space and atmospheric flight, generation of microwaves for satellite tracking, feed-back control systems, and electronic computers in control systems. These lectures were supplemented by inspection trips to the laboratories of the Departments of Aeronautical Engineering and Applied Mechanics, Chemistry, Electrical Engineering, and Physics, to the Microwave Research Institute, and to the New York Naval Shipyard.

On 7 May Dr. N. Marcuvitz, Director of the Microwave Research Institute, discussed the properties of plasmas (ionized gases). The luncheon address on that day was given by Dr. Herman M. Mark, Director of the Polymer Research Institute, who spoke on "Recent Advances in Polymer Chemistry."

Weekend Seminar at USRL

On the weekend of 22-24 April 1960 a weekend group-training seminar was held at the Underwater Sound Reference Laboratory, Orlando, Florida. This seminar was planned and carried out by LCDR Percy F. HURT, USNR, Commanding Officer, Naval Reserve Research Company 6-8 of Orlando in cooperation with the Director, USRL, and the Commandant, Sixth Naval District. Forty-five Research Reserve officers of the Sixth Naval District participated.

The seminar opened at 2000 on Friday with opening remarks by LCDR HURT and the introduction of four speakers of the evening: LCDR J. R. ANTINK, USN, Commanding Officer, USNRTC, Orlando; Mr. O. M. OWSLEY, Director, USRL; CDR R. N. JENNINGS, USNR, Fifth and Sixth Naval District Research Reserve Liaison Officer; and LCDR E. F. KEHOE, USNR, Training Specialist, ONR Washington.

Saturday's agenda included a full day of presentations, discussions and tours at the USRN. CDR D. T. HAWLEY, USNR, Assistant Director, USRL, served as the seminar general chairman. CDR R. J. BOBBER, USNR, Head Research Division, USRL, opened the discussions for the day with a presentation on "The Navy's Interest in Underwater Sound." Shipborne Sonar and Sonar of the Future (SOLUS Project and ASROC Project) were discussed by CWO R. E. FORD, USNR, Head, Electronic Engineering Division; LCDR W. E. RADFORD, USNR, Transducer Engineer; and LCDR H. DENNIS, USNR, Head, Measurements Branch. Sonar of the Future was discussed in three phases: "New Concepts" by LCDR E. W. SAPP, USN, Project Officer, Undersea Warfare Branch, ONR Washington; LORAD Project by CDR HAWLEY; and the COLOSSUS Project by CWO FORD. For the tour of USRL, the seminar group was divided into four sections. Each visited the following areas: (a) Pier, (b) Transducer Laboratory, (c) High Frequency Laboratory, and (d) High Pressure Laboratory. Sunday morning was devoted to a briefing and tour of the Martin Company, under the direction of LCDR W. M. FURLOW, USNR, Manager, Research Department, Martin-Orlando. On the lighter side, members of the seminar group enjoyed a social hour on Saturday evening at the McCoy Air Force Base Officer's Club.

Submarine and Diving Medicine Seminar

A survey of the 42 officers attending the Research Reserve Seminar on Submarine and Diving Medicine—at the U. S. Naval Submarine Base, New London, Connecticut—revealed the concensus that this was one of the best and most informative seminars they had the privilege of attending. The seminar convened for a two-week period on 20 March 1960 and consisted of an excellent panel of speakers and arrangement of subjects, interspersed with appropriate tours—providing a first-hand observation of submarine problems and observation of demonstrations in the medical research laboratory.

The seminar was appropriately opened by RADM L. R. Daspit, USN, Commander Submarine Force, U. S. Atlantic Fleet and CAPT G. W. Lautrup, Jr., USN, Commanding Officer, U. S. Naval Submarine Base, New London. The Legion of Merit was presented to CDR George Bond, MC, USN, Officer-in-Charge of the Medical Research Laboratory (MRL) and a commendation and citation to CDR Mazzone for their outstanding contribution to diving physiology and medicine.

After introductory talks by RADM Bennett and RADM Daspit, the general subject of submarine medicine was introduced by CAPT R. E. Faucett, Force Medical Officer, SUBFORLANT and CAPT G. J. Duffner, Director of Submarine Medicine of BuMed. Thereafter the seminar launched into the more technical aspects of physiology of man as influenced by the atmosphere and other special conditions within a submarine.

The first week was devoted to environmental problems such as carbon-dioxide exposure, heat and humidity, survival in conditions of excessive cold, sanitation within a submarine, and the general problem of atmosphere control. The speakers were noted specialists within their fields, both civilian and military. These sessions also included a briefing on the Polaris program, an excellent general discussion of selection and training of submarine personnel, and a very interesting tour of the Underwater Sound Laboratories.

The second week was devoted largely to the physiology and problems of diving medicine, particularly the direct effects of pressure in deep diving, the indirect effects including decompression sickness, and special physiological problems related to deep sea diving. The lectures were interspersed with interesting and appropriate motion pictures and live demonstrations—including a visit to the Escape Training Tank. Two full days were occupied in a cruise on a fleet submarine and participation demonstration of diving-bell rescue operations. The submarine cruise was the highlight of all tours and demonstrations, giving each attending officer at the seminar first-hand experience in a submarine during its diving operations and much better understanding of the myriad of problems facing the submarine officer and his crew, in order to better appreciate the medical problems of life and operations aboard these important vessels.

The attending officers and a number of the speakers as their guests, ended a most profitable seminar with a banquet. The appropriate last word in closed-space problems was made during a dinner address by COL George M. Knauf, MC, USAF, Patrick Air Force Base, Florida. This was a beautifully illustrated, fascinating and vivid discussion of the operations and biomedical problems involved in space flight.

CAPT Medd Retires

CAPT Medd

CAPT John S. MEDD, USNR, retired from the Naval Reserve on 1 May 1960, concluding naval service which dated back to World War I. He was an active member of the Research Reserve Company 3-9, Brookhaven National Laboratory, Upton, New York, where he served as Commanding Officer and also promoted the highly successful Brookhaven Seminars in nuclear science. In his tenure as Commanding Officer, the company grew from an original membership of 15 to its present roll of 36. CAPT Medd, who received his degree in Mechanical Engineering from Stevens Institute of Technology, was active in electronic engineering until April 1942 when he was commissioned in the Naval Reserve. He was assigned duty as Electronics Production Superintendent for the New York Naval Shipyard. During the next four years he participated in over 5000 overhauls of ships of the line. Between the summer of 1946 and the end of 1948, he was the District Reserve Electronics Officer, reporting to the Commandant, Third Naval District. Since his return to civilian life in 1948 he has been employed at the Brookhaven National Laboratory as Property Co-ordinator.

CDR Rode Honored

CDR Rode

CDR Norman F. RODE, USNR, Commanding Officer of Naval Reserve Research Company 8-3, College Station, Texas, was named Engineer of the Year by the Brazos Chapter of the Texas Society of Professional Engineers. In civilian life, Mr. Rode is a professor of electrical engineering at Texas A&M College. A native of Charleston, South Carolina, CDR Rode was graduated from Clemson College in 1919 with a degree in electrical engineering. After a brief career with General Electric and as a marine engineering officer with the merchant fleet at sea, he joined the A&M faculty and was named a professor in 1930.

CNO on ASW

(Quotes from a speech made by ADM Arleigh Burke before the National Security Industry Association Antisubmarine Warfare Advisory Committee.)

"When the Soviets equal our submarine capabilities, when their submarines have nuclear power, better hull form, missiles like the Navy's Fleet Ballistic Missile system--POLARIS,--when they too have these things, our antisubmarine problems will grow. This is why we have to keep ahead of them, have to improve our abilities to cope with the best submarines anyone can put to sea.

"To do this we continue to emphasize ASW Research and Development,... [which] takes a lot of effort. It takes judgment to know what to do, to know which lead to pursue, which to discard, to know when to drop the ones that are not turning out as well as hoped for.

"Research is our hope for the future--but there are things we can do now...for our very progress and improvement have added to our problems. With improvements in our weapons and equipment have come increased complexity, oversophistication.

"Oversophisitication of equipment produces two problems--money and maintenance. Complex equipments cost more to buy, to maintain, to operate. We need so many weapons in sea warfare, so many in antisubmarine warfare alone, that we have to spread our dollars over a wide range of seagoing capabilities. The more each weapon costs, the fewer we can buy. The fewer we buy, the less capability we have in ASW, and in other vital areas. Even to approach the minimum numbers weapons must stay low in cost. They must be simple.

"The SIDEWINDER air-to-air missile is a good example of what can be done with low cost and high effectiveness. It is a wonderful weapon. Its effectiveness has been proved in battle. The Chinese Nationalists used SIDEWINDER with great success against Chinese Communist aircraft. We can buy more of these missiles with the same amount of money, than we can of more sophisticated, and sometimes less able weapons. And SIDEWINDER is easy to maintain.

"Maintenance is the second problem brought about by too much complexity by over-sophistication. We have to be self-reliant at sea. We must be able to maintain seaborne equipment ourselves. We must stay free of day-to-day dependence on shore facilities. Self-reliance is the difference between carrying the fight to an enemy, or staying in home waters waiting for an enemy to come to us. Our weapons and equipment must be maintained by the men who man our ships. The Navy bluejacket is able and willing, he works hard. We take youngsters in the Navy, we train them, they are good, but they are not yet master engineers. Gear that needs a master engineer to maintain it on a day-to-day basis has no place at sea. No matter how effective equipment may be, no matter how well it performs in the shop, it is of no use at sea, if we can't rely on it, rely on it to function when we need it most--in battle."

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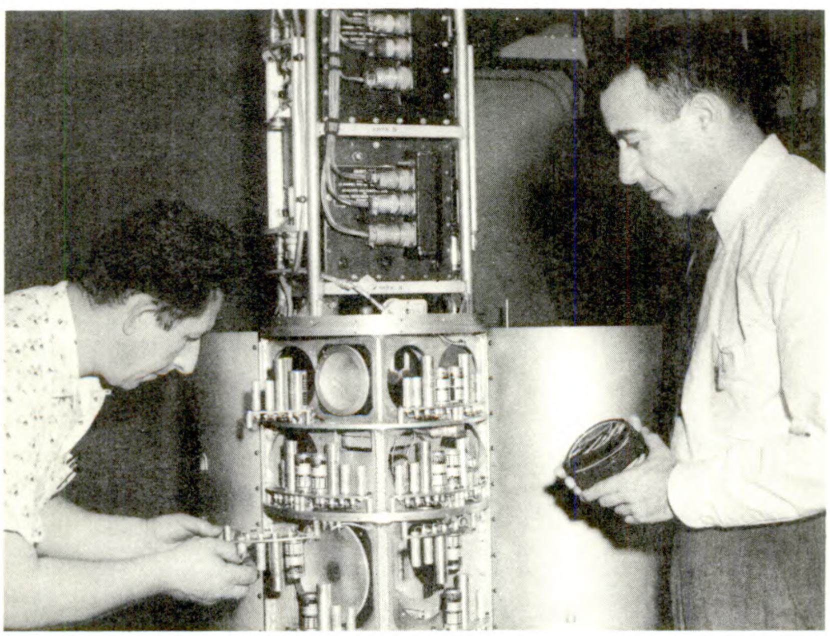
Ultraviolet Survey of the Night Sky

An array of eight small telescopes–sensitive to radiations of extreme ultraviolet wavelengths–was employed in a rocket astronomy experiment conducted by scientists from the Naval Research Laboratory on May 26 at 9:05 p.m., MST. The telescopes contained in the 235-pound instrument section were sent aloft in an Aerobee-Hi rocket–which reached an altitude of 135 miles over the White Sands (New Mexico) Missile Range and which remained above the atmosphere for five minutes. There the telescopes obtained a view, unobstructed by the dense sea of air surrounding the earth, and transmitted images to ground receivers that will provide valuable information about the structure of the stellar atmosphere–images of celestial ultraviolet emissions that cannot be "seen" with ground-based optical and radio telescopes. The images, obtained by scanning (as the rocket spun through its curved trajectory), were reflected by specially coated mirrors to photodetectors which converted the images into electrical impulses. Previous to this experiment, only one ultraviolet telescope had been sent into space and that by NRL scientists. This was on November 6, 1959, when another Aerobee-Hi rocket reached an altitude of 88 miles. Results of this preliminary experiment clearly distinguished the ultraviolet emission of individual stars and nebula. Rocket astronomy experiments serve the useful purpose of providing maps of ultraviolet radiations from celestial sources and discovering the range of phenomena worthy of more detailed study. The results of the May 26 experiment should provide the most complete map yet obtained of the sky in the invisible ultraviolet.



The 235-pound instrument section of the Aerobee-Hi rocket being checked out by NRL scientists, Dr. H. Friedman (right) and Mr. J. J. Nemecek (left).

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NAVAL RESEARCH reports highlights of technical progress in research by Navy laboratories and contractors and the development of important naval research facilities. The magazine 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. Changes of address should be sent to Code 740, Office of Naval Research, Washington, D. C. Use of funds for printing this publication was approved by the Director of the Bureau of the Budget, February 12, 1958.

A nuclear submarine comes home—from a long-submergence run made possible by chemistry. (See the related article on pages 7-11.)