RESTRICTED

RESEARCH REVIEWS

15 DECEMBER 1948

CONTENTS

OFFICE OF NAVAL RESEARCH

DEPARTMENT OF THE NAVY ☆ WASHINGTON, D. C.

NAVEXOS P-510

RESTRICTED

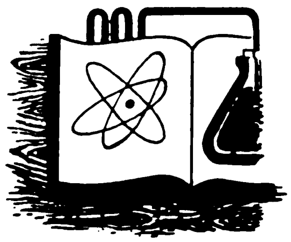
RESTRICTED

COVER PHOTO: A task ever prevalent in the Navy is that of fighting corrosion. This sailor does his part in the laborious job of painting his ship. A more scientific and less manual approach to the corrosion problem is the aim of ONR-sponsored research in this field.

Approved by Bureau of Budget, 13 April 1948

RESEARCH REVIEWS--

A monthly journal devoted to ONR-sponsored research



EDITORIAL MUSINGS

The President of the United States spoke recently of the status of science in this country. He said "we stand at this moment at the threshold of revolutionary developments." He spoke specifically of the problem faced by the Office of Naval Research when he said, "Our problem, therefore, is not a static one of preserving what we have. Our problem is to continue to engage in pure -- or fundamental -- research in all scientific fields. Such research alone leads to striking developments that mean leadership." ONR is undertaking to sponsor fundamental research but such an undertaking is only possible by means of the cooperation of the scientists of the country. These scientists are the men who contribute articles to Research Reviews. That they have responded so enthusiastically by sending us articles is evidence that they desire the men in the Fleet to hear their story. To understand specific problems of science will lead to support by the Fleet of scientific research and a realization of the influence of science in general on their daily lives.

LETTERS

(Write Code 484, Office of Naval Research.)

USS PHILIPPINE SEA
Care FPO New York

8 October 1948

Memo to Office of Naval Research

I feel sure that Captain Tolley's statement, under "Letters" in your 15 September issue, "My crew spends a large part of its time fighting rust with 1870 equipment . . . ," expresses the sentiment of every commanding officer in the fleet.

The need for doing something about it in the operating Navy is so basic that I am sure the entire fleet will cheer any action ONR may take to stimulate improvement of this rusty situation.

J. L. PRATT
Captain, U. S. Navy
Commanding.

The Office of Naval Research is sponsoring one of the leading corrosion research programs dedicated to the understanding of why metals do or do not corrode and the mechanism and kinetics by which such processes occur. The objective of this counter attack on corrosion - a most ubiquitous enemy - is to permit, ultimately, prediction of the corrosion behavior of metals and alloys in varying environments and the scientific "design of corrosion-resistant materials." It is our hope that such studies will permit the honorable retirement of the paint-brush and chipping hammer as the tools of the Navy's corrosion fighters.

The Editors

TABLE OF CONTENTS

(Contributors to Research Reviews are engaged in scientific research supported by the Office of Naval Research.)

LIST OF FIGURES

SEVENTY MILES ABOVE THE EARTH

O. G. Villard, Jr.
Stanford University

Radio reflections from meteors are providing a new technique for studying the upper atmosphere. Although meteors had for many years been suspected of being a source of ionization in regions 70 or more miles above the earth where radio waves are reflected, conclusive experimental verification did not come until after World War II. The great meteor shower of October 1946 gave investigators a dramatic opportunity to establish the relationship between shooting stars and the resultant radio phenomena. It was discovered that even ordinary, sporadic meteors may be investigated by radio with the aid of relatively simple equipment.

A meteor--that is, the visible flash--is caused by a collision between a particle of cosmic dust, called a meteorite, and the earth's tenuous outer atmosphere. Traveling at velocities up to ten times the top speed of a V-2 rocket, the dust particles possess an enormous energy in spite of their small mass. They expend almost all of this energy in collisions with gas molecules in their path, the smaller meteorites being chipped away and "sand blasted" until they disappear. Some of the larger meteorites survive their plunge and reach the earth's surface.

Behind each meteorite is left a long trail, in the turbulent central core of which gas particles are ionized--literally agitated--the collisions being sufficiently intense to produce a flash of light. This ionization rapidly spreads outward, becoming at the same time more diffuse and weaker in intensity. Although too weak to see, it is still intense enough to reflect radio waves even after the trail has swelled to many times its original size. Eventually, of course, the agitation dies away and the ionization disappears.

Radio waves can be bounced back from meteor trails in the same way that radar echoes are returned from aircraft targets. Passage of a large meteor may be detected by means of radio frequencies ranging from 3 to 100 megacycles per second.

O. G. Villard, Jr. is studying meteor ionization with L. A. Manning at Stanford University under an ONR-sponsored research program. He received his B. A. degree from Yale University (1938) and his degree in electrical engineering from Stanford (1943). In 1941-42 he did ionosphere research at Stanford under sponsorship of the National Bureau of Standards. During the war years he served at the Radio Research Laboratory of Harvard University which was devoted to work in radar countermeasures. In 1946-47 he was responsible for an Army research project on radio transmission techniques at Stanford University.

For the brighter meteors, the ionization column tends to become so large (a mile or more in diameter) that it is possible to obtain a reflection even from its moving head. Furthermore, this reflected signal, by virtue of the motion of the column, suffers a shift in frequency due to the Doppler effect, just as the roar of an approaching locomotive sounds higher in pitch than it really is. The shifted radio reflection, if combined with unshifted signal from the transmitter, gives rise to a beat note falling in the audible range.

Doppler "whistles" caused by meteors are often heard superimposed on the programs of short-wave broadcasting stations. They may, in fact, be tuned in on almost any sensitive short-wave receiver, if conditions are right. To hear the whistles, it is necessary to find a short-wave broadcast station--a frequency-shift telegraph station will also do--located within the skip zone surrounding the receiver at the particular time and the particular frequency chosen. Meteors are most plentiful between the hours of 10 p.m. and 8 a.m. local times. The signal received under these conditions will be very weak and unstable; voices or music will sound hollow and distant. Reflections from meteors will be noticed as sudden increases in the received signal--lasting perhaps two or three seconds on the average--during which time the program becomes strong and steady, without any trace of echo. Just prior to these sudden increases, the Doppler whistles can be heard. The sound, of brief duration and generally of descending pitch, may in some instances resemble a grunt, yet in others may be more reminiscent of the whine of a passing shell.

Oscillographic recordings have been made of the whistles (see Fig. 1). From an analysis of these oscillograms, the physical shape of the trail of ionization has been estimated and information obtained on its rate of growth and decay.

The Office of Naval Research is sponsoring at Stanford University a research program, the objective of which is to learn as much as

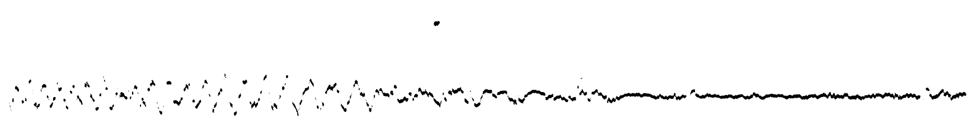


Fig. 1. The radio "sound" of a meteor recorded: An oscillogram showing a portion of the Doppler whistle produced when a radio signal is reflected from the moving head of the ionization column left behind by a meteor. Time advances from left to right. The interval between the two timing pulses at the right of the record is one-fifteenth of a second. Note the descending pitch of the whistle. Its disappearance at the right is due to receiver overloading. Radio frequency: 27 megacycles.

possible about the upper atmosphere, and about meteors themselves, by means of the radio reflection technique. It is hoped that such fundamental physical quantities as air temperature and density, as well as rate of ion diffusion and recombination, may be measured in this way at heights of the order of 70 to 100 miles. This continuously obtainable information is expected to supplement that obtained by direct measurement in the course of relatively brief V-2 rocket flights, and should be of direct benefit to designers of high-altitude aircraft and guided missiles.

Meteor studies are making possible a better understanding of the radio-wave-reflecting properties of the upper atmosphere. For example, meteor reflections play an important part in mechanism by which radio signals find their way in the otherwise-dead "skip" zone. Sustained meteoric ionization can reflect signals from very high frequency transmitters sufficiently to cause interference outside the normal service range of these stations. Echoes from meteors have even been observed on 100-megacycle radar screens, and were a source of one type of "disappearing contact" reported during the war. Meteor reflections probably cannot be observed at frequencies higher than this.

Since meteors announce themselves by radio during daylight hours when they cannot be seen, this new counting technique is of interest to astronomers. For example, during a typical night when an experienced observer might see 50 or 60 shooting stars, the radio method has registered several thousand. Unfortunately, it is not possible to say at the present time exactly what percentage of all meteors of detectable size actually do produce a radio echo. Finding an answer to this question is one of several intriguing assignments. The radio transmitter, as efficient in daylight or overcast as it is on the clearest night, may soon take its place beside the photoelectric cell and the cosmic static recorder as an accepted tool for astronomical and upper atmosphere research.

Applied science leads to improvements, but fundamental research leads to revolutions.

--Sir J. J. Thomson, British Physicist

THE WEATHER MAN'S BOTTLENECKS

Thomas F. Malone
Massachusetts Institute of Technology

Despite the mounting tide of popular articles on the weather which have appeared in magazines and newspapers during the past several years, meteorologists have not been striding toward new vistas of knowledge in the seven league boots that popular science writers have depicted. Real and important advances in knowledge concerning the weather have been made during the past 30 years and under the stimulus of wartime demands, this progress was accelerated; however, the cumulative effect has been little more than to scratch the surface of the general problem of a better understanding of weather processes. The general public has been disillusioned, and understandably so, by the failure of postwar weather forecasts to live up to the high performance predicted "after the wartime cloak of secrecy for security reasons" had been removed.

What happened to the "new knowledge and new techniques" which, it was heralded, were to make postwar weather forecasts highly accurate and dependable? The answer is fairly simple. "New knowledge and new techniques" were considerably overrated. The forecasts for military purposes during the war were neither better nor worse than those made available to the public since the war's end. It was principally the innovations and improvements in applying weather knowledge to specific military problems which made the meteorologists' contribution to the war effort so effective. Never before in military history had so much emphasis been placed on the weather as a factor in military operations. The reason was simply that never before had there been such a fund of meteorological "know-how" to apply. The results might be compared to the excitement which would be aroused if no forecasts had been given to the public during the past 50 years and then, suddenly, forecasts as accurate as those available today were disseminated by the press and radio.

Thomas F. Malone, assistant professor of meteorology at the Massachusetts Institute of Technology, received his S. B. degree from the South Dakota School of Mines and Technology (1940) and his Sc. D. degree from the Massachusetts Institute of Technology (1946). He was actively engaged in the meteorological training programs for the Navy and the Army during the war and served for a few months as a special consultant to the 19th Weather Squadron in North Africa. Interested in the problem of pressure changes since completing a thesis on interdiurnal pressure and temperature variations over North Africa, he is presently engaged on an Office of Naval Research contract on atmospheric pressure distribution.

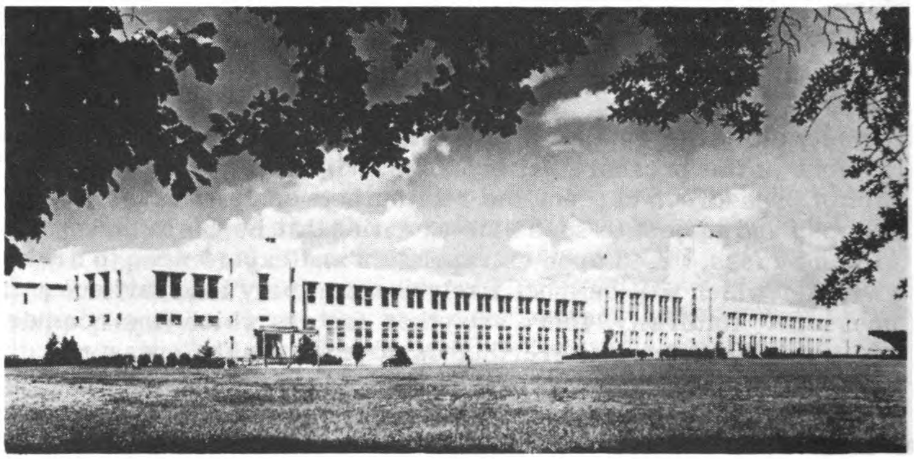
Actually, there have been relatively few important contributions to a better understanding of weather processes during the past eight years. Any marked improvements in weather forecasting must depend to a large extent on such contributions. One has only to consider present methods of forecasting to appreciate this. In somewhat oversimplified summary, they consist of charting the distribution of pressure at the surface and upper levels at intervals of 6 to 12 hours, observing the movement and development of these pressure patterns, and on the basis of experience and simple extrapolation procedures to determine the distribution of pressure 12, 24, or 36 hours in advance. The specific weather elements, such as wind, temperature, cloudiness, and precipitation, are analyzed in relation to the current pressure pattern and anticipated in the future on the basis of the expected pressure pattern.

There are two fundamental difficulties in this technique and both of them stem from deficiencies in our basic understanding of weather processes. Firstly, the meteorologist does not understand the physical mechanism which causes pressure changes and therefore, at best, can make only an intelligent guess concerning the future movement and development of the pressure pattern. Secondly, even if his guess on the matter of pressure is correct, the relation between pressure and weather is so loose and subject to such wide variation that he has to make another intelligent guess, based upon extrapolation and experience, to arrive at the weather which will be most likely to accompany that particular field of pressure. Naturally, there are other factors which are considered in preparing the forecast; nevertheless, forecasting the pressure pattern is the prime consideration in present techniques. If the accuracy of the forecasts produced by these techniques is to be improved, there must be forthcoming a better understanding of the physical mechanism of pressure changes.

A research program aimed directly at a solution of this problem is under way in the Department of Meteorology at the Massachusetts Institute of Technology under the sponsorship of the Office of Naval Research. The problem is no small one, and a complete answer is not expected immediately, but the time and effort which probably will be required to produce a satisfactory solution are fully justified by the basic importance of more information on this subject.

The method of attack includes the empirical as well as the theoretical approach. It is not possible to conduct controlled laboratory experiments of the type which would be necessary, so recourse must be had to the data from the network of weather observing stations scattered over North America and the adjacent oceans. Weather situations characterized by marked pressure changes have been selected and studied in great detail. The field of motion in all three dimensions has been charted and considered separately from the field of pressure. As a result of these studies, interest is now focussed on energy transformations in the atmosphere. One group is working on the theoretical aspects in an attempt to understand the mechanism for the release of kinetic energy. Another group is treating weather data by statistical methods in an effort to learn the location of regions of energy transformation and the synoptic conditions most favorable for the development of kinetic energy. When all the answers are in, it is hoped that the interrelation between the field of motion and the field of pressure may be described in a satisfactory and useful fashion and that the mechanism of pressure variations will be understood more clearly. It is probable that such results, when they are finally attained, will contribute materially toward removing two of the chief "bottlenecks" along the way to better forecasts.

Naval Scientific Establishments--
David Taylor Model Basin



The David Taylor Model Basin is the largest and most completely equipped plant in the world for research, development, and test work on ship models. Operating under Bureau of Ships, it is staffed by a highly trained and capable group of scientific and technical personnel. The basic function of the Model Basin is the solution of problems involving the design and operation of Naval vessels by the study of the performance of accurate scale models under controlled conditions. Included in the work are the determination of the speed and powering of ships, launching, stability, action in waves, turning and maneuvering, and propeller design. Investigation of problems of structural design of ships is a major activity; these problems relate to the strength of ships, their resistance to underwater explosions, structural vibration, gun blast, shock, and their protection from enemy attack. New designs of Naval aircraft are developed through extensive theoretical and experimental wind tunnel and aerodynamic work. The above photograph shows the entrance to the Administration Building. Other buildings at the Carderock, Maryland, establishment house hydromechanics basins, variable-pressure water tunnels, a circulating water channel, a glass-walled tank for studying the movement of bodies under water, and two modern wind tunnels. Research problems studied here require a wide variety of specialized instruments not commercially available. Most of these instruments are designed and built at the Model Basin.

STREPTOCOCCI AT WAR

Noble P. Sherwood
University of Kansas

Among many kinds of bacteria, there is one variety called streptococci that causes scarlet fever, erysipelas, blood poisoning, and many cases of upper respiratory infection such as tonsillitis, bronchitis, and pneumonia. Certain kinds of streptococci are responsible for much sickness in the armed forces and civilian population. The streptococci resemble beads about 1/25,000 of an inch in diameter and reproduce to form chains, thus appearing as a chain of beads.

A great deal is known about how streptococci in general perform in test tubes, but very little is known about the way they cause disease in the living body and likewise the way in which the body responds to their presence.

Under the sponsorship of the Office of Naval Research, the University of Kansas' Department of Bacteriology has been studying infection of the living animal by streptococci obtained from 75 different infections in man.

In reality it is a study of the weapons of offense and defense possessed by various kinds of streptococci and by the living animal in a war between the two.

This work may produce facts to help in evaluating the importance of the assumed heavy artillery of streptococcus and of the offensive and defensive weapons in the animal body. Just as in any war a knowledge of the weapons possessed by the enemy enables one to combat the enemy, so in the battle between streptococci and man, a knowledge of the actual weapons of offense possessed by streptococci will help in devising more intelligent methods of treatment or prevention. Also, this project may throw light upon why some bacteria produce subacute infections and others acute infections. It may also explain why some people with subacute bacterial endocarditis, a streptococcal disease causing inflammation of the heart lining, caused by a streptococcus do not respond to treatment with the sulpha drugs although the streptococcus is apparently sensitive to them.

Noble P. Sherwood, Head of the Department of Bacteriology, University of Kansas, since 1917, received his B.S. degree in civil engineering from that institution in 1905. After pursuing other interests he returned to the University of Kansas and received his Ph. D. in bacteriology in 1921 and his M. D. degree from the University of Minnesota in 1924. He has published 53 papers, many of them dealing with the subject of streptococci. He is a Fellow in the American College of Physicians, a Diplomate in the American Board of Pathology, and serves as pathologist for two hospitals in Lawrence, Kansas.

815066 O - 48 - 2

All but one of the streptococci used in this study were isolated from clinical cases in man, the one exception being isolated from an infection in a horse. Most of the clinical cases were acute infections such as tonsillitis, scarlet fever, erysipelas, and wound infections. Several streptococci were obtained from the blood of patients with subacute infections such as subacute bacterial endocarditis. The organisms from endocarditis cases were quite resistant to the sulpha drugs.

Two kinds of animal organisms were infected: the living unhatched chick about 7 or 8 days before hatching, and the white mouse. There are several reasons why these two kinds of animals were chosen. Mammals such as mice, rats, and pigs, after they are born and in many instances before they are born, have at least two well known weapons they can use to fight bacteria. One of these weapons is made up of specific chemical substances called antibodies that become attached to the surface of the bacteria and render them easy victims to the second kind of weapons which are living cells, phagocytes. Some of these living cells are free to wander within the body and others have fixed stations throughout the body. The unhatched chick has the free and fixed cells with which to fight, but is supposed not to produce antibodies or agents for chemical warfare until hatching time. The mouse, on the other hand,

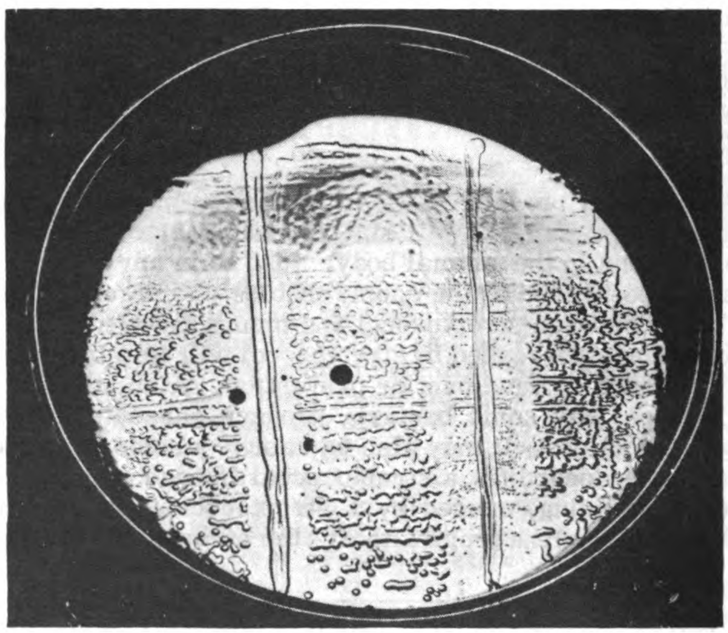


Fig. 2. A plate seeded with a mucoid streptococcus. On the left may be seen the inhibitory effect of one streptococcus on the other. On the right one has produced something that has digested the mucoid material in the outer layers of the streptococcus, making it a zone of very small colonies. (Photograph supplied by Dr. R. G. E. Murray University of Western Ontario.)

is known to possess both mobile and fixed cellular army and also the chemical substances or antibodies. Whether or not a non-antibody mechanism such as described by Wood under the heading of surface phagocytosis operates in the chick is unknown.

The chick at seven or eight days before hatching is surrounded by a membrane called the chorio-allantoic membrane, which is made up of three distinctly different layers of cells. It is possible to let the air out of the air sack and drop this membrane without injuring the chick. After the membrane is dropped one can place on its surface a small dose of streptococci and watch what takes place. After various periods of time the membrane can be removed, fixed, sliced very thin, mounted on glass slides, stained, and examined under the microscope. The mice are injected--some into the skin, others into the abdomen--and still others have the bacteria dropped into their noses.

The project has already produced results showing striking differences in the weapons of both offense and defense possessed by streptococci and chick, respectively. We have discovered that many of these streptococci attack each other by producing a substance very much like penicillin. If you should happen to have a harmless variety of streptococci producing this substance in your throat it could kill off many dangerous streptococci that might land on your tonsils and thus protect you from a sore throat.

It has been shown that some of the streptococci produce substances that destroy the outer layer of cells of the membrane but are stopped when they reach the middle layer, while others do relatively little damage to the outer layer and are able to spread within the middle layer. The surprising thing is that the destruction by some streptococci is stopped at the middle layer and they are unable to enter or spread within it although they are known to produce weapons that are supposed to enable them to enter and spread within the membrane. Other streptococci that are supposed to be unable to produce weapons are able to spread within the tissue. This confirms another investigator's opinion that more than one kind of weapon for spreading is produced by streptococci. It is also evident that the physiology of the group that cannot invade the middle layer and spread within it is different from those that do invade, because the former are readily killed by the mobile army of cells that swallow them up while the latter establish friendly relations with the mobile cells in the membrane and even multiply within them without being injured or doing any harm to their captors. This is one of the first bits of direct proof that such conditions exist as multiplying within a tissue without apparently injuring it. The results also show that the ability to spread within the membrane or the inability to spread does not correlate with the ability of the bacteria to kill the unhatched chick.

WHY STAINLESS STEEL RESISTS CORROSION

Mars G. Fontana
Ohio State University

The good corrosion resistance of stainless steels is a well known fact. The reasons that stainless steels resist attack by liquids and gases are not so well established and considerable differences of opinion exist. According to theoretical considerations chromium should not exhibit much better corrosion resistance than ordinary iron or steel, yet chromium is the chief alloying element or chief ingredient added to steel to make it stainless. If about 10 percent or more of chromium is added to steel we have a stainless steel. The good corrosion resistance of chromium is shown by its wide use for plating automobile bumpers and other parts familiar to all. If your automobile bumper shows rust (corrosion) it is probably due to the rusting of the steel underneath the chromium plating, which is either porous or too thin.

There are numerous varieties of stainless steel on the market today. Perhaps the most familiar one is the cutlery stainless steel used for the blades of kitchen knives. This material contains about 13 percent chromium with the balance iron. The buckets or turbine blades in steam turbines are made of a similar alloy. The garden variety stainless steel for resisting corrosion by acids and caustic in chemical plants, furnace tubes, and other places is the so-called 18-8 stainless steel which contains 18 percent chromium, 8 percent nickel, and the balance iron. A modification of this alloy is sometimes used for condenser tubing in the power plants of ocean vessels. For more severe applications involving high temperatures, such as a jet propulsion engine, higher chromium contents and other alloying elements are used.

Mars G. Fontana is chairman of the Department of Metallurgy of The Ohio State University. He attended the University of Michigan (1927-34), receiving a Bachelor's Degree in Chemical Engineering and Master's and Doctor's Degrees in Metallurgical Engineering. While at Michigan he was a research assistant in the Department of Engineering Research (1929-34). From Michigan he went to the Du Pont Company in Wilmington, Delaware, where his work (1934-45) included selection and specification of construction materials for all types of Du Pont plants, cooperation with the Design Division on new construction, and trouble-shooting on equipment failures. In 1945 Dr. Fontana joined the staff of the Ohio State University as professor of metallurgical research in the Engineering Experiment Station and professor of metallurgical engineering in the Department of Metallurgy. He is supervisor of metallurgical research for the Ohio State Research Foundation and director of the Corrosion Research Laboratory, which emphasizes fundamental corrosion research. He is a member of the Subpanel on Corrosion and Surface Treatment, Panel on Metallurgy of the National Military Establishment's
(Continued on p. 11.)

If stainless steel shows no corrosion when in contact with corrosion agents such as acid or sea water, the surface of the stainless steel is described as being passive. In other words, no chemical action or corrosion is taking place. If corrosion occurs, the surface is said to be active. Incidentally, sea water tends to be quite aggressive toward stainless steel because of the salt in the water. The sea water tends to attack stainless steel and to cause pits or holes to appear in the metal.

The sixty-four dollar question, then, is why do the stainless steels become passive, or in other words, why don't they corrode and rust like iron and steel? In an attempt to answer this question, the Office of Naval Research is sponsoring a fundamental corrosion research project at Ohio State University.

It is commonly accepted that a protective film forms on the surface of the stainless steel and thus prevents the acid, water, or gas from reaching the base metal. This film could be compared in a rough way to a paint film put on steel to prevent rusting. The object of the research investigation at Ohio State is to determine the nature of this protective film on stainless steel and how it forms.

One of the results of the work is the development of a new theory concerning this film. Our studies show that the film consists of an adsorbed gas, apparently oxygen from the air. Molecules or small particles of oxygen attach themselves to the stainless steel surface in a layer or layers and thus form a protective blanket. This adsorption of gases can be considered as condensed gases somewhat similar to the condensation of water vapor on a cold metal surface. For example, an ice cube metal tray, when removed from the refrigerator, quickly becomes covered with a thin layer of condensed water vapor. It will be noted that we use the word adsorption instead of absorption. Adsorption is a surface effect; absorption means that something is taken into the material as a sponge absorbs water.

Briefly, the adsorbed gas theory is based on the fact that passive (corrosion resistant) stainless steel becomes active (corrodes) if it is exposed to a vacuum. The vacuum removes or pulls off the protective gas layer. Experiments show that before subjecting stainless steel

---

(Continued from p. 10.)
Research and Development Board. Dr. Fontana is chairman of the Columbus Chapter of the American Society for Metals and a member of the A.S.M. publications committee. He is a member of the Board of Directors of the National Association of Corrosion Engineers and chairman of the Corrosion Division of the Electrochemical Society. A contributing editor for the magazine Industrial and Engineering Chemistry, he writes a monthly column on corrosion. He is a consulting metallurgical engineer for commercial concerns, a frequent speaker on metallurgical subjects, and author of numerous publications in that field. Dr. Fontana has been conducting fundamental corrosion research for the Office of Naval Research since June 1946.

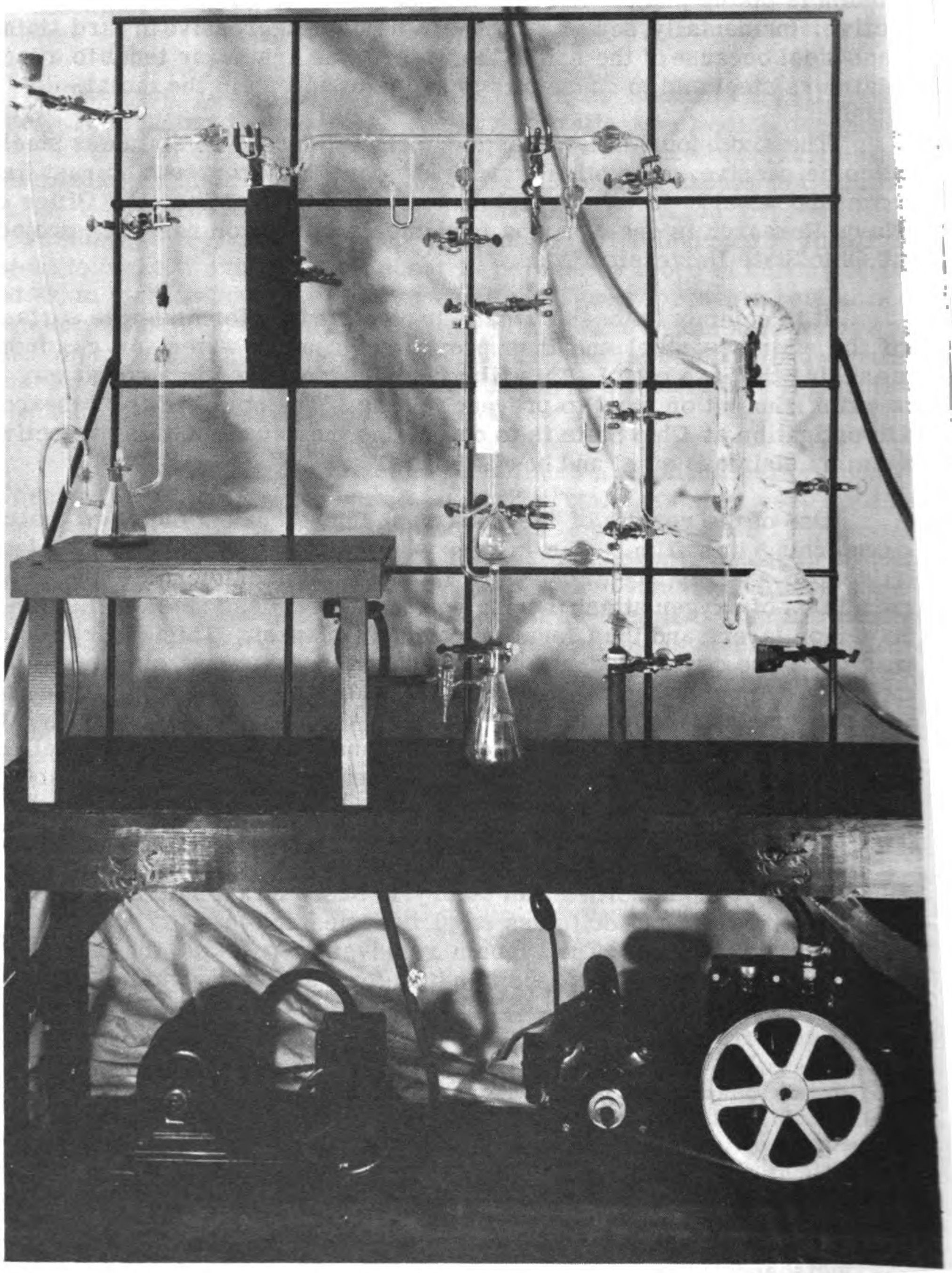


Figure 3. Vacuum breakdown apparatus.

specimens to a vacuum, this material is not corroded by acid or sea water. After exposing the specimens to a vacuum, they corrode rapidly in acid and develop pits in sea water. A passive sample subjected to a vacuum becomes active, but if it is then exposed to air the gases again adsorb on the surface and the metal again becomes passive. The process of passivation and activation can be continued indefinitely.

Figure 3 is a photograph of the apparatus used for breaking down or removing the passive film or gas layer. The unit on the right wrapped with asbestos rope is a mercury diffusion pump for producing a high vacuum. It works on the same principle as a steam vacuum jet. Mercury is used instead of water or steam. This pump will not operate against a high pressure, so the vacuum pump on the lower right beneath the table lowers the back pressure on the mercury diffusion pump. The glass gadget in the center, with the bulb and the flask containing mercury, is a McCleod gage for measuring low pressure or vacuums. The specimen is placed in the stoppered flask on the small table on the left and this flask is evacuated by the diffusion pump. After evacuation the stainless steel specimen is tested for corrosion resistance by running acid into the flask by means of the tube and funnel shown in the upper left portion of the photograph.

Additional studies are in progress to prove further or to disprove the adsorbed gas theory. We do not claim that the proposed theory is the final answer to the problem, but at least these studies are throwing some light on the behavior of stainless steels from the corrosion standpoint. When we understand thoroughly what goes on we will be able to design and make better and more economical stainless steels for use in the Navy, in industry, and elsewhere.

How Much Energy?

At an international conference on "Problems of Nuclear Physics" held at the University of Birmingham, September 14-18, 1948, Professor E. Teller pointed out that, if it is assumed that cosmic rays are present in inter-galactic space with the same average density as they are found to have on the earth's surface, their total energy would be 10,000 times the energy represented by all of the rest mass present in space. The accelerating field necessary to produce these cosmic rays of energies up to 10^{12} electron-volts or more would itself represent a larger source of energy than any other known in the universe.

WHAT MAKES THE WHEELS ROLL

Robert D. Vold
University of Southern California

No machine from the crudest turning wheel to the most intricate robot can operate successfully without proper lubrication. Lubricants may be broadly classified into fluids which are supplied continuously to the sites of friction between moving parts through some sort of circulatory, drip, or splash mechanism or some kind of wick or sponge feed, and thickened lubricants in which the body or stiffness imparted to the fluid oil, generally by a metal soap, is relied upon to maintain a friction-reducing film between moving surfaces. Lubricants of the latter class are termed greases.

As new machines have been developed, the art of producing adequate greases has kept pace reasonably well, but what goes on when soap is introduced into oil has never been fully understood. It is with the conviction that elucidation of the physical chemical changes occurring during manufacture and use of greases will provide a short cut to development of more economical and convenient processes and better products that the University of Southern California undertook the ONR-sponsored project to study the basic structure of systems of soap in oils.

The major constituents of a pound of ordinary cup grease are about thirteen ounces of oil, a little less than three ounces of dry powdered soap, and about a teaspoon full of water. Yet if these three components are stirred together at room temperature, the product is a soapy granular paste bearing little resemblance to the unctuous buttery solid termed grease. In most cases there is no great chemical difference between the two products. The difference is in the way in which the soap and oil and water molecules are arranged relative to each other. Such differences are related to the difference between water and ice and are termed phase differences.

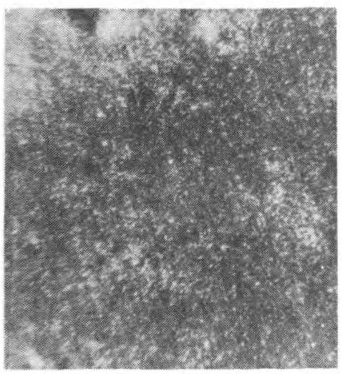
The problem then is to determine what molecular arrangements or phases are present in a grease, how its nature depends on the way in

---

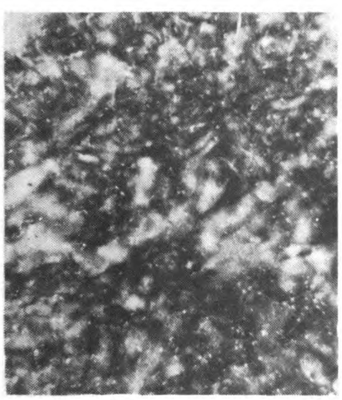
Robert D. Vold is engaged in research at the University of Southern California on an ONR-supported project in the field discussed in this article. Dr. Vold received his A. B. and M. S. degrees from the University of Nebraska, his Ph. D. from the University of California. In 1935-37 he was research chemist with Proctor & Gamble Co., and from 1937-1941 he was research associate at Stanford University. Since 1941 he has been with the University of Southern California, now holding the title of professor. He is associate editor of the *Journal of Colloid Science*; Chairman of the Division of Colloid Chemistry of the American Chemical Society; and editor of the Register of Phi Lambda Upsilon.

which it is formed and on the amount and kind of soap, oil, water, and other possible constituents (known as additives) it contains, and what happens to it under conditions of storage and use. The problem can be attacked in several different ways, no one of which alone can provide answers to all questions. The results of each must be analyzed and correlated with the others.

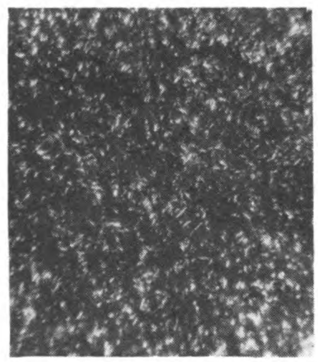
One procedure is to examine the visual appearance, consistency, and texture of samples of soap incorporated in oil in various ways, both at ordinary temperatures and during heating and cooling, noting particularly at what temperatures or compositions various forms such as free oil or opaque undissolved soap first appear or just disappear. Use of a polarizing microscope at 50 to 200-fold magnification is a valuable adjunct to visual observation, particularly since some of the soap phases are optically anisotropic and thus appear bright when viewed between crossed polaroid pieces.



A



B



C

Fig. 4. Typical microscopic appearances of calcium stearate in naphthenic lubricating oil. (125-fold magnification, crossed polaroids.)

A. A thin grease (8% calcium stearate).

B. The same grease after cooling slowly from 300°C (in the absence of air). The sample was fluid. Note increase in fiber size.

C. The same grease after rapid cooling from 300°C. The blotches are undercooled liquid crystal. Fibers have begun to re-form as the sample stands at room temperature. It is an unstable gel.

Figure 4 shows three photomicrographs of calcium stearate in lubricating oil. (A) is a true grease and is seen to consist of a network of very fine fibers which retain at least part of the oil by much the same mechanism that a sponge holds water. (B) is the same grease after heating to a higher temperature and cooling. The fibers have clumped together giving the "sponge" bigger pores; it cannot retain so much oil and the sample is a thick slightly turbid fluid. (C) is the same sample which has been cooled very rapidly from a high temperature and allowed to stand several days. In addition to fibers there are present relatively large irregular bright patches. This material is what is termed a mesomorphic or liquid crystalline phase. It has some of the optical properties of a crystalline solid and some of the flow properties of a liquid. In molecular arrangement it is intermediate between the two. The sample is best described as a stiff, somewhat unstable gel, and so is not useful as a grease. Some of this material may be desirable in a grease to give added body for a given soap content, but fibers must be present also to impart the proper texture.

Another method of study is to obtain x-ray diffraction patterns of samples of soap in oil. When a beam of x-rays is directed at a glancing angle against a grease surface, most of it is reflected at the same angle, but a few rays are found at other angles. These are the diffracted x-rays. The intensity of the diffracted x-rays as a function of the angle at which they occur depends on the way in which the soap and oil molecules are arranged. However, it is difficult to work backward from the diffraction pattern to the molecular arrangement.

Relatively expensive apparatus is required to obtain accurate x-ray diffraction patterns. The instrument shown in Fig. 5 is a Geiger-Mueller x-ray spectrometer (made by the North American Philips Co.). X-rays emerge from a window in the x-ray tube (A) and impinge on the sample. A geiger tube (similar to those used to detect radioactivity) rides on the circle (B), and measures the intensity of the x-ray beam at each angle. The impulse is transmitted to the strip chart potentiometer (C) so that the desired data are recorded automatically.

Figure 6 shows the kind of record that is obtained. The top curve is for calcium stearate. The next is for calcium stearate monohydrate, a compound formed between calcium stearate and water molecules. Even though neither pattern can be uniquely related to a particular arrangement of molecules, it can be recognized that the two are distinctly different. The dry soap shows two prominent peaks near 20° marked (A) and (B); in the hydrate (B) has disappeared and (A) is reduced in intensity and three new peaks (C, D, E) are prominent. It follows that when a grease system is examined which shows a pattern like the second curve of Fig. 6, superposed of course on a pattern due to the oil, and modified by considerations of particle size, surface orientation, and other factors, that grease is composed of soap hydrate and oil. Probably the true thickening agent in the ordinary calcium base cup grease is calcium soap hydrate rather than calcium soap.

Curve III is for a sample of dry calcium stearate in cetane which had been cooled slowly from 170°C. The pattern of the dry soap (A and

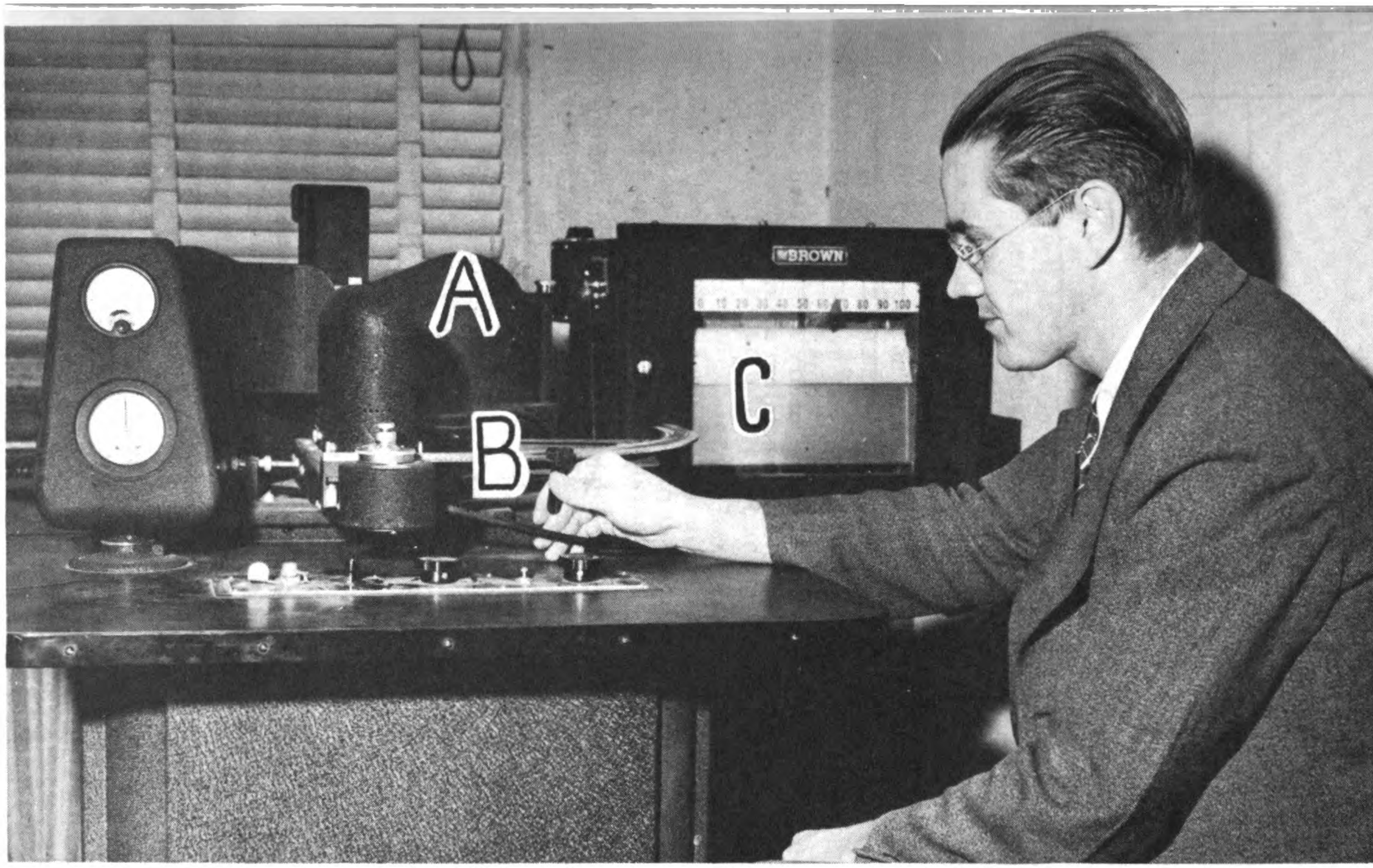


Fig. 5. R. D. Vold in front of the Geiger-Mueller x-ray spectrometer. A is the x-ray tube. Diffracted x-rays are distributed over all angles and enter the geiger counter which is moved along the circle B. The impulse received by the counter at each angle is recorded on the ship chart potentiometer C.

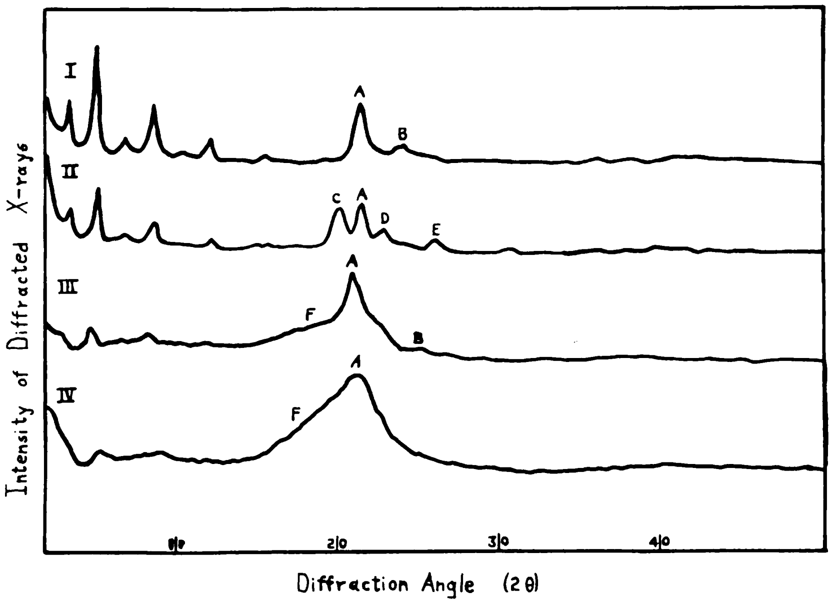


Fig. 6 X-ray diffraction patterns of dry and hydrated calcium stearate, and of systems of calcium stearate in cetane.

I Anhydrous calcium stearate
II Calcium stearate monohydrate
III 47.6% calcium stearate in cetane, slow cooled
IV 38.5% calcium stearate in cetane, fast cooled

and B) is superposed on that of the cetane (F). The widening of the peaks and lowered intensity of the peaks at small angles show that the crystallites are much less perfectly developed than in the oil-free soap. Curve IV is for a comparable sample which had been cooled very quickly. The complete absence of peak (B) shows that the soap is present in a non-crystalline state, but one which still retains some regularity of molecular arrangement, since the peaks at small angles are still present, though reduced in intensity.

A third procedure is to measure the amount of heat absorbed in phase changes as grease temperature rises or falls, and thus to determine the temperature of the phase transition. The particular technique employed is known technically as differential thermal analysis - differential because the heat absorption is not measured directly but compared with that of a reference material which does not undergo any phase changes in the temperature range under investigation as both sample and reference material are heated in the same environment. Here also, expensive equipment is required for accurate work, because heat input must be rigidly and precisely controlled and temperatures measured very precisely to about 0.01°C.

Figure 7 shows the kind of record obtained. Curve I is typical for a sample undergoing no phase changes. After a small initial rise in

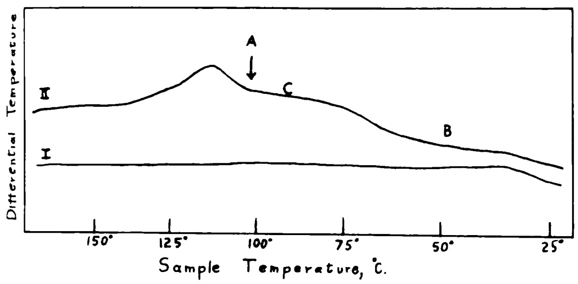


Fig. 7. Differential heating curves. I. Lubricating oil alone. II. 12% dry calcium stearate in lubricating oil. The peak beginning at A corresponds to heat absorbed as the grease softens to a liquid, which begins to occur at about 105°. Other heat absorbing processes are occurring over the range of temperature between B and C.

which a thermal steady state is being established, the curve is perfectly flat. Curve II is for a grease containing 12% anhydrous calcium stearate in naphthenic lubricating oil. The well defined peak beginning at A is due to heat absorption as the grease softens to a fluid. The theory of the method has been developed sufficiently to calculate the magnitude of the heat absorbed. This quantity, as a function of the amount of soap present, can be used to indicate what fraction of the soap is involved in the softening process. The gradual increase in differential temperature between B and C shows that phase changes occur even below the visual softening point as greases are heated.

With these three experimental procedures, considerable valuable information has already been obtained. The phase behavior has been determined for a large number of metal soaps in the absence of oil. These data will be useful in interpreting the behavior of oil-containing systems. Ordinary lubricating oils are exceedingly complex mixtures of hydrocarbons, and contain in addition some sulfur and nitrogen compounds. Consequently, it seemed desirable to examine the phase behavior of at least one soap in a number of pure hydrocarbons representative of the types of molecules that may exist in actual oils. The phase behavior of calcium stearate in decalin and in cetane has been partly determined in this program, and comparison is being made with that in lubricating oil systems.

The project does not have solution of any particular practical problem as its goal. It is building a background of basic understanding so that specific problems can be more easily and quickly solved as they arise. It has often happened that such programs lead to previously unconceived developments. By giving one's imagination complete liberty it is possible to write down a number of such possibilities--for example, a soap to be stirred into oil at ordinary temperatures to yield a grease of any desired consistency which will neither thicken at low temperatures nor thin at high temperatures--or a grease which will liquefy on the slightest agitation, yet solidify again to its original consistency almost instantaneously when the agitation ceases. It is not to be inferred that these are specific objectives; they are merely illustrations of the kind of development inventive genius might build when science has made sufficient progress in furnishing a basic understanding of the behavior of grease systems.

NAVAL RESEARCH RESERVE MEETS

Lt. Ann Ewing, USNR
Research Chemist
New York Rubber Company, Beacon, N. Y.

As an assignment for my two-week training cruise in the Navy, I was asked to prepare a bulletin to acquaint scientifically qualified Reserves with the program for Volunteer Research Reserve Units. Having heard that there was to be a meeting of the Washington (W-1) chapter of the Naval Research Reserve during my training cruise, I decided to attend--partly out of curiosity and partly because I thought it might give me valuable material for the bulletin which I was writing. The Commanding Officer of the Unit, Comdr. Fred C. Wiesner, USNR, called the meeting to order, and explained that the subject matter of the talk that night was classified. Discussed here, of course, are only the unclassified portions of the talk.

The speaker that night was Captain Lawrence R. Daspit, USN, Chief of Undersea Warfare (Submarines) in the Office of the Chief of Naval Operations. He began by reminding the audience of the unique features of the submarine. It is the only craft which can operate successfully in waters controlled by the enemy. This feature stems from the fact that water is relatively impervious to energy. The submarine's invisibility and surprise have been its chief advantages. The present, necessary limitations on the maneuverability, speed, and tactical usefulness of the submarine are gradually being reduced, but there are still many obstacles to be overcome.

Captain Daspit stated our basic knowledge of the ocean was still very meager, when compared, for instance, with our knowledge of the air. He said, "Every time I try to find out what we know about the ocean, I am told that we know practically nothing. It is a medium which is relatively impenetrable. Our best penetrator is a sound beam. Due to the lack of homogeneity of sea water, the maximum average echo range

---

Lt. Ewing is research chemist with the New York Rubber Company located at Beacon, New York. Her account of the Washington meeting is the first in a series planned to cover meetings in various parts of the country to exchange information with "Reservists" on what other units are doing and thinking.

oday is very limited. We know of no way to increase this because there re a number of factors about which we know practically nothing. We ave discovered that there is a sound channel in the ocean where sound ravels for thousands of miles. There are other experimental facts hich have been discovered. I do not believe we clearly know the theory ehind many of them. No commercial interest has been demonstrated n this field, except by people who want to sell things to the Government. t's the Navy's field and nobody is interested in it except the Navy. No other agency of the Government supports it. Most of the theoretical nowledge has been obtained by two civilian institutions, Woods Hole nd Scripps Institution of Oceanography, which are in part supported by Navy funds. We need not only money; more than that we need men."

Captain Daspit lent a note of levity to his serious subject when he suggested that the discovery of a real, live mermaid off our shores would probably create an increased amount of interest in this subject.

He asked for the assistance of all the "Research Reservists" in selling the need for intensive exploration of this field. He pointed out that the airplane is progressing to the point where we can no longer maintain home territory completely inviolable. "It is theoretically possible," he said, "to bomb from a base across the ocean but such use of the airplane at the present time and probably for some time to come, is economically unsound. War is still a matter of carrying masses of materials, from mines and other sources, to our factories, and then transferring the finished materials to the battlefield. The side that controls the ocean still has the power to carry the war to the other side. Control of the surface of the ocean is no longer enough to effect that control. We need all the knowledge we can obtain about the ocean and about what it permits us to do."

When he finished the discussion there were, of course, many questions from the members of the Unit. Judging by the variety and number of questions asked, it was very evident that Captain Daspit's talk had started many of the officers thinking about problems connected with submarine warfare. Each officer, however, made inquiries pertinent to his own field, so the questions ranged from the psychological effect on personnel of prolonged underwater submersion to the possibility of using newly developed plastics for submarine hulls.

When these and other questions had been discussed, the Commanding Officer announced that there would be a short recess, during which the smoking lamp was lighted. Normally the second hour of such a meeting is devoted to discussions by specialized groups. On this occasion, however, the second hour was devoted to comments, suggestions, and questions from the members of W-1 unit. Typical of the subjects discussed were: the attendance at unit meetings of officers who were visiting in Washington and who were in the Naval Reserve, but who were not affiliated with any organized or volunteer unit; the qualifications of enlisted

personnel required for affiliation with a Volunteer Research Reserve Uni
and the proper procedure for formation of other Research Reserve Uni
in other parts of the country. Specific information on the procedure
follow in the formation of Volunteer Research Reserve units may be ob
tained by consulting the September and October issues of Research Re
views, or by writing to the Naval Reserve office of the Office of Nav
Research.

The operating facts about submarines and the possible future de
velopment of submarine warfare as discussed at this meeting were s
interesting to me that I was sorry to realize I would not be in Washingto
for the next meeting when various aspects of nuclear physics will be dis
cussed. It is very satisfying to learn what the Navy is doing in its re
search program, and how current developments in the research field ar
shaping the future trends of its program.

ONR BRANCH OFFICES

Commanding Officer
U. S. Navy Office of Naval Research
Branch Office

495 Summer Street
Boston 10, Massachusetts

50 Church Street
New York, N. Y.

America Fore Building
844 North Rush Street
Chicago 11, Illinois

801 Donahue Street
San Francisco 24, California

1030 East Green Street
Pasadena 11, California

Note: For the Southeastern area Research Reserve matters should be referred to the Director of Research Reserve, Office of Naval Research (Code 103R), Department of the Navy, Washington 25, D. C.

U. S. GOVERNMENT PRINTING OFFICE : O—1948

RESTRICTED

DISTRIBUTION LIST

From "Catalog of Activities of the Navy, including Standard Navy Distribution List, Part II:"

8MM	Reserve Training Centers
7E1	Air Bases Command Naval Districts
6B4	Air Reserve Training Command

From "Standard Navy Distribution List, Part I:"

3-b.	Aircraft Carriers (CV) (CVB)
3-c.	Aircraft Carriers, Small (CVL)
3-d	Aircraft Carriers, Escort (CVE)
3-e.	Ammunition Ships (AE)
3-f.	Amphibious Force Flagships (AGC)
3-j.	Surveying Ships (AGS) (AGSc)
3-o.	Cargo Ships (AK)
3-p.	Cargo Ships, Attack (AKA)
3-x.	Destroyers (DD)
3-bb.	Drydocks, Floating (ARD)
3-kk.	Hospital Ships (AH)
3-mm.	Landing Craft (LC (FF)) (LCI)
3-oo.	Landing Ships, Dock (LSD)
3-pp.	Landing Ships, Medium (LSM)
3-ww.	Minesweepers (AM)
3-yy.	Minesweepers, Coastal, Underwater (AMc(U))
3-zz.	Minesweepers, High Speed (DMS)
3-fff.	Net Laying Ships (AN)
3-lll.	Repair Ships (AR)
3-ooo.	Repair Ships, Heavy (ARH)
3-ppp.	Repair Ships, Landing Craft (ARL)
3-ttt.	Salvage Vessels (ARS)
3-uuu.	Salvage Lifting Vessels (ARS-D)
3-www.	Seaplane Tenders (AV)
3-yyy.	Seaplane Tenders, Small (AVP)
3-bbbb.	Submarines (SS)
3-ccc.	Submarine Chasers (PC) (PCE) (PCS)
3-dddd.	Submarine Rescue Vessels (ASR)
3-eeee.	Submarine Tenders (AS)
3-ffff.	Transports (AP)
3-gggg.	Transports, Attack (APA)
3-jjjj.	Transports, High Speed (APD)
3-ssss.	Underwater Demolition Teams

ONR Special Distribution List #75.