• MARCH 1949

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RESEARCH REVIEWS

- TECHNIQUES TO STUDY AIRBORNE INFECTIONS
- WHITHER FLUORINE CHEMISTRY?
- GRAIN GROWTH IN METALS
- THE CONFIGURATION OF THE EARTH
- SPECIAL DEVICES RESERVE UNIT 11–1

OFFICE OF NAVAL RESEARCH
DEPARTMENT OF THE NAVY
WASHINGTON, D. C.

NAVEXOS P-510

COVER PHOTO: Special autopsy hood. The operators are protected by glass plates and by germicidal ultraviolet lights mounted in the top of the hood.

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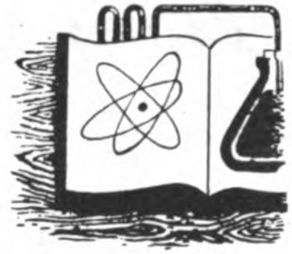
Approved by Bureau of Budget, 13 April 1948.



● *Informs the Fleet of ONR-sponsored Research*

Editorial musings

Recently, Rear Admiral T. A. Solberg, USN, Chief of Naval Research, spoke before the American Council on Commercial Laboratories. An excerpt from his speech entitled "National Co-operation in Research and Development" follows:

"Looking at our past procedures in research and development, it appears that no comprehensive study has been made of methods of integrating scientific research and technical development. The lack of this has contributed to the large time gaps between the access of scientific data and the end products which come out of research. In fact one of the important problems of modern technology is that of streamlining this process.

"As corollary to this, it does not appear that there has been, or that there is today, enough coordination and integration within the physical sciences themselves. There has been too much tendency for each individual scientific group to remain aloof from the others. To be sure, this is natural in view of the high degree of specialization required in modern science.

"But today no one branch of science can be self-sufficient unto itself.

"The compartmentation which exists in science today is disastrous to progress and to coordinated attack on any scientific barrier. The physicist needs the help of the chemist, and the chemist needs the physicist. The metallurgist needs the help of both. All need the help of the mathematician.

"It is perhaps too early to determine what nuclear physics can contribute toward progress in the other branches of science. But it is already evident that its impact will be great, and therefore any effort in that direction can be expected to reap great benefits."

In furthering the exchange of information of which Adm. Solberg speaks, the Office of Naval Research has planned or participated in a series of conferences in the various fields of ONR-sponsored research.

A recent one was held on titanium. A complete report of this conference may be obtained by writing the Supt. of Documents, Government Printing Office, Washington 25, D. C. Also a report entitled "Symposium on Magnesium" held in April 1947 is available.*

Another recent conference was held in the field of chemistry on fluorides and fluorocarbons. This conference is discussed on p. 10, and a report will be available in approximately a month.*

A conference in the field of corrosion was sponsored by the Deterioration Prevention Committee. For a discussion of this conference, see p. 16.

A conference on low-temperature physics was sponsored by ONR and the University of California, held February 1-2, 1949, and reports of this conference will be available in May 1949.*

A symposium on wood is scheduled June 16-17 to be held at the National Academy of Sciences.

*Write Code 484, Office of Naval Research, Washington 25, D. C.

Letters

Dr. T. J. Killian, Science Director:

"....The purpose of this note is to thank you for the foresight in getting your Research Reviews out to the Fleet and to tell you that I find it a very interesting and well done publication. From the first issue no article has gone unread, and it has been an assumed duty to insure the copies reach the wardroom for general perusal. I feel you deserve particular credit in presenting vastly technical subjects to laymen without either looking down your nose at them or talking over their heads. (Spoken by a layman)...."

Thomas R. Weschler
Lt. Comdr, USN
USS Macon (CA-132)
c/o Fleet Post Office
New York, N. Y.

Thank you. Research Reviews is glad to know it hit the mark in this case. Research Reviews aims to look at its readers eye-to-eye.

The editors are delighted to know that Research Reviews is placed on CA-132 where it can be read by all the crew during their leisure hours.

The Editors

To the Editor:

...You are to be congratulated not only on the general excellence of the scientific material which it (Research Reviews) contains, but on the editorial choice of articles having a broad scientific interest. Research Reviews should certainly lead to a greater appreciation of the value of the fundamental research being sponsored by ONR.

"....Mellon Institute is proud of its record of cooperation with the Navy Department and its successful fulfillment of various wartime Naval research contracts. Research Reviews could serve as an effective means of continuing the interest which many of our people have in Naval Affairs."

E. R. Weidlein, Jr.
Lt. (j.g.) USNR

Mellon Institute of Industrial Research
University of Pittsburgh
Pittsburgh 13, Pa.

We thank Lt. Weidlein for his encouraging comments. One of the byproducts of the fundamental scientific research program is to familiarize civilian scientists with naval problems and to stimulate their interest in attempting to solve these problems.

The Editors

TECHNIQUES TO STUDY AIR-BORNE INFECTIONS

Albert Paul Krueger
University of California

Early in the 1930's, Naval Laboratory Research Unit No. 1 was established in the Department of Bacteriology, University of California, as a component of the Bureau of Medicine and Surgery's reserve organization. Just a year before Pearl Harbor, Admiral Ross T. McIntire, Surgeon General, United States Navy, placed the unit on active duty status and by the time war broke out, it was well embarked on a program of research relating chiefly to respiratory diseases.

Very likely this project would have remained the Unit's sole mission were it not that intelligence agencies soon brought to light the fact that Germany and Japan were actively at work on biological warfare. This meant that counter-measures had to be sought by the United States, and our group, now renamed Naval Medical Research Unit No. 1, was one of those assigned to this task.

By and large, the new directive resulted in a strenuous pursuit of solutions to a variety of problems having both practical and academic aspects. To carry on the work, special equipment was designed and constructed to atomize bacterial and viral suspensions as "clouds," and to expose small animals to infection with measured aliquots of the cloud; to sample the clouds for quantitative analysis; to interpose a bacteria-tight barrier between the experimental system (clouds + animals) and the experimenter.

Albert Paul Krueger is professor of bacteriology, chairman of the Department of Bacteriology, and lecturer in medicine, University of California, Berkeley, California. He received his A.B. in 1925 and his M.D. in 1928 from Stanford University. He was then instructor and assistant professor of bacteriology and experimental pathology at Stanford University. From 1929-1931, he was associate in general physiology at the Rockefeller Institute for Medical Research. Since that time he has been associated with the University of California, except for the years 1940-1946 when he was Captain, MC, USNR, Medical Officer in Command of Naval Medical Research Unit No. 1, receiving the Legion of Merit. He is now working under an ONR-sponsored contract discussed in this article.

The apparatus was used to good advantage and by the time the war was over, the staff had acquired considerable skill in its operation. Furthermore, our collective curiosity was aroused by many basic phases of the whole air-borne infection problem, particularly the major question of experimental epidemiology. We felt that all the ingredients were at hand to carry on investigations along these lines if arrangements could be made to keep the equipment and key personnel of the staff at Berkeley.

Through the good offices of the Bureau of Medicine and Surgery and the Office of Naval Research, this was effected and in July 1946 a project was established in the Department of Bacteriology, University of California, to "conduct research on air-borne infections." This combined operation utilizes the services of NAMRU No. 1 personnel, civilian employees whose salaries are paid under the ONR project, and certain staff members of the Department of Bacteriology. Consultants from other departments of the University are available as need arises and, to a limited extent, opportunity is provided for qualified graduate students to conduct research within the project.

Because the mechanical equipment is the focal point for all work involving air-borne organisms, it is described here briefly. The experimental chamber and an attached holding unit are pictured in Figs. 1 and 2. In Fig. 1 the experimental chamber on the right is being tested under positive pressure for air-tight integrity. Alongside is a control panel with various valves and gauges; from this central location the various air streams within the tanks can be manipulated and the air flows measured. The panel operator has the important duty of maintaining the internal air pressure slightly negative to the atmospheric pressure to prevent infectious organisms escaping into the room if a leak should develop.

Figure 2 is an end view of the experimental chamber with the closure plate removed. At either side stands an operator with hands thrust into full-length rubber gloves; the proximal ends of the gloves are sealed into gaskets in the tank wall. He is able to observe the tank interior through a thick glass port located at the top of the chamber. The operators in the picture have their hands on the sub-unit in which the infectious cloud is generated and the experimental animals exposed. Six cylindrical animal holders are visible at the sides of the central cloud passageway. In each holder is a guinea pig with his snout protruding through a rubber diaphram into the stream of infectious air. The glass bulb seen at the back of the chamber just above the animal holders is the atomizer which generates the cloud. By turning by-pass valves, the cloud can be directed away from the animals into samplers and aliquots secured for quantitative determination of bacterial or viral content.

It is possible, then, to evolve a mist of highly infectious nature, expose animals to infection via the respiratory tract and, at the same time, protect the experimenter from contact with the agent used. The next step is to make sure that all the air traversing the chamber is disposed of safely, i.e., in a manner which will avoid creating a health hazard to the staff or to others working in proximity to the laboratory. This is accomplished by leading the air through layers of incandescent fire brick in order to incinerate all suspended organic matter. Not only is incineration practiced in treating air from the experimental chambers,

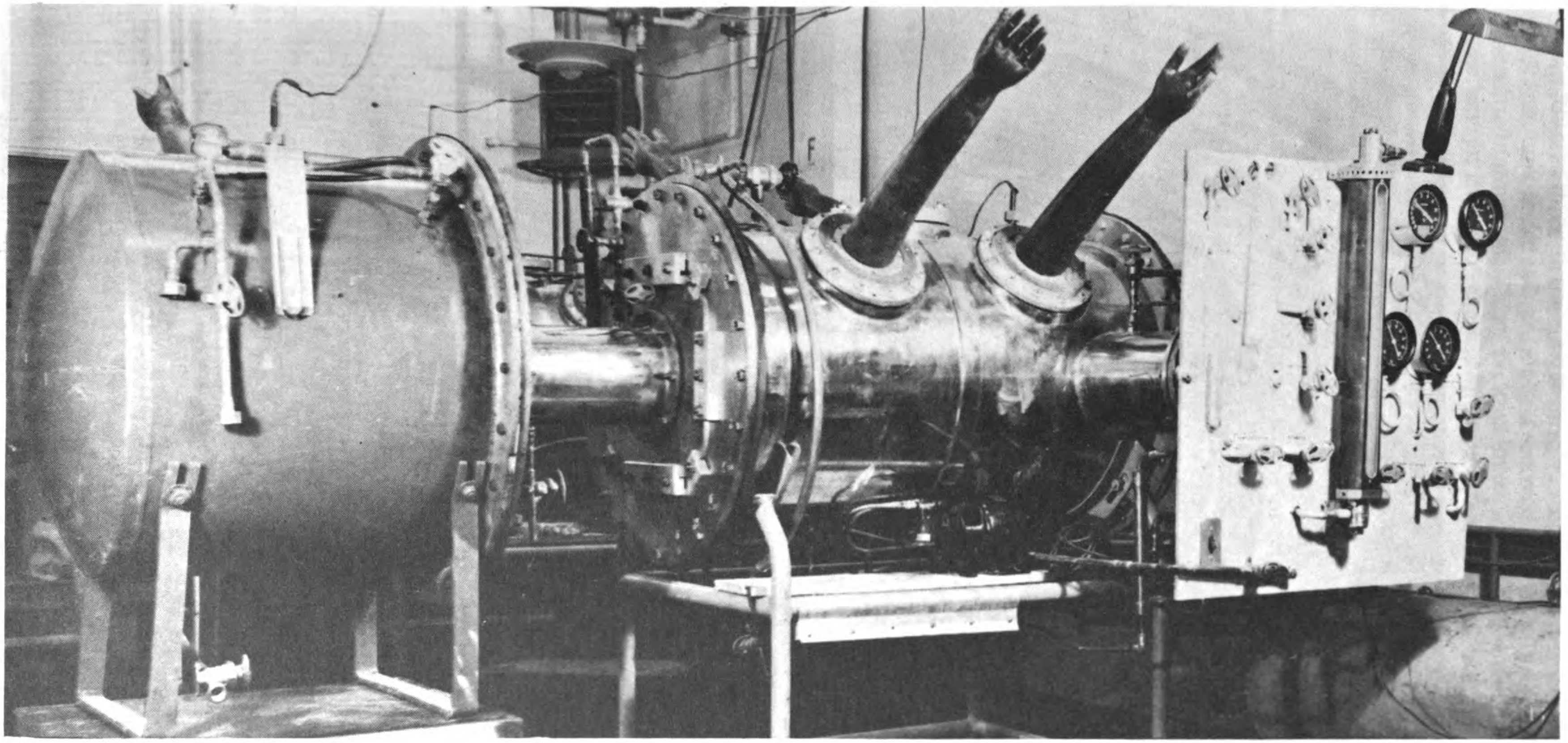


Fig. 1. At right is experimental chamber with control panel. At left is holding unit in which animals exposed to air-borne infectious agents may be kept for observation. Gloves are everted during test of chamber under positive pressure.

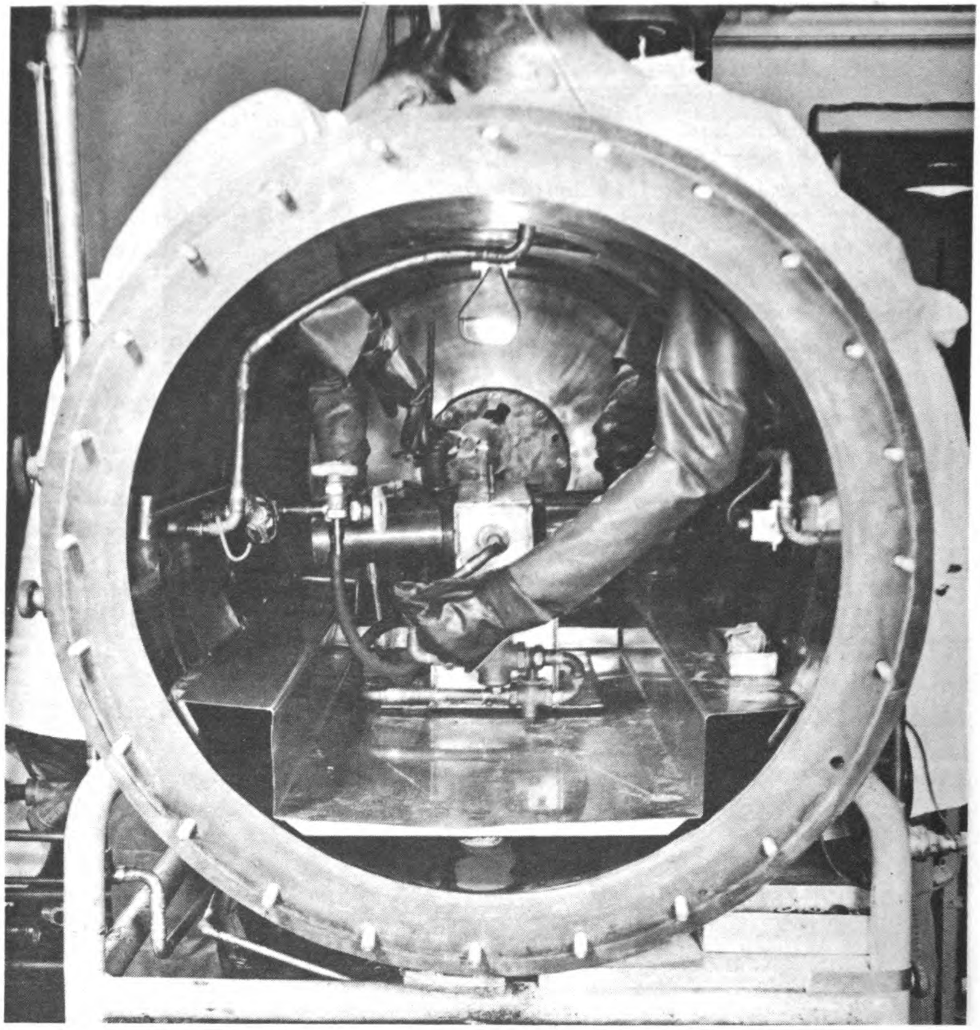


Fig. 2. Experimental chamber with end closure removed, showing how operators on either side manipulate animal exposure apparatus through long rubber gloves sealed into sides of tank.

but it is employed as well for air that comes from the units in which animals are held for observation after exposure to infection.

Such a holding unit is shown attached to the experimental chamber at the left of Fig. 1; it has only one glove which can be seen protruding from the far side just to the left of the sight port. Through an interconnecting airlock the exposed animals are passed into the unit, airtight doors are closed at each end of the airlock, and the latter is sterilized by flooding with germicidal solution. After drawing off the solution the connection between the two chambers may be broken, converting them into independent, airtight units.

The holding unit is then wheeled into another room where it is connected to air and steam lines. Any necessary handling of the animals is performed through the single long glove; food and water are introduced into the tank and dead animals removed through the attached airlock. Thus the test animals may be kept under observation for months without ever having them or the air they breathe brought into contact with the experimenter.

Many different kinds of ancillary equipment not described here are required in the safe operation of the experimental unit. For example, an electronic sensing element is connected to the air incinerator. In the event of a gas line failure, the circuit functions at once to shut off the air and to signal the failure to the operator. Another essential device is a circuit by means of which a number of thermocouples can report temperatures to a central station. The thermocouples are placed in various spots within the chambers; then, upon completion of an experiment when steam is turned on for sterilization, we can be sure that all dead spaces attain the minimal temperature requisite for complete safety.

Routine handling of cultures, preparation of plates for counting bacteria, and isolation of microorganisms are conducted within protective hoods of the type shown in Fig. 3. The operator sits before the hood,

Fig. 3. Protective hood in which routine experimentation is conducted with highly infectious agents such as the plague bacillus or psittacosis virus. Long rubber gloves sealed into front panels protect the hands; all air is drawn into incinerator, and chamber is irradiated with ultraviolet light.

his hands thrust into long gloves sealed into a removable front panel. As he works, he and those near him are protected against the hazard of air-borne infection by germicidal ultraviolet lights bathing the entire field and by negative pressure within the hood, which carries contaminated air directly to the incinerators.

Since most of our interests involve some aspect of infection, we necessarily must perform large numbers of tests to establish the disease-producing capacity of bacteria and viruses. Because there are no suitable biochemical tests for virulence, we employ animal inoculations to establish the quantity of a given agent capable of killing fifty percent of all animals challenged. This procedure results in a heavy load of animal autopsies and poses another safety problem, namely, protection of the staff members responsible for their performance.

Here again, resort has been had to mechanical shields as shown in the cover photograph. Each experimenter works with gloved hands extended into a compartment almost entirely enclosed in glass. The operative area is protected by towels soaked in germicidal solution, and the field is irradiated with ultraviolet light from tubes mounted at the top of the autopsy unit.

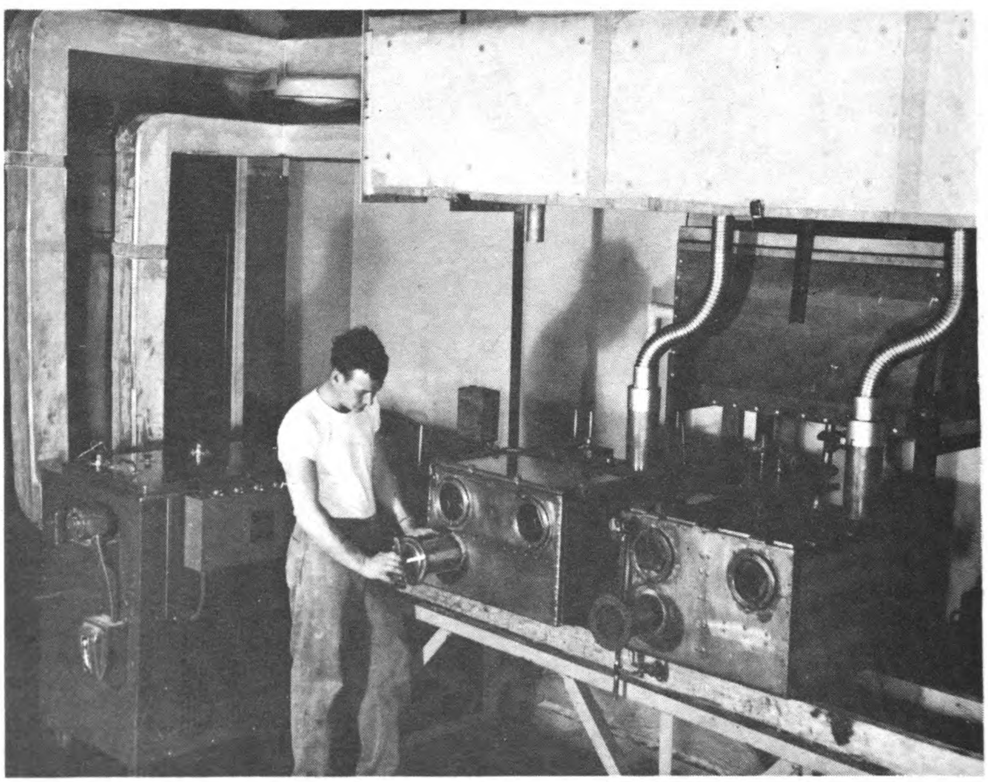


Fig. 4. Newly constructed chambers for studies on experimental epidemiology of air-borne diseases. The climate control equipment at left permits maintenance of groups of small animals at predetermined temperature and humidity.

Of a somewhat different character are the facilities under construction for investigating air-borne contagion in animal herds under completely controlled climatic conditions. (See Fig. 4.) Within limits, these chambers permit us to maintain animals such as mice at selected temperatures and humidities. At intervals animals suffering from a particular respiratory infection may be introduced and spread of the infection studied. Experiments such as determination of the efficacy of vaccines or evaluation of chemoprophylactic and chemotherapeutic agents may be carried out without changing the environment or exposing the experimenter to the risk of air-borne infection.

It is not possible within the scope of this article to discuss the actual experiments being performed in the equipment described herein. However, it may be stated that these applications of biological engineering permit work with air-borne preparations of the greatest infectiousness, e.g., the agents of plague and psittacosis, and long-term experiments designed to assess the factors concerned in the rise and decline of experimental epidemics.

Beginnings

Seventy years ago a Naval Laboratory was established at Washington, D. C., to conduct research in the fields of medicine that were of special interest to the Navy. One of the first of the new Laboratory's projects was an investigation of the relationship between atmospheric impurities and disease, for the support of which Congress appropriated $1,500 in 1880. The findings of this project were used in redesigning the ventilation systems of the Navy's ships in 1882.

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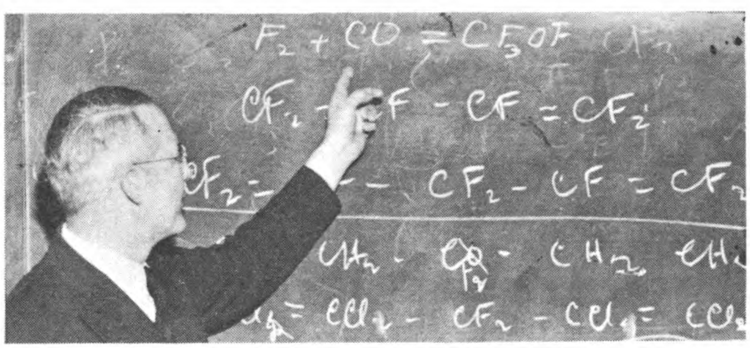
WHITHER FLUORINE CHEMISTRY

George H. Cady
University of Washington

Although the element fluorine has been known since its discovery by Davy in 1813, development of its uses and a knowledge of its compounds have been greatly retarded because of the difficulty of isolation of the free element, and because of the corrosive action of its compound, hydrogen fluoride, upon the glass and porcelain vessels normally used in chemical research. Very few of the pathfinders in chemistry have worked in the field of fluorine chemistry. Nearly all have found a liberal supply of interesting problems, which did not involve the added difficulties and dangers of working with fluorine or hydrofluoric acid. In spite of this relatively slow progress, a number of applications for compounds of fluorine had been developed by 1940, and the basic knowledge of the element had reached a status which permitted different military applications to be envisioned by technical men in Germany, England, and America. As a result, fluorine gas was produced during the war for the first time on an industrial scale both in Germany and in the United States. The enemy used fluorine to produce an incendiary agent, chlorine trifluoride, which had apparently not reached the stage for use in the field, and we used fluorine to form uranium hexafluoride and fluorocarbons, substances needed for isolation of uranium of atomic weight 235. These important applications have greatly increased scientific investigation in the field of fluorine chemistry, and there is now rapid progress in an area which for years was relatively quiet.

The Office of Naval Research is encouraging fundamental studies of fluorine chemistry by sponsoring projects at several universities.



The author describes one of the fluorine compounds, discussed in this article.

George H. Cady, professor of chemistry at the University of Washington, has been engaged in research on the chemistry of fluorine much of the time since 1928. During the war he served as leader of a group of men working on fluorocarbons at Columbia University as a part of the Manhattan Project. He received his A.B. and A.M. degrees from the University of Kansas in 1927 and 1928, respectively, and his Ph.D. degree from the University of California in 1930. He is now directing an ONR project at the University of Washington on the chemistry of compounds of fluorine.

Since the writer is most familiar with the work in progress at the University of Washington, he will use this as an example of the type of research which is being supported. In this project three lines of study are being followed. The greatest energy is devoted to a thorough investigation of a few pure compounds of fluorine and carbon, a class of substances called fluorocarbons. Work is also being done on derivatives of fluorocarbons, and upon reactions of fluorine with inorganic acids.

As a class of substances, fluorocarbons are of interest because of their resemblance in many ways to hydrocarbons and because they differ by being non-inflammable and much more resistant to heat and chemical attack. Compounds represented by the formulas CF_4 and CH_4 are both gases. The former is inert while the latter burns readily and is the principal component of natural gas. One of the hydrocarbons in gasoline has the formula C_6H_{14}. The corresponding fluorocarbon, C_6F_{14}, is also a volatile colorless liquid, but it does not burn and it is substantially odorless. Some fluorocarbon products are waxes like paraffin while others are plastics and still others are lubricating oils. Because of their stability and inertness one can imagine many valuable uses for such materials. Without doubt they will be used in increasing amounts as they become familiar to more people and as the cost of production is decreased. Their practical value will also be increased by gaining exact information regarding their characteristics through work of the type being done at the University of Washington. This study comprises an investigation of the boiling points, densities, freezing points, surface tensions, viscosities, pyrolysis, and behavior as solvents of a few pure liquid fluorocarbons. The experimental measurements have revealed unexpected differences between substances, the molecules of which differ in structure but not in total composition. Some progress has also been made in the direction of a theoretical understanding of the observed behavior of the compounds.

In the part of the project relating to derivatives of fluorocarbons, a gaseous compound represented by the formula, $\mathrm{F\text{-}\overset{F}{\underset{F}{C}}\text{-}O\text{-}F}$, has been prepared for the first time, and several of its properties have been determined. This compound is one of the few known examples in which oxygen and fluorine atoms are bonded to each other. Like other substances of this type, the compound is extremely reactive and it must be handled with caution in the laboratory because of its corrosive action upon body tissues, particularly those of the lungs.

Another new compound, fluorine perchlorate, $\mathrm{O\text{-}\overset{O}{\underset{O}{Cl}}\text{-}O\text{-}F}$, has been obtained as a part of this project by the action of fluorine upon perchloric acid. In addition to the compound's high reactivity and irritating action upon the mucous membrane, the laboratory worker is exposed to the added hazard of a possible violent explosion without much encouragement. The explosion may be caused by gentle heating, contact with organic matter, or by freezing.

This project not only increases understanding of this field, but it also sponsors the education of highly trained scientific personnel who are so urgently needed by the laboratories of our country. The work just discussed has already helped to train two Ph.D. men for work in atomic energy laboratories. Three other Ph.D. candidates are at work.

One M.S. degree graduate is now employed in the laboratory of an oil company, and another is just starting his research here at the University.

Regarding the future of fluorine chemistry, who knows what it will bring? Who can tell whether the fluorocarbons and their derivatives will continue to find more and more valuable applications or whether new compounds of unusual properties will some day fill important needs? At the present time the growing infant seems very healthy, and his future looks bright. Fluorine chemistry is a field to watch not only for practical applications but for its interesting additions to scientific knowledge.

Conference on Fluorides and Fluorocarbons

Dr. L. W. Butz, Head, Chemistry Branch, and Ralph Roberts, Chemist, Chemistry Branch, Office of Naval Research, seated at a round table discussion during the recent conference sponsored by ONR on the subject of fluorides and fluorocarbons.

An extensive program of research is underway in this field with ONR-sponsored projects at the University of Washington, Duke University, Illinois Geological Survey, University of North Carolina, University of Florida, Cornell University, Western Reserve University, Clemson Agricultural College, University of Oklahoma, University of Rochester, and University of California.

The conference was opened by Rear Admiral T. A. Solberg, USN, Chief of Naval Research. His remarks stressed the potential importance of fluorine compounds to naval applications. The preparation, properties of fluorides and fluorocarbons and their applications were the main topics treated.

GRAIN GROWTH IN METALS

Paul A. Beck
University of Notre Dame

Metallic objects, such as the armor plates of battle ships or the brass knobs used on doors, consist of small crystals or grains. These grains are usually not large enough to see with the unaided eye, but can be seen with the help of a microscope. In order to reveal the grain structure of a piece of metal, the sample has to be carefully polished and then etched with a suitable reagent. In most applications where metals are used, high strength is desirable. This is often obtained in alloys by heat treatment. The first part of the heat treating process consists of heating the alloy to a relatively high temperature for a definite period of time. Thus, when hardening steel, a temperature in the order of 1400° to 1500°F is reached. The steel, which is an alloy of iron and carbon, should transform into its high temperature modification,

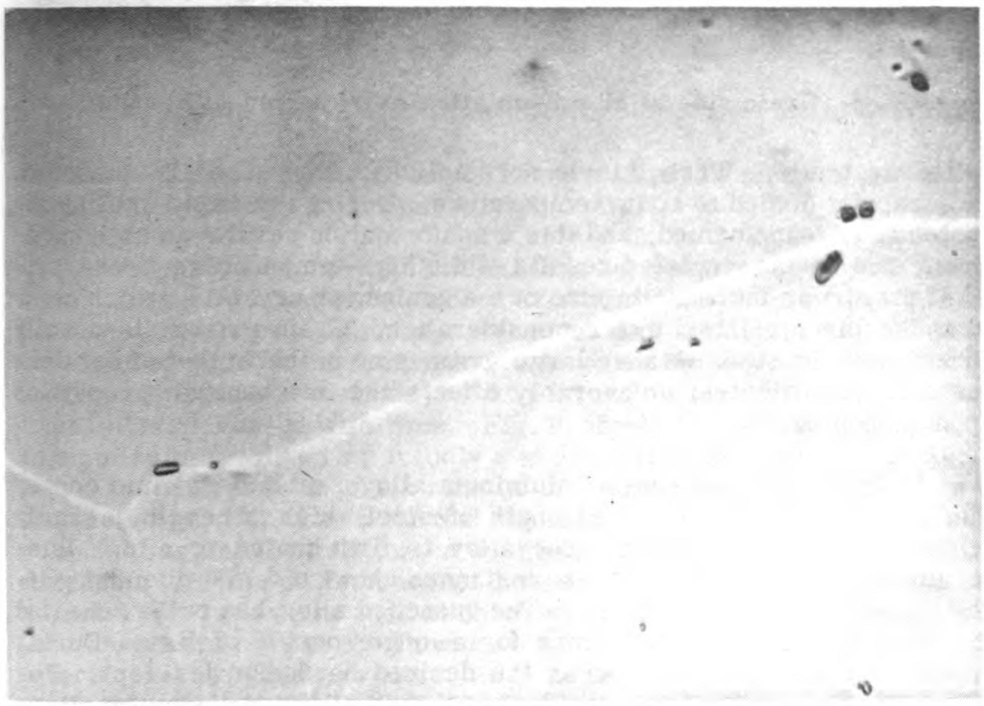


Fig. 5. Shape of grain boundary in alloy (aluminum + 1% manganese) in which alloying element has formed a new kind of crystal.

Paul A. Beck, associate professor of metallurgy, University of Notre Dame, has a broad background of experience in the field of metallurgy. He is a graduate of the Polytechnic Institute in Budapest, Hungary, in the field of mechanical engineering, and in 1931 he received his M. S. degree in metallurgy from the Michigan College of Mining and Technology. He has done graduate research with Prof. M. Polanyi at the Kaiser Wilhelm Institut, and with Prof. Jean Perrin at the University of Paris. From 1937 to 1941 he was research metallurgist with the Research Laboratories of the American Smelting and Refining Company, Barber, N. J.; later he was chief metallurgist at the Beryllium Corp., Reading, Penna., and from 1942-45 he was superintendent of the metallurgical laboratory of the Cleveland Graphite Bronz Company.

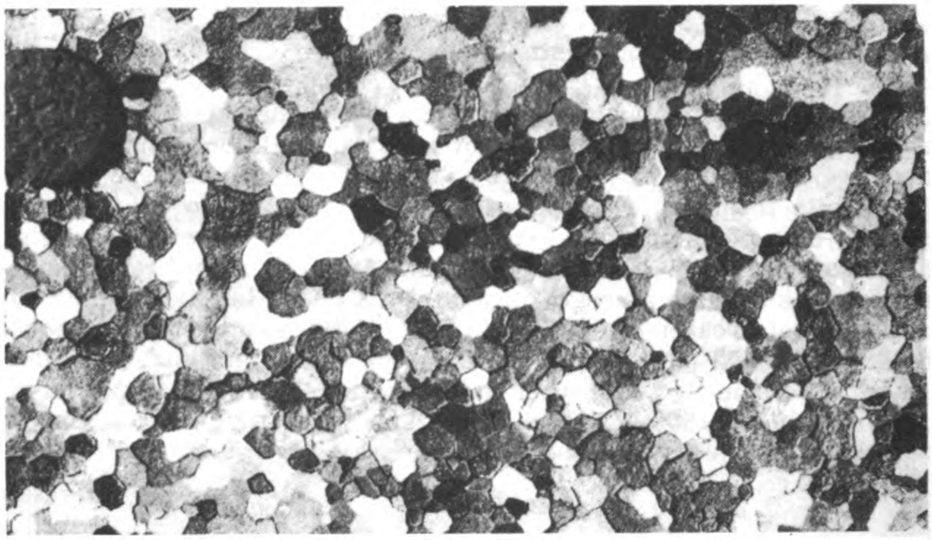


Fig. 6. Grain size of aluminum after short period of heating.

called austenite. When this is accomplished, the steel is quenched, i.e., rapidly cooled to room temperature. During the rapid cooling the austenite is transformed, and this transformation results in high hardness. One of the unwanted results of the high-temperature heat treatment may be an increase in size of the grains, or crystals, which compose the piece of steel under consideration. Grain growth is usually undesirable in steel because large grain size in the high-temperature austenite modification unfavorably affects the mechanical properties upon quenching.

In duralumin and similar aluminum alloys, or in beryllium copper (the copper alloy with the strength of steel) high strength is again achieved by heat treatment. The alloy is first heated to a high temperature and quenched. In these instances, however, the quenching itself does not impart hardness. The quenched alloy has to be reheated at a suitable, lower temperature for a longer period of time. During this so-called "ageing" process the desired hardness develops. For our consideration, the important fact is that in all these cases the alloys have to be exposed to high temperatures, and that such a treatment often results in an increase of the grain size. The grain size influences the mechanical properties and therefore to control the grain size is desirable.

The fact that the grain size increases when metals and alloys are heated to high temperatures has been known for a long time. The famous American metallurgists, C. H. Mathewson and Z. Jeffries, did the fundamental work in this field some 30 years ago. Recently, the interest of metallurgists in the phenomena of grain growth was revived. Newer methods of research and the availability of high purity metals now allow the re-examination of this important field with hope of obtaining significant additional information. During the last two years intensive studies of grain growth were conducted at the University of Notre Dame. Since even small impurities may have a profound effect on grain growth,

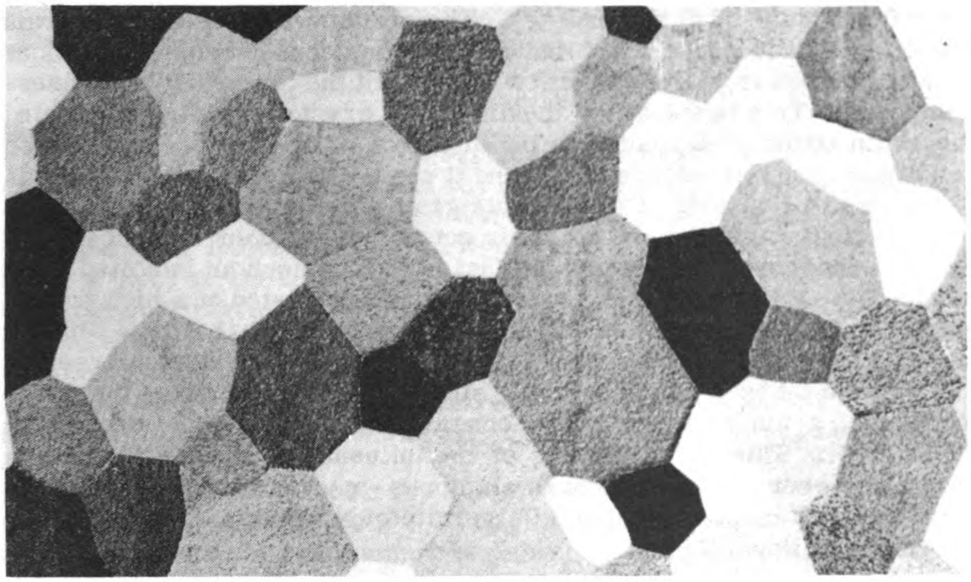


Fig. 7. Grain size of aluminum after prolonged period of heating.

the investigation was started using a very high purity metal, and extended later to alloys made from high purity metals.

Extremely high purity aluminum has been obtained from the Aluminum Company of America, and this material has been rolled into the form of thin strips. The strips were cut into small specimens which were heated at different temperatures for various lengths of time, ranging from 20 seconds to 11 days. At all temperatures investigated, the grain size increased with time. Fig. 6. shows the appearance of such an aluminum specimen after only a short period of heating, and Fig. 7 shows the increase in grain size at the same temperature after prolonged heating. It turned out that the rate of increase of the grain size was not constant. Initially, when the grains are small, they are growing very fast. As the grains became larger, the rate of their growth decreases. There was no indication, however, that growth would stop in pure aluminum. When alloys were made in which the alloying element entered the aluminum crystals to form so-called solid solutions, the grain growth behavior remained fundamentally the same as found in pure aluminum. Solid-solution alloys appear to be subject to unlimited grain growth, like pure metals.

Grain growth is "unlimited" only as long as the size of the grains is smaller than the thickness of the strip used. As soon as the grains are large enough to occupy the whole cross section of the strip, their growth stops. This condition is reached within a few seconds at temperatures near the melting point of pure aluminum. By heating the specimens for 11 days at the same temperature, no further growth can be induced. This "specimen-thickness effect" explains some of the puzzling results of earlier investigators.

If alloys are prepared in which the alloying element forms a new kind of crystal, one often finds that these new crystals appear within, and between, the aluminum grains, in a finely dispersed condition. The small particles of the new crystals in such a case have great influence on grain growth. Fig. 5 shows the shape of a grain boundary in such an alloy (aluminum + 1% manganese). The reader will note that the grain boundary is not smooth, but that it undergoes considerable contortions to adhere to some of the dispersed crystals of the aluminum-manganese compound. This tendency of the dispersed crystals to attract and bind the grain boundaries results in inhibition of grain growth. Under such conditions grain growth is slow, and it stops altogether after a certain grain size is reached. This ultimate grain size depends on the number of dispersed particles and on their potency in stopping the movement of the boundaries. The surprising fact is that, if such an inhibited alloy in which the grain size remained fairly small is heated at a high enough temperature, the inhibition effect may suddenly break down. If this happens, extremely large grains develop in the alloy. Sudden coarsening of this kind takes place in certain steels. When it occurs, the large increase in grain size results in a considerable change in the properties of the steel. This understanding of the influence of various factors on the phenomenon of coarsening in aluminum-manganese alloys has been the result of recent work at the University of Notre Dame, sponsored by the Office of Naval Research.

Corrosion

The Office of Naval Research participated actively in a recent symposium on corrosion called by the Corrosion Subcommittee of the Deterioration Prevention Committee. The DPC Committee is composed of members of the National Military Establishment. The purpose of the conference was to provide a means for the exchange of information on problems confronting government activities and the various programs underway in the government, the major portion of which are supported by the Armed Forces. All government activities concerned with corrosion problems participated. The many aspects of corrosion and applications for combatting the destructive influences of corrosive environments made for lively discussions and stimulated interest in this field.

To mention just one of these highlights, a successful method was reported for protecting the lock gates at the Panama Canal by cathodic protection, i.e., electro-chemical protection, using sacrificial anodes. Previously, this same method had been successfully used for the protection of underground pipe lines, but the system used in the Panama Canal is one of the first large-scale applications, resulting in considerable saving in costs of maintenance and materials, as well as providing a more effective method. Cathodic protection is also finding use in the Navy to prevent deterioration of ships' hulls and other shipboard components.

Reports of this symposium will be available from the Deterioration Prevention Committee, Corrosion Sub-Committee, National Academy of Sciences, 2101 Constitution Avenue, N. W., Washington, D. C.

THE CONFIGURATION OF THE EARTH

J. Lamar Worzel
Columbia University

Gravity observations on the surface of the Earth are made for two reasons, to determine the figure of the Earth and to get information about the distribution of densities in the Earth. Until recently the more usual way of pursuing information on the figure of the Earth was by measurements of arc, or the astronomical-geodetical method, but this method could not be used in finding the figure of the Earth in ocean regions which constitute 70 percent of the Earth's surface. The gravity method permits the possibility of finding the figure of the Earth in ocean regions. This is done by the pendulum method, described in this article, the only one so far which has provided an accurate measurement of gravity.

Twenty six years ago, gravity measurements at sea were first successfully carried out by Dr. F. A. Vening Meinesz of the Netherlands. By the use of a submarine a stable platform was obtained below the depth where wave action was serious. From this expedition, Meinesz developed a new type of pendulum apparatus for use in submarines. First employed in 1924, this apparatus has since been used for all gravity observations at sea. In 1937, B. C. Browne of England called attention to the need for corrections for certain second-order terms. The magnitude of these terms approached 0.010 cm/sec^2 or 10 milligals. In 1940 Meinesz added a long period pendulum apparatus to the previous equipment for determination of the Browne corrections.

About 1400 gravity observations were made on expeditions conducted on board Naval vessels of the Netherlands in 1923, 1925, 1926, 1927, 1929, 1932, 1935, and 1937; of the United States in 1928 (S-21), 1931 (Nautilus), 1932 (S-48), 1936 (Barracuda); of the U. S. S. R. in 1930 and 1933; of Italy in 1931 and 1935; of Japan in 1932, 1934, and 1935; and of France in 1932.

In June 1947 the group at the Geophysical Laboratory, Department of Geology, Columbia University, began a program for gravity measurements at sea. This work was jointly sponsored by the Geological Society of America and the Office of Naval Research. Recently the program has become sponsored solely by the Office of Naval Research.

Since the commencement of this work, cruises have been made aboard the U. S. S. TUSK (June-July 1947), the U. S. S. CONGER (August,

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J. Lamar Worzel, a graduate student at Columbia University and geodesist in charge of a program of gravity measurements at sea, was born at West Brighton, Staten Island, New York, February 21, 1919. He received his B.A. degree in engineering physics from Lehigh University in 1940. From 1940 to 1946, he worked at the Woods Hole Oceanographic Institution, under Navy contracts, on problems of underwater sound transmission. In September 1946, he entered the graduate school of Columbia University, Department of Geology, and received his M.A. degree in June 1947, specializing in geophysics. He is now working under an ONR-sponsored project with Columbia University.

September, and October 1947), the U. S. S. ARGONAUT (February, March 1948), the U. S. S. MEDREGAL (May-June 1948), the U. S. S. CAPITAINE (July-Dec 1948), and the U. S. S. BERGALL (Jan-Mar 1949). Approximately 1000 gravity observations have been made at various stations on these cruises, covering the Atlantic coast between Maine and Florida, the northern Bahama Islands, the north coast of South America, and the west coast of South America from the Canal Zone to Valparaiso, Chile. In addition a few stations were made between Valparaiso and Cape Horn. Two complete cruises have now been completed across the Pacific from Hawaii to China. These observations have been made to study specific geological problems of the earth's crust, and to investigate further the transition from continent to ocean basin.

Used in this work were the Meinesz apparatus and a Bell Telephone Laboratories' crystal chronometer, both made available by the Woods Hole Oceanographic Institution. The Meinesz apparatus consists of a thermally insulated case, which contains the main gravity pendulums, and a camera for recording the swings of the pendulums. There are three identical main pendulums, which swing in the same plane and two auxiliary damped pendulums, one in a parallel plane and one at right angles, in the main case. In a normal observation, the two outside pendulums are started swinging with equal amplitude and opposite phase. In this manner the horizontal accelerations of the apparatus caused by the motion of the pendulums are canceled to a first order of approximation. The middle pendulum is allowed to hang on its knife edge but is not given any amplitude. Horizontal accelerations of the apparatus caused by the motion of the submarine affect all pendulums equally. By recording the difference obtained optically between the angle of one of the outside pendulums and the angle of the central pendulum, a fictitious pendulum is obtained which is not affected by these accelerations. By maintaining the depth and course of the submarine over the period of the observations, the vertical accelerations are averaged out. The damped pendulums are recorded on the same record, and show the deviation of the apparatus from the direction of the total acceleration vector. (See Figs. 8-10.)

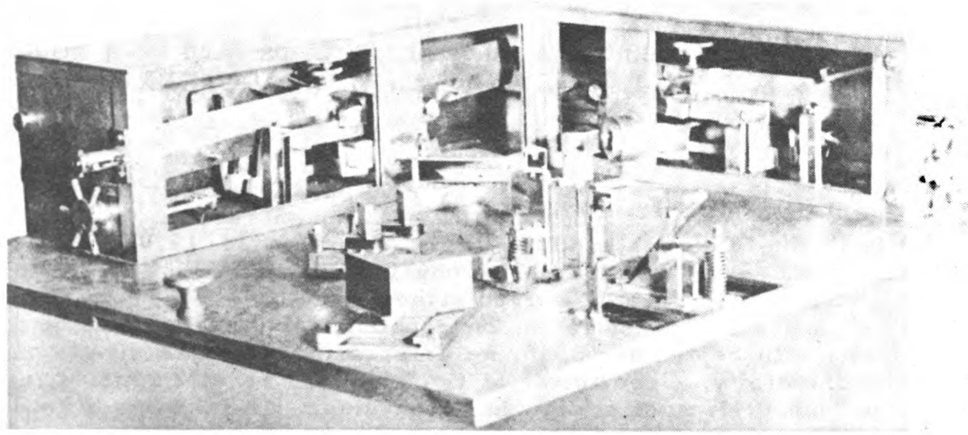

Fig. 8. Slow pendulum apparatus for measuring horizontal accelerations.

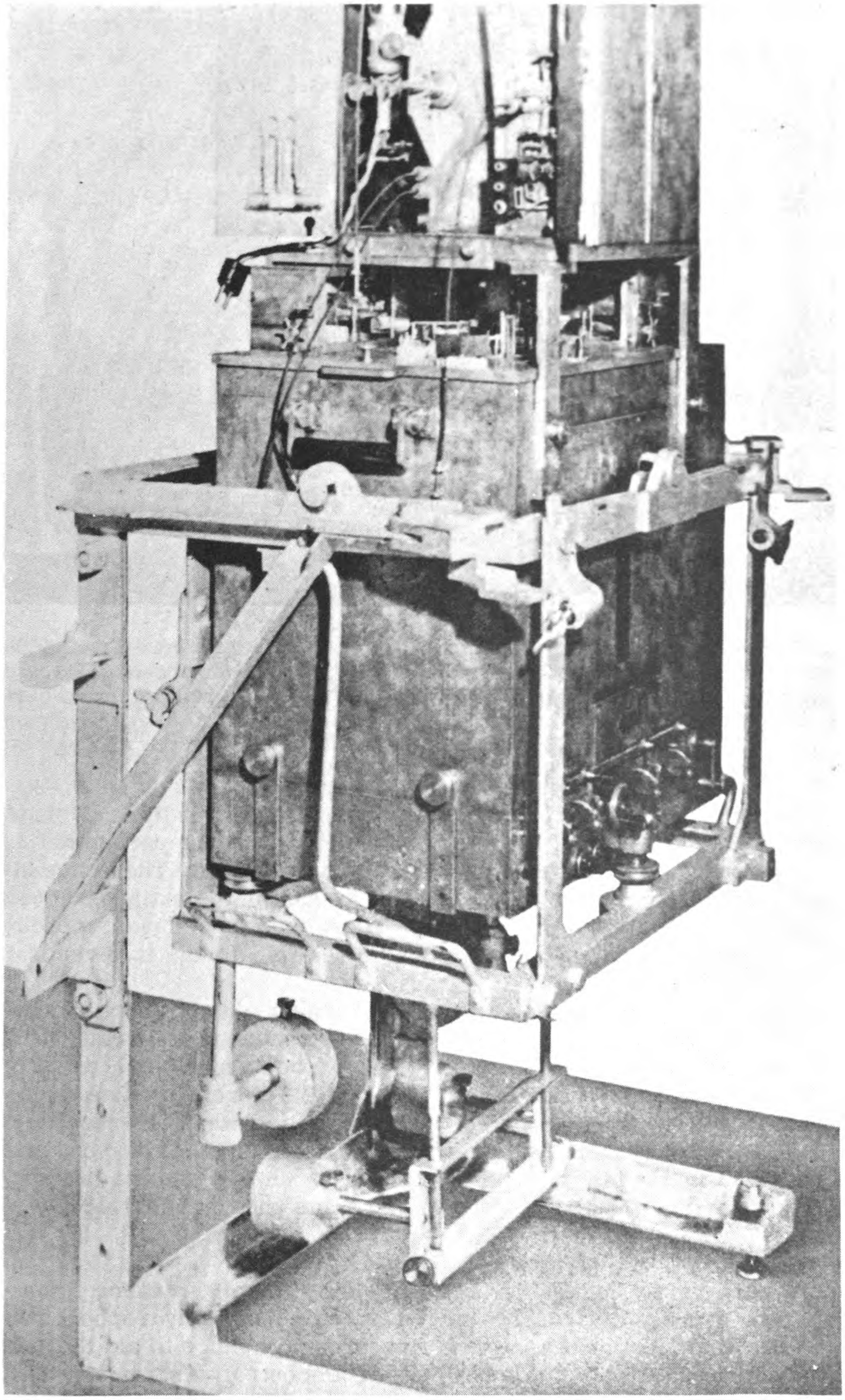

Fig. 9. Pendulum apparatus for gravity determinations at sea; the slow pendulum apparatus of Fig. 8 is introduced between the recording and the pendulum apparatus.

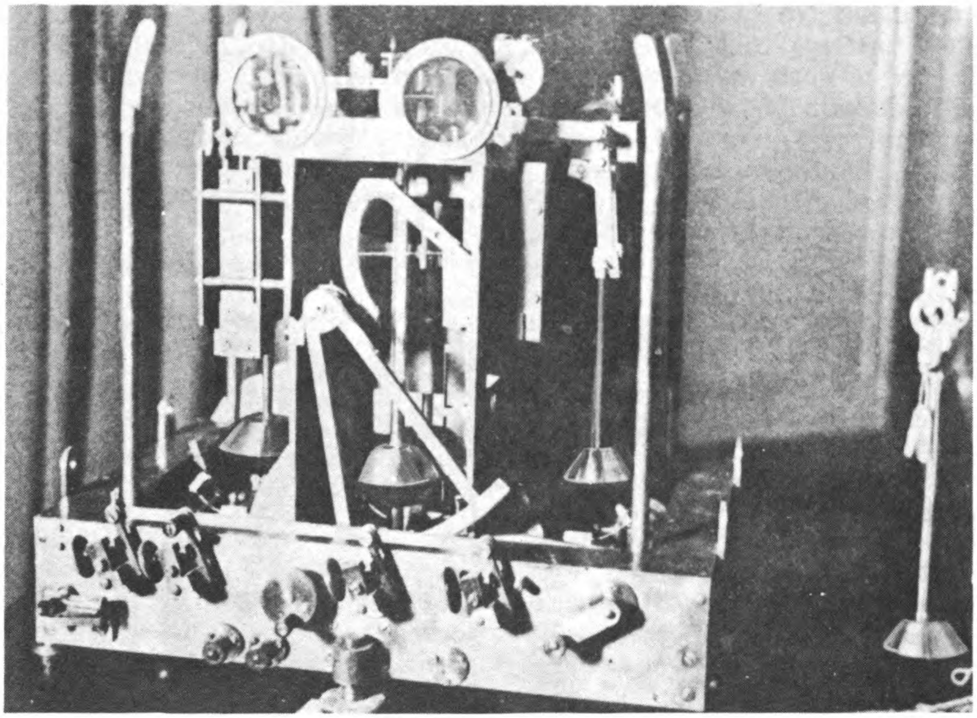

Fig. 10. Pendulum case with insulating cover removed. Two of the three pendulums are visible at the sides; the dummy pendulum with thermometer and the hair hygrometer can be seen in the central part. The damped pendulum is shown at the upper left side. A reserve pendulum stands beside the apparatus. At the bottom the clutch and release levers are shown, and at the left side a spirit level.

The long-period or slow pendulum apparatus, loaned by Dr. Meinesz for this work, consists of two pendulums of such a long period that the wave motions do not appreciably affect their position. There are two such pendulums, one in a plane parallel to that of the main pendulums and one at right angles to this plane. These then permit the recording of the position of the pendulum apparatus relative to the true vertical.

A light beam is focused on a slit to furnish a light source for the recording of the various pendulums. This light beam is broken at the slit by spokes on a wheel driven by a synchronous motor controlled by the crystal chronometer. Light interruptions are therefore caused twenty times a second in the light beams following each path. The records of the two fictitious pendulums, the central pendulum and one damped pendulum optically combined, the other damped pendulum, and the two long-period pendulums are all recorded on the same photographic tape. (See Figs. 11-12.)

In addition to the gravity apparatus, the Naval Ordnance Laboratory of the Bureau of Ordnance has provided a Mark I hydrophone. We are using this instrument as a sensitive pressure gauge to aid the submarine in maintaining the best possible depth control. As a by-product, we are also obtaining much data on pressure fluctuations at various depths from passing water waves. (See Fig. 13.) This information, coupled with the acceleration data of the gravity gear, should provide much useful information on water waves.

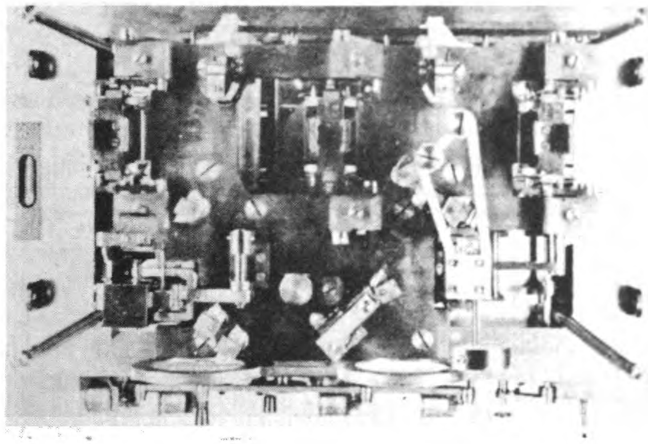

Fig. 11. View from above of interior of pendulum case of apparatus, showing arrangement of prisms.

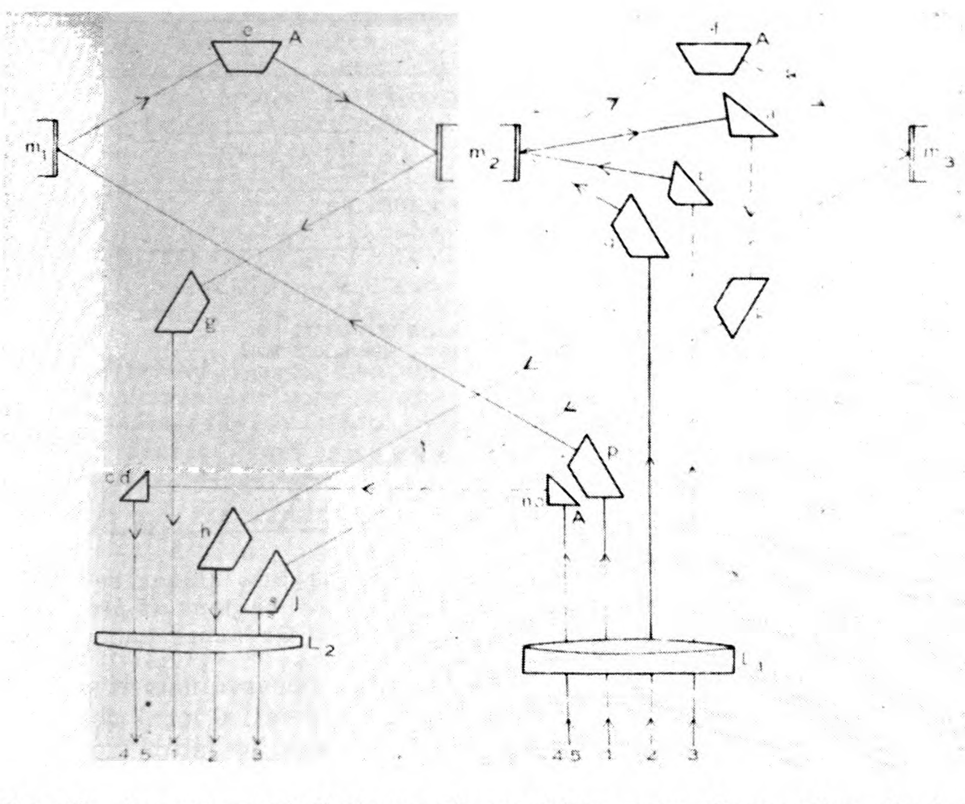

Fig. 12. Arrangement of mirrors in pendulum case of apparatus. L_1, L_2 are the entrance and exit lenses, respectively; m_1, m_2, and m_3 are the three nearly isochronous, free-swinging pendulums mounted on a single supporting straight bar; a and d are two damped pendulums, a swinging in the same plane with m_1, m_2, m_3, while d swings in a plane normal thereto. Prism c is vertically above d and prism n above o.

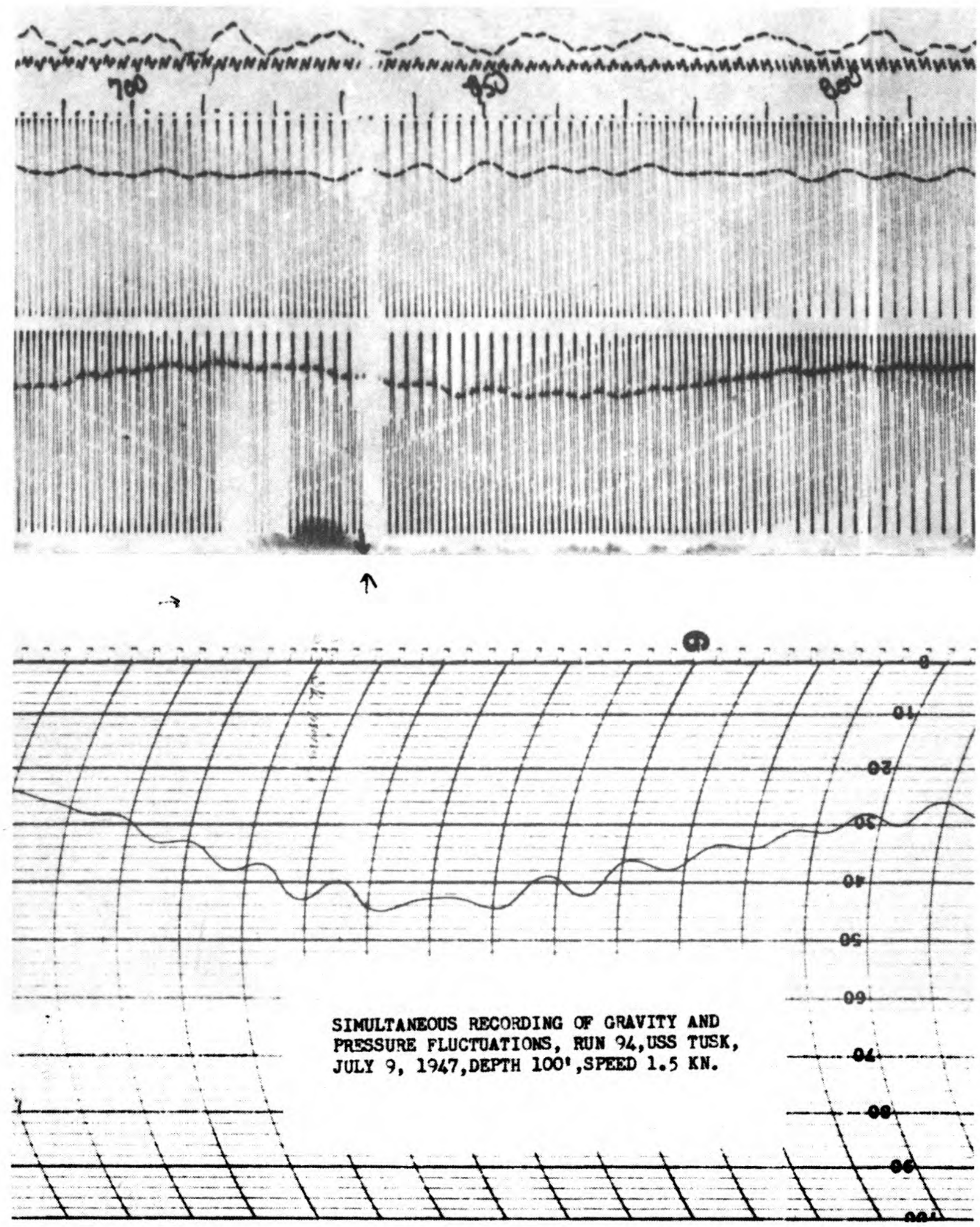

Fig. 13. Record of the Meinesz pendulum apparatus. Upper record is measurement of gravity; lower record is measurement of pressure, using Mark I pressure gauge, loaned by the Naval Ordnance Laboratory.

There are two main programs for gravity observations at sea, (1) broad network coverage observations, and (2) detailed local observations. To date all of our gravity cruises have been the latter type. The broad network coverage observations are designed to provide a suitable network of gravity stations to determine a more precise shape of the earth. For this purpose the goal is to obtain complete world-wide gravity observations at equal spacing of about 50 miles between stations.

The detailed local observations are designed to investigate local gravitational and geological features. In certain areas there are large variations in the gravitational field which are of interest as relating to volcanic and earthquake activity, and probably to mountain building processes. The arcs of the East and West Indian Islands are such places. Probably similar areas are the Aleutian Islands, Sandwich Islands, Tonga Islands, Kurile Islands, Bougainville, and possibly the coast of Chile. These places merit detailed gravitational investigation.

Reconnaissance surveys will probably uncover other areas where detailed investigations are desirable. Detailed surveys of volcanic island areas, such as the Hawaiian Islands, should give valuable geological information about the strength of the earth's crust and its probable thickness.

The shape of the earth is of military value for the precise navigation of rockets and jet-propelled missiles. Gravitational effects near islands, mountains, and continental coasts often cause deflections from the vertical. These make the precise location by astronomic means of Loran, Sofar, Radar, and other long-distance navigational stations subject to errors greater than a mile. The only known means of evaluating these errors is by a suitable gravitational survey of the region surrounding each station.

Among the ONR Contractors

Dr. Clark B. Millikan, Acting Director, Guggenheim Aeronautical Laboratory, California Institute of Technology, and Acting Chairman, Jet Propulsion Laboratory, is the principal investigator on an ONR contract in the field of power. He was recently elected 1948 American Honorary Fellow of the Institute of Aeronautical Sciences. Only persons eminent in aeronautics may be elected to Honorary Fellowship in the Institute. Dr. Millikan adds this distinction to his already long list of positions and awards in recognition of his outstanding contributions to the field of aeronautics.

Dr. Millikan serves as a member of the Naval Research Advisory Committee, which advises the Chief of Naval Research on scientific research matters. He holds a commission as Lieut. Commander in the U. S. Naval Reserve.

SPECIAL DEVICES RESERVE UNIT 11-1 MEETS

Los Angeles, California

The Pasadena group VNRR Unit 11-1 is the first Special Devices Unit in the country and the first Volunteer Naval Research Reserve Unit established in the Eleventh Naval District. Commanding Officer of the Unit, Hubert J. Pedersen, Lt. Comdr., USNR, reports on the third meeting held in January. The Scientific Section of the ONR Los Angeles Branch office presented a report to assist the group in fulfilling its first mission, that of familiarizing itself with the program of research in the field of special devices underway in ONR. This Unit is now preparing a syllabus of training for the coming year. The group plans to break up into sections corresponding to the sections of the Special Devices Center in New York. These individual sections will keep in touch with the Center and report to the group as a whole on the activity in each section of the Center. After the group becomes thoroughly familiar with the work at the Special Devices Center, it will attempt a tangible contribution to the Navy. The Center may help in this matter by making specific recommendations. VNRR Unit 11-1 has a good cross section of experience, being composed of officers with training in radar, navigation, service branch, maintenance, films, flight, land fall technique, gunnery and bombing, training aids, and procurement.

The group may undertake some individual projects. For example, two officers plan to work with the human centrifuge at the University of California. Several work shops have been offered to the group.

Some of the officers plan to take Navy courses to supplement the one meeting a month. It is hoped that every officer in the group will have an opportunity to complete his 50 points per year, but probably only a small percentage will be able to devote that much time. Inquiries have been received from officers who would like to attend meetings of other reserve units associated with ONR activity, and they are being encouraged to do so.

Attendance at meetings has been good, in spite of the fact that some members must travel as far as thirty miles. The paper work is a problem which no doubt is confronting all units. The Los Angeles Branch office has been most cooperative in assisting, and some of the officers have used their business offices. A Standard Volunteer Unit filing system has been set up to expedite the handling of details.

The Unit plans to meet on the Tuesday closest to the 15th of each month. The dates of the meetings can be adjusted to coincide with those of personnel from the Special Devices Center planning trips in this area, or with those of representatives from the Eleventh Naval District. Notification should be sent in advance so that the VNRR Unit 11-1 can take advantage of such visitors.

Note to Research Reserve Units

Send your reports of meetings, your accomplishments, and your plans to Director of Research Reserve, (Code 103R) Office of Naval Research, Department of the Navy, Washington 25, D. C. The Washington office is interested in accounts of activities and other Research Reserve units are, too.

VOLUNTEER RESEARCH RESERVE UNITS

DESIGNATION	TYPE	LOCATION	COMMANDING OFFICER
1-1	Composite	Boston, Mass.	Capt. J. W. Hammond, USNR
3-1	Composite	Cornell University Medical College 1300 York Avenue New York 21, N.Y.	Cdr. James S. Hardy, USNR
3-2	Special Devices	Special Devices Center Sands Point, Port Washington Long Island, N.Y.	Cdr. Len E. Yoder, USNR
4-1	Composite	Princeton University Princeton, N.J.	LCdr. Paul Busse, USNR
4-2	Composite	Franklin Institute Philadelphia, Pa.	(Pending)
W-1	Composite	Department of the Navy Washington, D. C.	Cdr. Fred. C. Wiesner, USNR
5-1	Composite	University of Virginia Charlottesville, Va.	Lt(jg) Peter B. Buck, USNR
5-2	Composite	Virginia Polytechnic Inst. Blacksburg, Va.	LCdr. E. D. Harrison, USNR
6-1	Composite	Georgia Institute of Technology Atlanta, Ga.	Cdr. James E. Boyd, USNR
6-2	Composite	Alabama Polytechnic Inst. Auburn, Ala.	Lt. James E. Land, USNR

DESIGNATION	TYPE	LOCATION	COMMANDING OFFICER
6-3	Composite	Oak Ridge, Tenn.	LCdr. David J. Mallon, USNR
6-4	Composite	University of Florida Gainesville, Fla.	Lt. J. S. Johnson, USNR
9-1	Composite	University of Chicago Chicago, Ill.	Capt. George Lamb, USNR
9-2	Composite	University of Illinois Urbana, Ill.	LCdr. A. O. Williams, USNR
9-3	Composite	University of Michigan Ann Arbor, Mich.	Cdr. Charles M. Davis, USNR
9-4	Composite	Ohio State University Columbus, Ohio	LCdr. C. E. Krill, USNR
9-5	Composite	Iowa State College Ames, Iowa	LCdr. O. C. Kreider, USNR
11-1	Special Devices	510 W. 6th Street Los Angeles, Calif.	LCdr. H. J. Pedersen, USNR
11-2	Composite	680 E. Colorado Drive Pasadena, Calif.	LCdr. John H. Biggar, USNR
11-3	Composite	University of California Los Angeles, Calif.	Cdr. L. P. Delsasso, USNR
12-1	Composite	ONR San Francisco Branch Office U. S. Naval Shipyard Hunter's Point San Francisco, Calif.	Cdr. J. E. Laurance, USNR
12-1 (Sub)	Composite	University of California Berkeley, Calif.	Cdr. Carl J. Vogt, USNR
12-2	Biological Sciences	University of California Berkeley, Calif.	LCdr. Nello Pace, USNR
12-3	Composite	Stanford University Palo Alto, Calif.	Cdr. L. S. Jacobsen, USNR
12-4	Composite	Fresno State College Fresno, Calif.	Cdr. Ralph A. Jack, USNR
13-1	Composite	University of Washington Seattle, Wash.	Cdr. H. S. Bennett, USNR

AN INDEX OF ARTICLES AND AUTHORS

The following index lists all the articles and authors that appeared in Research Reviews since its first issue, January 15, 1948, up to and including the February 1949 issue.

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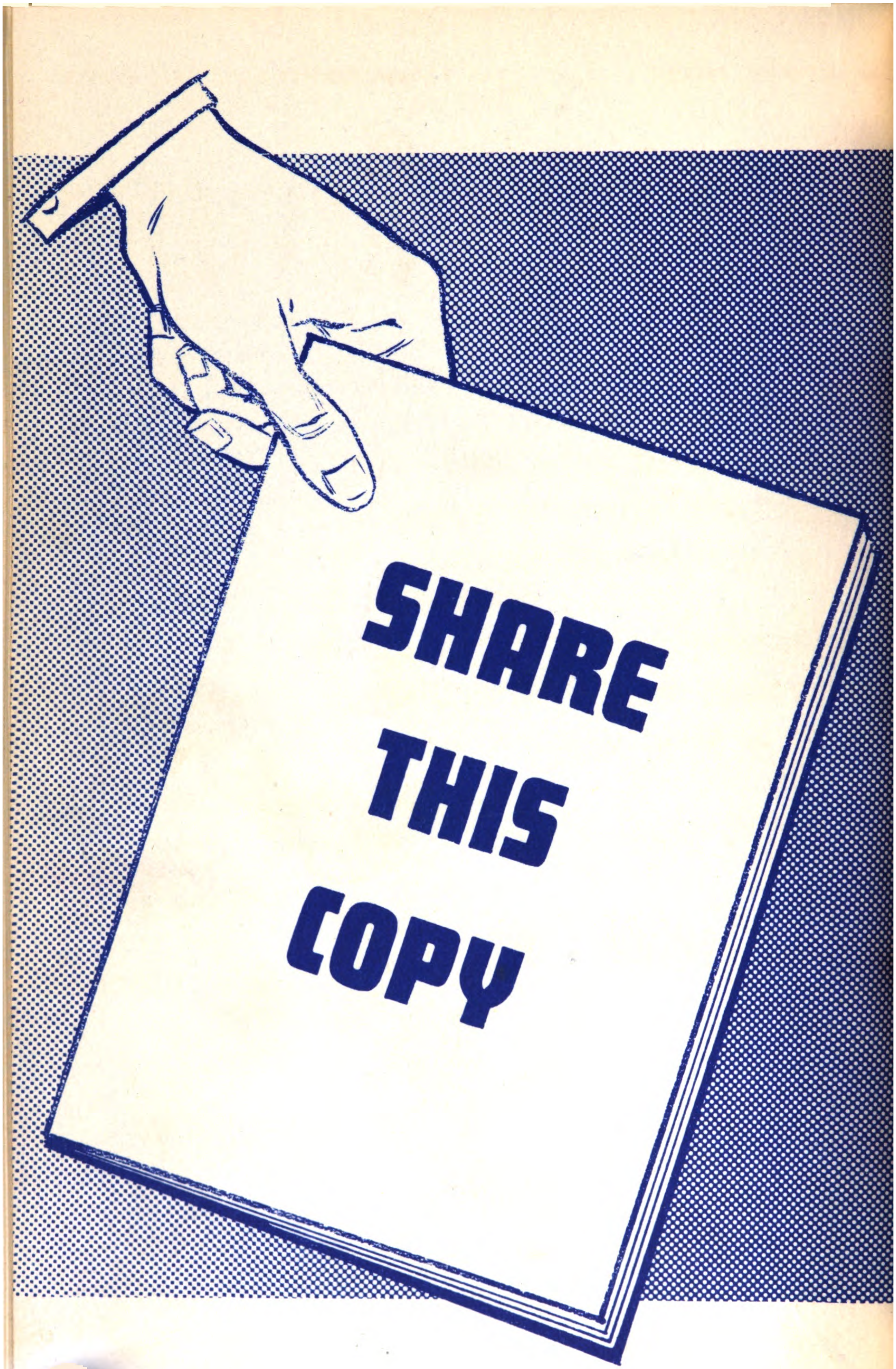
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