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RESEARCH REVIEWS

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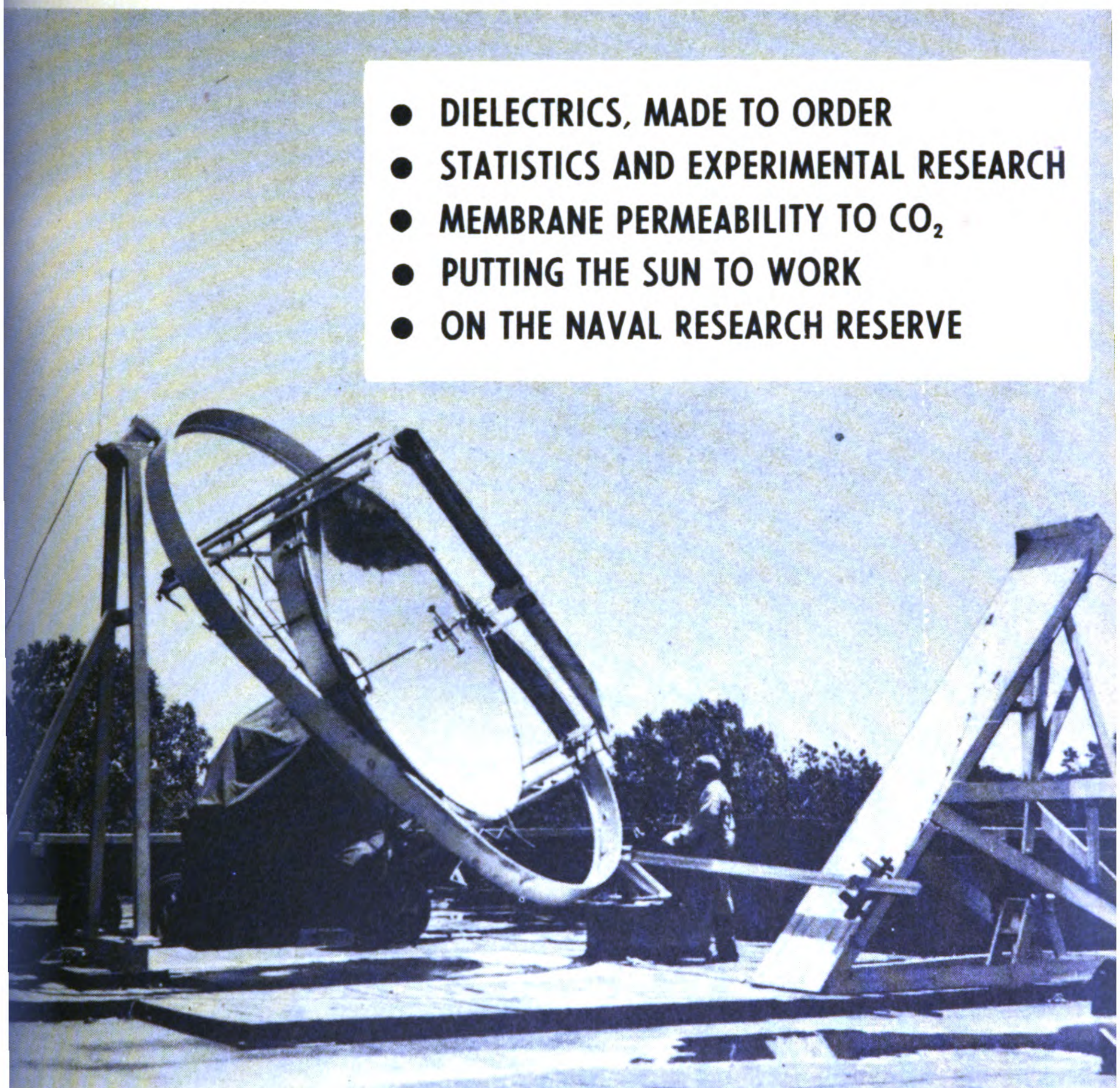

OFFICE OF NAVAL RESEARCH
DEPARTMENT OF THE NAVY
WASHINGTON, D. C.

NATIONAL MILITARY ESTABLISHMENT · UNITED STATES OF AMERICA

NAVEXOS P-510

COVER PHOTO: One of modern science's most effective tools for high-temperature research--the solar furnace--is shown. This furnace, which was developed at Rockhurst College under ONR contract, produces tremendous heats by using a 120-inch paraboloidal mirror to concentrate radiant energy from the sun in a small area. The project is described on pp. 16-18 of this issue by Dr. William M. Conn.

Approved by Bureau of the Budget, 13 April 1948.

RESEARCH REVIEWS

Informs the Fleet of ONR-sponsored Research

Contents

AUGUST 1950

DEPARTMENT OF THE NAVY ★ OFFICE OF NAVAL RESEARCH ★

Editorial Notes

The problems that the Navy must solve in order to do its job well are obviously not confined to any one field, but are scattered in widely varied areas, ranging all the way from engineering to personnel selection. It is the task of the Office of Naval Research to expedite the solution of these problems through its support of research in Government laboratories, in industry, and in universities all over the nation. Such a task is patently a "big order", yet one which must be filled if our country's security is to be assured. The widely diversified way in which ONR-sponsored research is accomplishing this mission can be illustrated by a brief survey of articles that have appeared in recent issues of Research Reviews. The following articles, selected more or less at random, show the wide applicability of ONR-sponsored investigations to the everyday problems of the Navy.

● A study that may eventually lead to the production of structural alloys for high-temperature service--a constant need in Navy construction--is discussed in "The Refractory Carbides" by John T. Norton of MIT, in the July issue. Heretofore very little of a fundamental nature has been known about these important substances.

● A problem that the Armed Forces have found tremendously crippling and costly--the destruction of equipment by climate, dirt, and biological agents--is being attacked through ONR-sponsored research at the Prevention of Deterioration Center. This work is described by Dr. Glenn A. Greathouse in the June issue of the Reviews.

● In the May number, George H. Markstein, an investigator under ONR contract at Cornell Aeronautical Laboratory, Inc., discusses flame propagation. This again is a field in which basic information is still rather meagre. Eventually it is hoped that studies like the ones described in this article will lead to more straightforward design of jet and rocket propulsive devices.

● Dr. Reuben L. Kahn, University of Michigan investigator, reports in the April 1950 issue that a medical test of wide applicability is being developed which may be of immense value, not only to the Navy, but to medicine in general. This test, discussed in the article "Universal Reaction--an Indicator of Health", is aimed at determining an individual's general state of health, just as simple blood tests for specific diseases have been found in the past.

● Problems faced by the pilot of modern high-speed aircraft are, of course, vital ones to the Armed Forces. ONR's interest in these problems was shown in its support of investigations being conducted by A. A. Canfield at Northwestern University. In "The Human Centrifuge", an article which appeared in the March issue of the Reviews, Dr. Canfield described important research which he is conducting in connection with the psychological effects on pilots of certain stress situations encountered in modern planes.

Thus, even from this brief sampling, we can see the wide range of practical usefulness of ONR research. Moreover, many other investigations are being supported which, though their applications may not be so immediate, offer promise of long-range results that will be of inestimable value to our Nation's welfare. Research today--both basic and applied--has become one of the Navy's most vital interests, and ONR is working to see that it is one of the Navy's most profitable ones.

Dielectrics, Made To Order

by
Arthur R. von Hippel
Massachusetts Institute of Technology

The relatively inefficient use of materials in electrical engineering today stems from the still prevailing idea that dielectrics have unalterable properties and are bestowed on us, either by Nature (oil, mica, and shellac) or by industry as the more or less accidental by-products of a manufacture directed toward other goals (plastics, paper, and ceramics). These premises have to be revised. The properties of materials can be changed within wide limits, and our goal should be to tailor them to order by combining the proper atoms and molecules in the fitting patterns.

On this postulate the Laboratory for Insulation Research was founded twelve years ago and carries on an extensive fundamental research program, now sponsored jointly by the Navy Department, the Army Signal Corps, and the Air Force under ONR Contract. It is aimed at acquiring the basic knowledge for a synthesis of materials with prescribed electric and magnetic properties.

For this type of approach, the old definition of a dielectric as a "nonconductor of electricity" has lost its meaning. Any material may show conduction to a varying degree, depending on the conditions and the pretreatment chosen. A slab of rock salt, for example, may, at room temperature, be an excellent insulator with about 10^{17} ohm/cm resistivity. If used, however, at 450°C in a field of about 1000 volt/cm it will fail dramatically. For a few minutes the only indication of trouble may be a slowly climbing ammeter needle, indicating that the resistivity is falling to about 10^{7} ohm/cm. Then suddenly, like an erupting volcano, the cathode begins to eject cherry-red clouds which drift rapidly through the clear crystal toward the counter-electrode (Figure 1); the current simultaneously rises steeply. The clouds are formed by electrons issuing from the cathode and migrating to the anode. Reversal of the voltage may still pull them back and save the dielectric.

Behind this smoke screen of electron clouds, however, other events occur which damage the crystal beyond repair. From the cathode a structure like a Christmas tree begins to grow -- a dendrite of sodium

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Arthur R. von Hippel, Director of the Laboratory for Insulation Research at the Massachusetts Institute of Technology, received his Ph. D. from the University of Goettingen, Germany, in 1924. After serving as Assistant Professor at the University of Jena, he became a Rockefeller Fellow at the University of California and later a Professor at the Universities of Istanbul and Copenhagen. Noted for his research in the fields of electrical insulation, gaseous discharges, semi-conductors and photoelectricity, Dr. von Hippel has been a contributor to many technical publications. He is a Fellow of the American Physical Society and of the American Academy of Arts and Sciences.

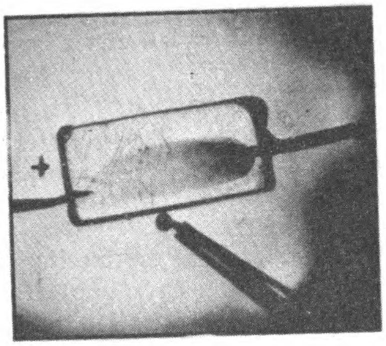

Figure 1. Electron emission from cathode in rock salt crystal

deposited by discharging cations, which rapidly throws a metallic bridge across the electrode gap (Figure 2). To replace these ions, the copper anode releases invisible copper ions into the rock salt. As the electron clouds of Figure 1 approach this anodic region, they begin to act like a developer: each copper ion traps an electron to neutralize its charge, and a brilliant red copper colloid appears, circling the anode like a halo (Figure 3). Then an electric spark bursts forth from the anode in zig-zag patterns similar to lightning and, striking the dendrite, completes the destruction in a grand finale (Figure 4).

A casual observer, not aware of these turbulent events, will notice a hole in the crystal (Figure 5) and comment in casual complaint that the insulation broke down. Yet this outcome,

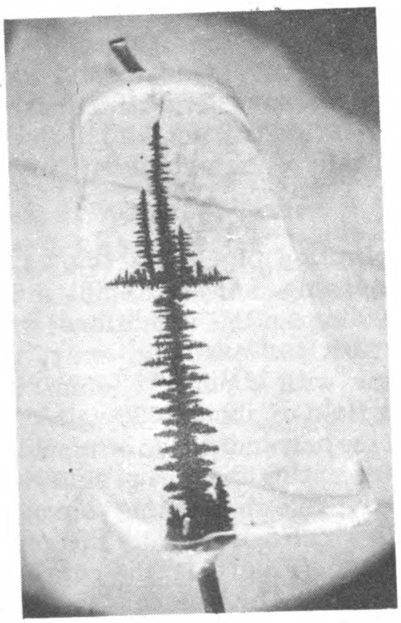

Figure 2. Sodium dendrite growing from cathode

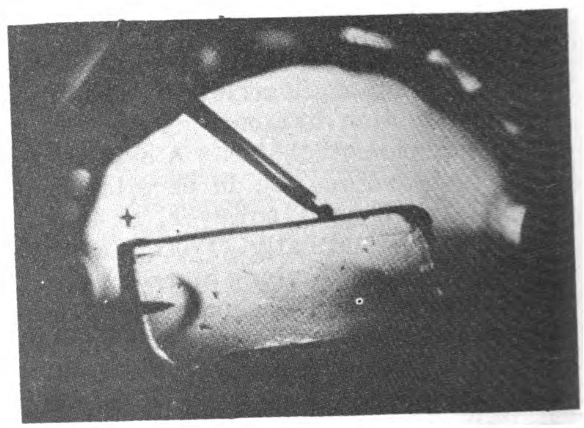

Figure 3. Halo of copper developing near anode

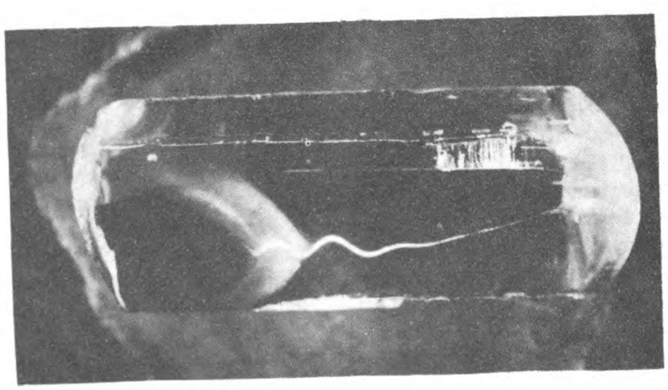

Figure 4. Spark bursting from anodic region

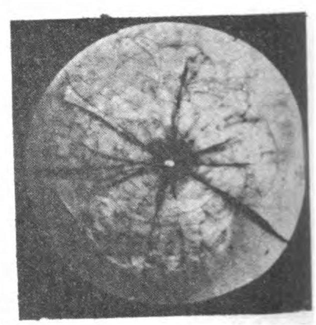

Figure 5. The breakdown hole in the crystal which results

like the climax in any good murder story, might have been prevented, if the influences at work had been properly appraised and controlled. We should learn how to contain the electrons in the cathode and how to release them at will; we should understand the laws of migration of electrons and ions and know how to interfere with their motions when necessary. This, then, is one of our long-range problems. It requires research ranging from gases to liquids and solids, and from insulators to semiconductors and metals; the successful solution of this problem may lead to dielectrics of higher breakdown strength and materials of controlled conductivity which might fundamentally alter the present practices of electrical design.

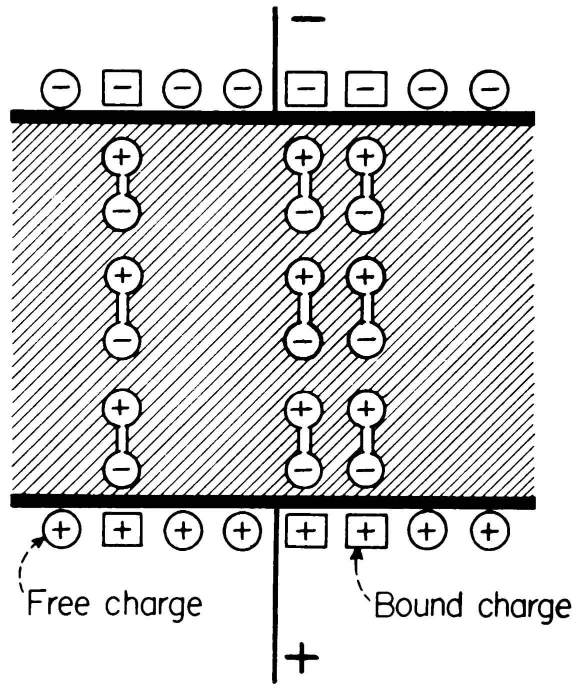

Figure 6. Dipole chains in dielectrics

There are other problems of equal importance. Materials serve for a concentration and storage of electric and magnetic energy. It is a well-known fact that a capacitor can store more charge per unit voltage if the interspace between its internal electrodes is filled by a dielectric instead of vacuum. How much more it can store is expressed by the dielectric constant (permittivity) of the filling medium. Normally one has to be satisfied with constants ranging from 2 to 5, but recently materials have become available which may increase the storage capacity a thousand to ten-thousand-fold for special applications. These materials are called ferroelectrics, and our Laboratory has spent much research effort in developing one of the important prototypes, barium titanate.

A dielectric material increases the storage capacity of a condenser because it polarizes in the applied electric field. Schematically speaking, chains of electric dipoles form in the medium and the charged ends of these electric dumbbell chains bind countercharges at the electrodes (Figure 6). These dipoles may form under the influence of the applied voltage because the positive charges of the atoms and molecules move slightly toward the cathode and their negative counterparts toward the anode. On the other hand, the dielectric may already contain preformed dipoles which tend to turn under the influence of an electric field like magnetic needles in the earth's magnetic field. The effect will normally be small and the dielectric constant low because the applied field is very small in comparison to the strong fields binding the atoms and molecules and tending to destroy the orientation of the permanent dipoles by thermal agitation. In special materials, however, below a critical or "Curie" temperature the dipoles sometimes align their

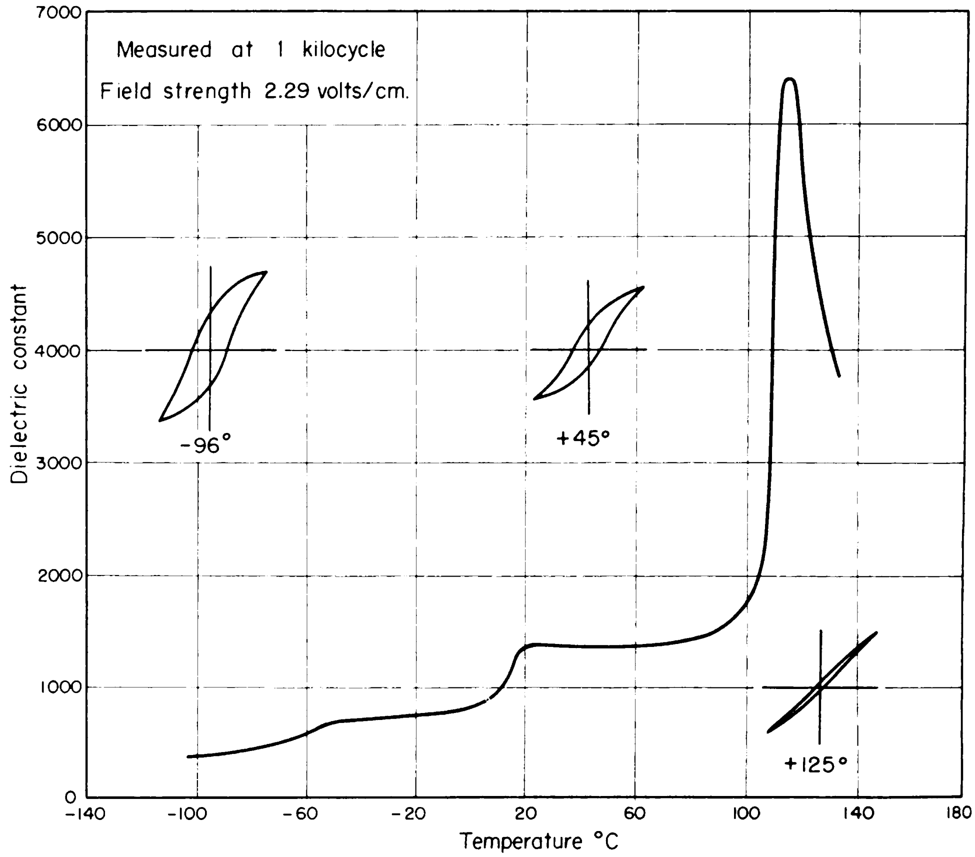

Figure 7. Temperature dependence of dielectric constant and hysteresis loops of barium titanate ceramic

moments spontaneously in parallel orientation by mutual interaction. If this happens to magnetic dipoles, ferromagnetism results, as in iron, nickel, or cobalt; in the case of electric dipoles, ferroelectricity is obtained--for example, in rochelle salt or barium titanate.

Figure 7 illustrates the situation for a piece of barium titanate ceramic. As the sample is cooled through the critical temperature region near 120°C, the dielectric constant shoots up and traverses a peak reaching a value of about 7000. Simultaneously it is not a constant any more but becomes a function of the applied field strength; that is, the polarization describes hysteresis loops like the magnetization in ferromag-

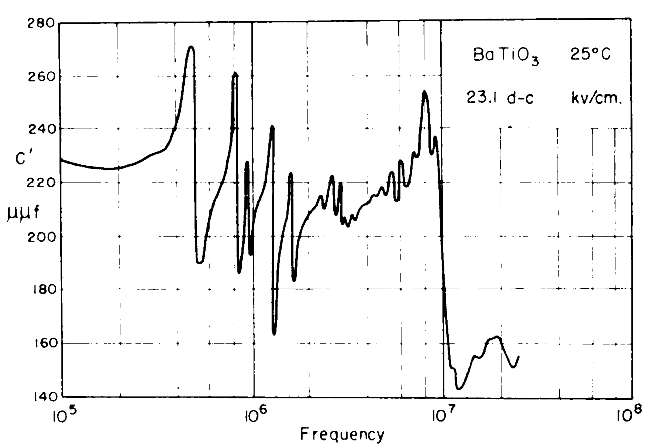

Figure 8. Piezoelectric resonances of barium titanate ceramic

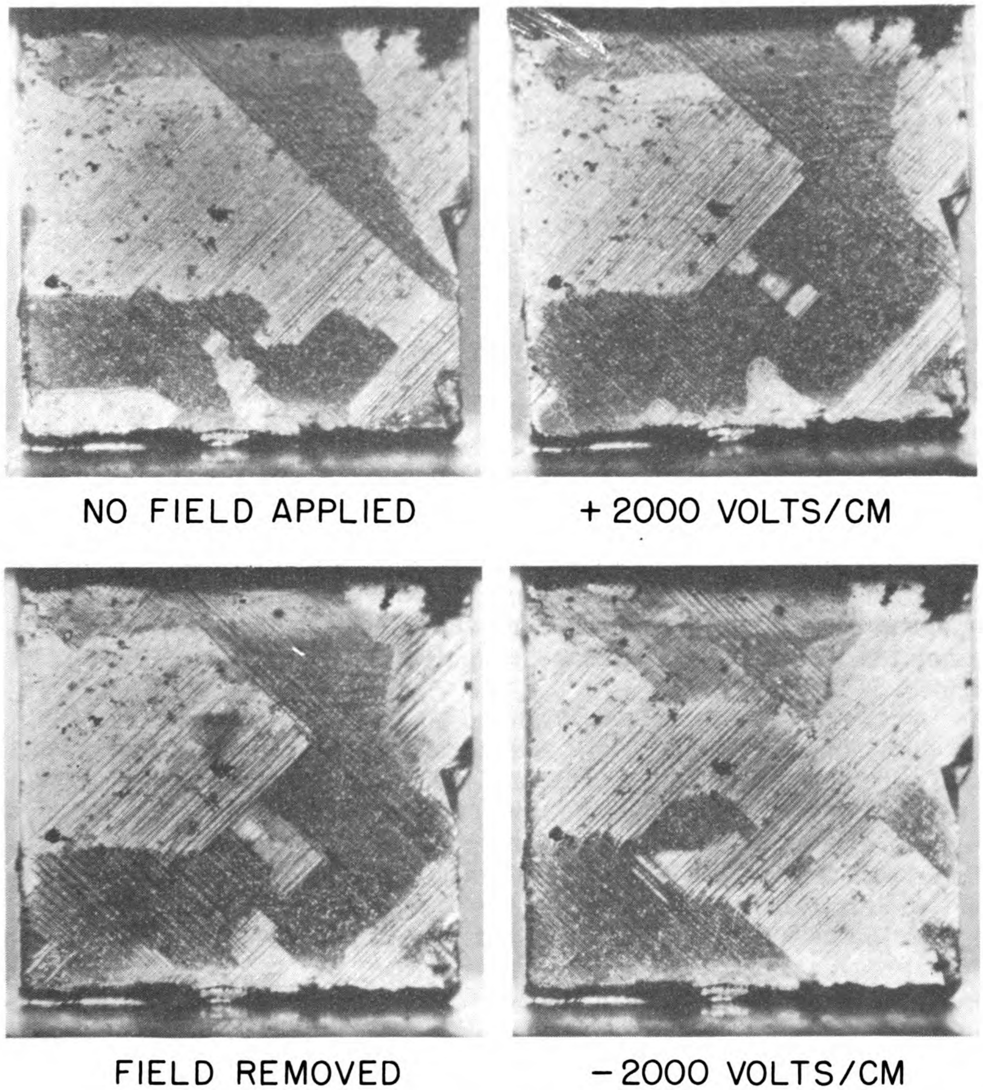

Figure 9. Effect of electric field on domain structure of barium titanate

netic metals. This makes the material not only useful for storage of energy but also as a nonlinear device in amplifiers, modulators, and as tuning elements in electric circuits. We found furthermore, that these ceramics, once polarized, are piezoelectric resonators; they respond to electric fields by mechanical deformations (Figure 8) and generate electric voltages under mechanical distortion. Thus ultrasonic generators, pickups, microphones, accelerometers, delay lines, and many other devices can be based on these materials, a development carried forward after our findings by a number of industrial laboratories.

Studies on single crystals are required instead of the measurements on the multicrystalline ceramics if one wants really to understand the mechanism of ferroelectricity. We therefore learned to grow single crystals and discovered that such crystals below the critical temperature contain a variety of shaded areas (Figure 9). In an electric field these areas were seen to expand or contract, sections of new shading suddenly emerged, and disconnecting of the voltage left a rema-

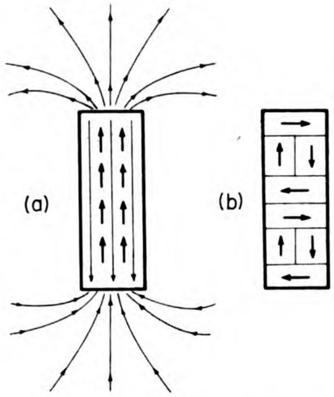

Figure 10. Field surrounding permanent magnet and its removal by domain structure

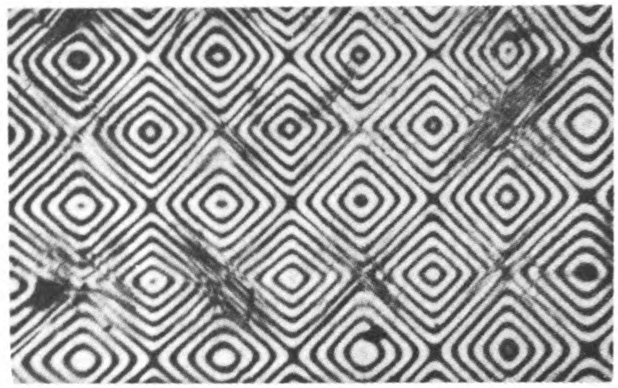

Figure 11. This photograph shows the square-net domain pattern of barium titanate single crystal. Note the beautiful geometric regularity of this pattern.

nent state which required a countervoltage for its removal. Viewed in alternating fields under stroboscopic illumination, the whole crystal appeared in violent agitation, and in polarized light the flickering of the transmitted birefringence colors gave the impression of Broadway at night.

The implications of this spectacular phenomenon become clear when one turns to a ferromagnetic analogue and considers the difference between a permanent magnet and a piece of soft iron. In a steel magnet a strong magnetic field originates from the free north poles of the dipole chains and terminates in the free south poles of the opposite end. A part of this field closes directly through the bar and tends to turn the dipoles in the opposite direction. In magnetically "hard" materials the dipole groups are firmly clamped in place and resist this suicidal tendency, but in "soft" ferromagnetics the array breaks up into microblocks or "domains" which eliminate the external field by mutual compensation (Figure 10). Since the metals are opaque, their domain structure can only be derived indirectly. Our ferroelectric crystals are transparent, and the domain pattern therefore lies visible before our eyes. Such patterns may have a beautiful geometrical regularity, as Figure 11 demonstrates.

Detailed investigations have clarified the ferroelectric mechanism operating in barium titanate, and the material is beginning to play an important role in electrical engineering devices. Other studies may lead: to ferromagnetic insulators or organic "metals," to photocells of higher sensitivity or rectifiers of improved characteristics, to new cables for high-voltage transmission or microwave uses. We do not know yet what will be realized, nor consider it a matter of primary concern at present. Fundamental research thrives best in a detached and unhurried atmosphere, with full freedom to follow targets of opportunity.

* * *

Statistics and Experimental Research

by
W. G. Cochran
The Johns Hopkins University

One striking characteristic of research during the past 20 years is the greatly increased use of statistical methods. This may be noticed both in the changing content of the articles in scientific publications, and in the appearance of a group of new publications (e.g., Econometrica, Psychometrika, Biometrics, Industrial Quality Control, Annals of Mathematical Statistics) that are devoted wholly or partly to developing the application of statistical techniques. The increasing popularity of statistics has led rather naturally to a demand for trained statisticians which considerably exceeds the supply. In 1947, the National Research Council issued a report: "Personnel and training problems created by the recent growth of applied statistics in the United States", with the object of finding ways for increasing the number of trained statisticians.

I shall attempt to describe briefly what the statistician does, and to indicate what the statistical method has to contribute to the experimental research worker.

Statisticians are a heterogeneous group, and it is difficult to give a definition of their work that would be acceptable to a majority of them. Some prominent statisticians are in demand primarily because they have a thorough quantitative knowledge of some applied field in which statistics are produced. Others who carry the title of statistician are essentially clerks experienced in preparing certain kinds of tables or graphs. Others devote their time to solving problems in probability--for example in ballistics and operations research.

For a discussion of the relation of statistics to other branches of science, a definition that is fairly appropriate is given in the National Roster of Scientific and Specialized Personnel:

"The statistician uses inductive reasoning, based on the mathematics of probability, to develop and apply the most effective methods for collecting, tabulating and interpreting quantitative information."

In other words, the statistician specializes in techniques for collecting, tabulating and interpreting data, and in this process he somehow uses the theory of probability. Of these functions, the actual business of collecting and tabulating data has long been specifically associated

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W. G. Cochran received M.A. degrees in mathematics and statistics from Glasgow University and from Cambridge University. In 1939 he came to the United States to accept a position as Professor of Mathematical Statistics at Iowa State College. From 1946 to 1948 he was Associate Director of the Institute of Statistics of the University of North Carolina. He is now Professor of Biostatistics, School of Hygiene and Public Health, The Johns Hopkins University.

with the statistician, as in the case of government officials concerned with basic national data. The intensive study of how to collect data and how to draw conclusions from them is relatively new, and represents the principal content of modern statistical method.

The logical procedure would be to discuss how to collect data before discussing how to draw conclusions from such data. But most scientists make their first acquaintance with statistical techniques because of some problem in the interpretation of their results. A simple example may illustrate the typical problem.

The data come from a series of experiments on remedies for seasickness, reported by Tyler (Amer. Jour. Physiology, June 1, 1946). The men were divided by lot into groups of about equal size, and each group was given a different pill which was supposed to combat seasickness. Thereafter they proceeded to sea in landing craft barges, about 30 men to a barge. Each barge contained equal numbers from each of the experimental groups. Data are shown below for two of the pills, one a medicinal drug, and one a preparation of lactose, which was not thought by the researchers to be of any medicinal value against seasickness. The lactose pill was included, however, because there may be real psychological value in thinking that one has taken a remedy for sickness. Such pills, called placebos, are commonly made a part of clinical experiments. The word placebo is interesting. It is a latin word, meaning literally "I shall please." In medicine it has come to mean a pill or injection given primarily to please the patient, and containing nothing of medicinal value. Hence, in experimental medicine, it is now used for a pill or injection that is inactive medicinally, although the sailors would probably not be in the least pleased if they learned that their seasickness pills were inert.

The results of the tests with the two types of pills are shown below.

	Number of men	Number sick	Percent sick
Placebo	130	36	28
Drug	129	8	6
Total	259	44	17

The results seem to indicate a substantial benefit from the drug. But the cautious scientist may wonder how far the results can be taken at face value. If the trials could be repeated under similar conditions, is there any assurance that the results would be equally favorable to the drug? Possibly the placebo was allotted (just by chance) to a group of men unusually prone to seasickness.

A line of reasoning that helps to settle such doubts is as follows. Let us ask whether we could get results which look as favorable to the drug as those above, if there were really no difference between the effectiveness of the drug and the placebo. Assume for simplicity that in the long run 17 percent of the men would be seasick with either drug, since this is the average percent seasickness found in the trial. Without venturing to sea, we can simulate the situation by putting a large number of dried navy beans into a bag. Each bean represents a man, and 17 percent of the beans are marked S to represent a seasick man. The beans are mixed thoroughly, and we draw repeatedly two samples of about 130 each, one sample corresponding to the placebo and one to the drug. In each sample we note the percent of S's, or seasick men, that turns up.

Sometimes the sample results are definitely in favor of the drug, sometimes definitely in favor of the placebo, and sometimes they indicate that the two perform about equally well. From the samples, we can find out how frequently the results would be as favorable to the drug as those observed in the trial. The frequency is about 1 in 10,000. This means that if the drug had no real superiority, we would be very unlikely to obtain results that appeared as favorable to it. We can therefore conclude with confidence that the trial does indicate a real superiority of the drug. If, on the other hand, the frequency had turned out to be 1 in 2, the trial would not have established the superiority of the drug, since as large a difference in its favor as that observed would occur quite frequently when the drug and placebo were actually equal in effectiveness.

This type of argument, called a test of significance, is a common tool in the statistical method. Since many scientists are forced to draw their conclusions from relatively small amounts of data, a test of significance is helpful in deciding whether the data supply convincing evidence of real differences in the effects of different experimental treatments. In practice, we seldom need to draw actual samples as described above. The odds can be obtained more quickly by the theory of probability.

The same question as to the reliability of data is present when we wish to measure the superiority of one treatment or procedure over another. In the trial, the drug appeared to reduce seasickness from 28 percent to 6 percent, or by about 75 percent. If the trial could be repeated again and again under similar conditions, would the reduction in seasickness in the long run be close to 75 percent? We can get a partial answer to this question by a different kind of probability calculation which is made from the results of the trial. Two limits, called confidence limits, can be found, within which the "long run" or "true" reduction is almost certain to lie. These limits show how closely this has been measured by the experimental data. If the limits turn out to be 65 and 85 percent, the trial has determined the true effectiveness of the drug fairly precisely. If, however, the limits are 40 and 95 percent, we are unable to give an accurate figure for the percent reduction in seasickness, except that we are confident that it is at least 40 percent.

Much of the research in the theory of statistics today deals with attempts to construct tests of significance and confidence limits in more complex situations. This provides an increasing volume of techniques that may be of service to the research worker when he is engaged in drawing conclusions from his data.

As I have mentioned, the intensive study of methods for the collection of data is more recent than study of methods for making inferences from data. In part, this line of development is natural. On examining data that are supposed to supply the answer to some scientific question, it is often found that no clear inferences can be drawn, because some defect existed in the way in which the information was collected. The obvious reaction is to turn one's attention to the process of collecting data, in order to avoid such disappointments in the future.

The most frequent cause of disappointment stems from the fact that the experimental difference in which we are interested has been inextricably mixed up with something else. For example, the seasickness trial could be conducted by giving the drug to all the men on one barge and the placebo to all those on another. But if the two barges differed in their steadiness under a heavy sea, any observed difference in the percent of seasickness might be due to the barges and not to the drugs. Thus, any conclusions about drugs drawn from a trial of this type would be open to criticism.

This difficulty has long been recognized in experimental work. The classical method for coping with it is to make the two procedures that are being compared absolutely alike in everything except in the specific contrast that is under investigation. A good laboratory worker will often take endless pains to ensure that this is so.

Modern statistical ideas are in sympathy with this approach, though with qualifications. Actually it is often impossible to make two experimental procedures absolutely alike except in one respect. For example, there seems to be no way of selecting two groups of men who would be exactly alike in their propensities for becoming seasick when exposed to a given amount of oscillation. There are also many situations where it is too expensive, though feasible, to standardize all the conditions of the experiment. Thus, the statistician, instead of recommending that conditions be made exactly alike, is inclined to present a weaker recommendation: namely, to make conditions as alike as seems justifiable in view of the money and labor required to do so.

When conditions cannot be standardized, careful planning of the experiment may nullify disturbing effects that might otherwise be present. Suppose we have four different machines that perform the same operation. We wish to compare the machines, perhaps in the quality of product or in the speed with which they do their job. Each machine is hand-operated, and there are differences in the skills of the operators. An obvious step is to make each operator perform the same task on each machine in turn. This ensures that a comparison of the merits of the machines is not confused with differences in the abilities of the operators. It may happen, however, that the order in which the machines are used will influence the results, perhaps because the task is relatively unfamiliar to the operator but becomes familiar with repetition on successive machines. If so, the machine on which the operator works first is handicapped, and that which he uses last is favored.

The best way of dealing with this source of bias depends on the circumstances. The following diagram, which gives instructions to the operators, illustrates one method.

		Operator			
		1	2	3	4
Order in which	1	D	A	C	B
machines are	2	C	D	B	A
used	3	B	C	A	D
	4	A	B	D	C

The letters A, B, C, D stand for the four machines. Operator 1 works machine D first, then C, B and A in succession. The basic feature of the diagram is that every machine is the first to be used on one occasion, the second on another, the third on another and the last on another. For this reason, any average effect of the learning process automatically cancels out when we compare the four machines, as well as any consistent difference in the skills of the operators.

A diagram of this type is called a latin square. Its characteristic property is that every letter occurs just once in each row and column of the square. During recent years, there has been intensive study of ingenious arrangements of this type which can be used to advantage in the planning of experiments. One merit of such arrangements is that their use often entails no extra trouble or expense.

A plan of this type, however, does not completely remove the personal factor from the comparison. Any operator may be subject to unpredictable variations in his skill. Some operators may learn the task more quickly than others, and perhaps show no improvement with the later machines. Consequently, there always remains some uncontrolled variation that favors some machines.

With respect to this residual variation, the best that we can do is to allot it fairly among the different experimental treatments, in the hope that it will not continuously favor one treatment at the expense of another. One useful device is known as randomization. We make certain decisions in the experiment by tossing a coin or drawing numbers from a hat. In the seasickness trial, randomization was applied when assigning the men to the drugs. Cards of different colors were distributed to the men from a well-mixed deck, the color of the card determining the pill to be taken. The method gives the two pills an equal chance of reaching any men who are particularly subject to sickness. It appeals to one's sense of fairness. Some research workers feel uncomfortable about randomization, on the grounds that it seems unscientific, if not undignified, to plan very carefully the major part of an experiment, and then deliberately leave other steps to be decided by the toss of a coin. But there is actually no inconsistency in the proper use of randomization. It is intended to deal only with the residuum of variation that remains to affect our results after the resources of careful planning have been exhausted.

The relation of the statistician to experimental research is peculiar, in that he often gives quite detailed advice about the conduct of an experiment, although he may know little about the line of research of which the experiment forms a part, and may never do any experiments himself. Undoubtedly, much of the benefit which an experimenter derives from discussion with a statistician comes just from the discipline of having to expose one's plans to the criticism of someone who can look at the issues afresh. It is to be expected that the statistical point of view in experimental design will gradually become a commonplace among experimenters. Indeed, there are signs that this is happening. One of the real pleasures in statistical consulting is to observe how quickly an experimenter becomes mature statistically, making very ingenious use of a few statistical notions, and becoming independent of the need for statistical advice. The only annoying feature of this process is that the few problems which he continues to bring get harder and harder!

Membrane Permeability to CO_2

by
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University of North Carolina

Radioactive isotopes are proving extremely useful in investigating a question that is of fundamental importance in the storage processes of living plant tissue. In particular, what we are trying to discover is the extent to which gaseous carbon dioxide permeates the outer skin (epidermis) of leaves.

For a long time it was thought that the exchange of gases between the internal tissue of leaves and the atmosphere depended entirely on the stomates. These are small orifices on the surfaces of leaves, which open in the light and close in the dark; they are also affected indirectly by any change in the environment that influences the water content of the plant. The exact mechanism of activity of the stomates is not completely understood, but it was believed that their closure largely prevented exchange of carbon dioxide between the leaf and the atmosphere.

Yet findings by certain investigators seemed to indicate that this idea was not completely correct. Mitchell's studies (1), for example, did not confirm it. It was known that wilted leaves had their stomates closed, and under this condition, gas exchange presumably would be limited to direct epidermal penetration or would not occur at all. Mitchell, however, reported that although stomates on leaves of Cineraria apparently were closed before wilting occurred, a rapid drop in carbon dioxide absorption was obtained only after the onset of visible wilting. Furthermore, when low relative humidity caused the stomates to close, the amount of carbon dioxide fixed under this condition was 70 percent of the amount fixed in plants with the stomates open. Later Schneider and Childers (2), in a study of the influence of soil moisture on photosynthesis, several times found high rates of photosynthesis when the stomates appeared to be completely closed. Verduin and Loomis (3), in studying carbon dioxide absorption by corn, found that wilted plants absorbed less carbon dioxide than turgid plants, but the decrease in carbon dioxide absorption was not proportional to the decrease in stomate size as measured by a porometer. Freeland (4) discovered that in plants with stomates on only one side of their leaves, considerable variation occurred with respect to the absorption of carbon dioxide through the epidermal cells during photosynthesis. In all cases, the rate of apparent photosynthesis through the stomatal epidermis was greater than through the non-stomatal side. In certain plants the amount of carbon dioxide exchanged through epidermal cells alone was some-

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W. M. Dugger, Jr. received his B. S. from the University of Georgia in 1941 and an M. S. from the University of Wisconsin the following year. After serving in the Army from 1942 to 1946 he became a graduate assistant in the School of Agriculture and Forestry of North Carolina State College, where he is now working on an ONR-sponsored project under the direction of Dr. D. B. Anderson.

times about equal to the amount diffused through the stomates. In other plants of this group--particularly those with a thick cuticle--little or no apparent photosynthesis could be detected through that part of the epidermis possessing no stomates.

These investigations and others have presented evidence that epidermal walls are more permeable to carbon dioxide than had been generally assumed, but previous methods have not measured direct penetration through epidermal membranes. A way to make such a measurement is now offered by radioactive isotopes: radioactive carbon dioxide is passed over non-stomated leaf surface for a definite period of

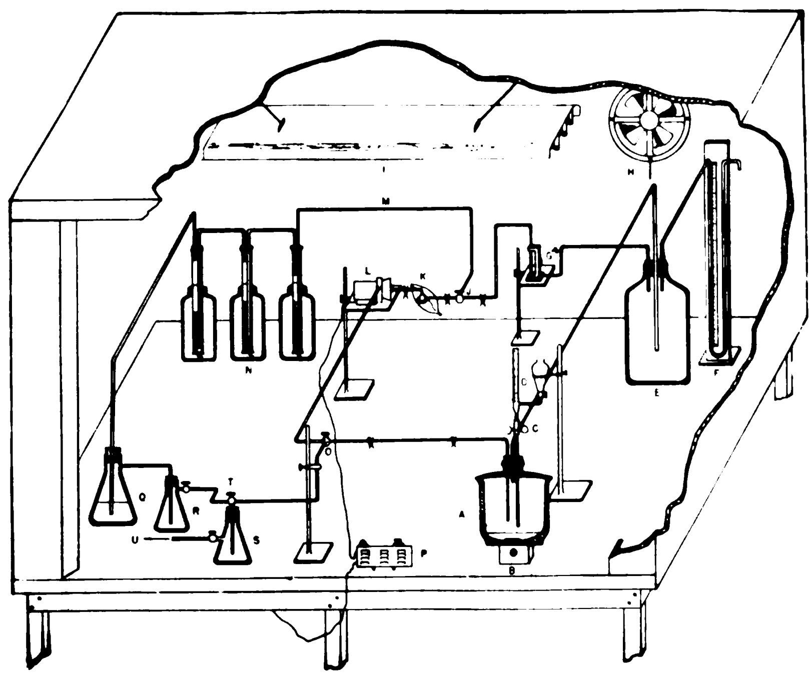

Figure 1. Gas flow system

time and direct penetration of the gas through the epidermis is measured by the use of a Geiger counter and radioautographs.

This method is a modification of the well-known gas flow and carbon dioxide absorption technique employed in measuring apparent photosynthesis. A weighed amount of $BaCO_3$, $BaC^{14}O_3$ and a known volume of water are placed in the large dessicator, indicated by (A) in Figure 1. The exact amount of $BaCO_3$ necessary is calculated from the known volume of the system, from the reaction, $3BaCO_3 + 2H_3PO_4 \longrightarrow Ba_3(PO_4)_2 + 3CO_2 + 3H_2O$, and from the percentage of carbon dioxide desired in the system. After the system from stopcock (O) to stopcock (J) has been evacuated to the desired level, as measured by manometer (F) phosphoric acid is added through burette (D) with clamp (C) controlling the flow. When the acid comes into contact with the barium carbonate, evolution of carbon dioxide occurs - a reaction hastened by the magnetic stirrer (B). Within less than 30 seconds the manometer arms are level, indicating that the total pressure inside the system is equal to atmospheric pressure. The leaf cup (K) and fan (L), which were ex-

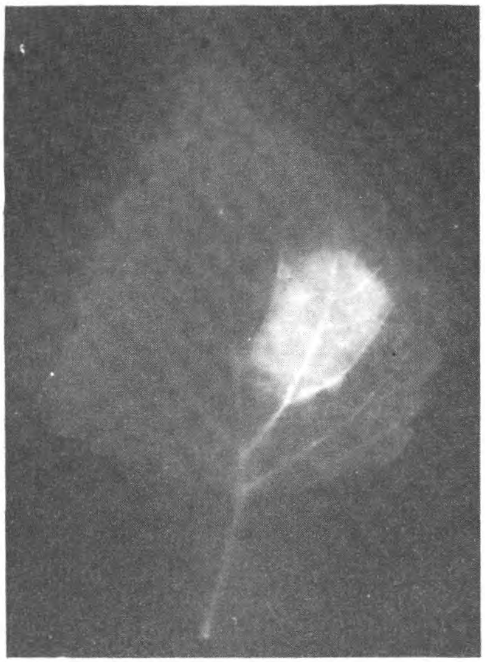

Figure 2. Flat radioautograph of coleus leaf after four-hour exposure of $C^{14}O_2$ to upper epidermis

cluded from the initial evacuation to prevent injury to the leaf, are cut into the system at this point by manipulation of stopcock (J). After the system from the fan (L) to the reaction chamber (A) has been made continuous by manipulation of stopcock (O), the fan is started in order to circulate the gas across the leaf. The rate of gas flow, measured by the Fisher Poter "C-Clamp florator" (G) in the line, is controlled by adjusting the speed of the fan through transformer (P) and a voltage regulator. The large bottle (E) is to add volume to the system. The plant is illuminated by three 40-watt fluorescent tubes (I) in the top of the hood. These provide maximum illumination at leaf level of 260 foot candles, as measured by a Western Illuminator meter. With the leaf chamber in place this illumination is reduced to 200 foot candles. Of course the hood can be made dark when absorption studies in darkness are being made.

At the end of the determination, the gases within the system are pumped through NaOH absorption towers (N) via stopcock (J) and tube (M) where the radioactive carbon is removed. In line with the absorption towers is a $Ba(OH)_2$ check flask (Q), a trap (R), and a drying flask (S). During the absorption process the hood can be placed under a slight negative pressure by fan (H), to prevent any unabsorbed radioactive carbon dioxide from remaining in the hood or from getting into the room. Monitoring at all times during absorption is obtained by a portable thin-window survey meter.

At the end of the experiment the leaf and leaf cup are removed from the plant and system and the area under the cup is cut out with a cork borer of the same diameter as the cup. The leaf surface which was exposed to the $C^{14}O_2$ is washed with .1N H_3PO_4 and water to remove any CO_2 adsorbed on the epidermis. Then this leaf disk is dried between filter pads at 80°C and the activity is determined by a thin-window Geiger tube and laboratory scaling unit. Other disks from the exposed leaf are removed, dried, and the activity determined. A sample from the opposite leaf is removed and treated the same way.

For gross radioautographs the treated leaf is removed from the leaf chamber, dried in a photographic press at 80°C and placed in contact with a no-screen X-ray film. At the end of the exposure time the film is developed and fixed.

Preliminary results from studies made on coleus and hydrangea leaves show that penetration through non-stomated surfaces of leaves does occur, and to a much greater extent in the light than in the dark.

TABLE I. Absorption of CO_2 by Leaf Tissue as Measured by the Activity of Leaf Sections Treated with 10% CO_2, $C^{14}O_2$ for 4 Hours.

Plant	Epidermis treated	Activity (counts per second)					
		Upper and lower epidermis	Epidermis treated	Untreated section of leaf	Check leaf	Background	Light or dark
Coleus	upper	1.07	15	.44	.27	.25	light
	"	1.09	36	.90	.83	.23	"
	"	1.00	8	.32	.51	.23	"
	"	.88	21	.30	.47	.23	"
	"	.97	0.36	.30	.42	.23	dark
	"	1.06	0.33	.24	.26	.23	"
	lower	1.85	6	.32	.32	.23	light
	"	1.11	57	.48	.24	.23	"
	"	1.00	21	.42	.23	.23	"
	"	1.02	44	.28	.30	.23	"
	"	.98	0.37	.23	.38	.23	dark
	"	1.03	0.30	.25	.25	.23	"
Hydrangea	upper	1.16	7	.53	.32	.26	light
	"	1.25	5	.47	.31	.26	"
	"	.98	1	.29	.28	.26	"
	"	1.05	7	.26	.24	.24	"
	"	1.15	2	.29	.34	.24	"
	"	1.11	3	.21	.24	.24	"

Figure 2 shows a flat radioautograph of a coleus leaf after four hours exposure of $C^{14}O_2$ to the upper epidermis. The area where the cup was sealed is indicated by the bright spot. The vein system of the lower part of the leaf is well outlined also, indicating that some translocation of $C^{14}O_2$ does occur out of the leaf. But the autograph indicates that the majority of the CO_2 is fixed, in place, into some intermediate compound shortly after entering the leaf. When X-ray film was exposed to a leaf which had been similarly treated in the dark no pattern of activity could be seen. Counting data, as shown in Table I, substantiates this.

Table I also indicates that the amount of diffusion occurring through the upper epidermis (having few if any stomates) is a large fraction of that occurring through the lower epidermis (having numerous stomates)--additional evidence to substantiate the idea that photosynthesis does occur when the stomates are closed.

This work is part of a more comprehensive investigation of the permeability of epidermal membranes to gaseous carbon dioxide. In addition to the leaf study described here experiments will be conducted using five and one percent CO_2 atmospheres. In another test radioactive carbon dioxide will be bubbled through culture solutions in which roots of several species of plants are growing. The penetration of the gas will be determined by testing sections of roots with Geiger counters and by the use of a histological photographic technique. In addition, fruits of certain plants will be exposed to radioactive carbon dioxide in sealed containers for short periods of time and sections tested, again by means of a Geiger counter. It is hoped that such studies will contribute to our understanding of the fundamental processes of plant life.

REFERENCES

1. Mitchell, J. W., Bot. Gaz. 98: 87-104, 1936
2. Schneider and Childers, Plant Physiol. 16: 565-583, 1941
3. Verduin, J. and Loomis, W. E., Plant Physiol. 19: 278-293, 1944
4. Freeland, R. O., Plant Physiol. 23: 595-600, 1948

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Putting the Sun to Work

by
William M. Conn
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For some time high-temperature studies have been an important tool in the investigation of various problems of pure and applied research. One instrument that has been very effective in such work is the recently developed solar furnace, which, by using the radiant energy of the sun, is able to effect high temperatures in a small area. The solar furnace has proved useful in many instances and some of these are of importance to the ONR program of research on heat-resistant materials. The solar furnace is particularly effective for studies of refractory substances--for instance, in determining their melting points; in discovering the high-temperature crystalline modifications of such compounds; and in preparing and studying possible glass forms of refractory oxides. Of course the furnace has many other uses. For example, it is being employed in an attempt to extend the internationally accepted temperature scale and in the development of new materials able to withstand very high temperatures under various conditions.

The way the furnace works can be explained rather simply. Radiant energy from the sun falls on a parabolic mirror which concentrates it in a sample placed near the focal area of the mirror. The amount of energy that can be used increases with the size of the mirror; the size of the image and the area of heating increase as the focal length is extended. If the sample melts, the liquid drops into a crucible with a refractory lining, which is preferably of the same material as the sample tested. The device which holds the sample permits it to be moved in all directions, so that new parts of a melting substance can be constantly brought into the focal area. Powdered material can be poured continuously into the region of extreme temperature.

The advantages which the furnace offers the researcher are many. Substances can be heated under very pure conditions and with great speed--for example, a temperature of $3,000^{o}$ C is reached in 10 seconds. Yet cooling is also quick. Moreover, a variety of experimental conditions is available. Not only can the researcher heat material in an oxidizing atmosphere, but, by placing a quartz-glass container over the sample, he can work in a reducing or neutral atmosphere or in a vacuum. Finally, large electric or magnetic fields are not present to disturb reactions or spectra being studied.

Of course the furnace also has some drawbacks. The small area of heating provided is one limitation. Another is the fact that unfavorable weather conditions hinder or prevent use of the furnace. Temperatures up to $3,000^{o}$ C may be obtained even if the day is slightly

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hazy but greater heats than this require a clear atmosphere. Cumulus clouds or a considerable overcast preclude the use of the furnace.

The largest mirror which we have is an aluminum one, 120 inches in diameter; this size was originally computed for obtaining an area of maximum temperature of about 4" to 5" in diameter, because the work contemplated required a comparatively large area heated to medium high temperatures (1000 - 2000^{o} C), rather than a very small area held at extreme temperatures. Upon entering into Contract N8-onr-69700 in the fall of 1948, several changes in the furnace became necessary in order to carry out research in the fields of interest to ONR. The most important considerations in this connection were that: (1) specimens should be exposed to the highest possible temperatures; and (2) exposures should be extended over a considerable length of time.

The cover shows a photograph of the furnace which uses the 120-inch mirror. Since it was originally designed for use in Flint, Michigan, the furnace had to be adapted to the latitude of Rockhurst College. The mirror is mounted on a polar axis which is parallel to the axis about which the earth rotates. The polar axis mounting consists of a heavy steel oval ring supported on trunnions at either end of its major axis around which it can be rotated. Inside the oval ring a circular ring 123 inches in diameter is mounted, which actually supports the mirror. To adjust the mirror in declination, ring and mirror can be rotated about the minor axis of the oval ring by means of trunnions fastened to it.

The polar axis is rotated by means of a rigid lever clamped to its lower end. The other end of this lever is equipped with a trolley. It is connected by a cable, guided in a circular track, with an astronomical driving clock (controller). This clock, by means of a fly-ball governor, controls the downward rate of travel of the trolley and lever, and through them, the rotation of the polar axis turns the mirror so it tracks the sun along its path in the sky. The length of the track permits continuous experiments of more than two hours without need for resetting the lever.

A considerable amount of work has been spent to produce an accurate, well-defined paraboloidal surface of aluminum with an aperture of 120 inches and a focal length of 34 inches. The method developed is deemed applicable to the construction of even larger metallic mirrors for future work, and no limitations in size seem apparent at this time. The size of the image of the sun obtained here is 3/8" in diameter.

An adjustable bridge (clearly shown in the cover photo) is mounted above the reflector. It allows the sample under test to be moved in and out of the focal area by remote control. Another adjustable bridge under the reflector is provided for mounting an auxiliary mirror (plane or corrected hyperbolic) or for supporting the crucible.

We also have a 60-inch searchlight metallic mirror in operation which serves for preliminary work. In addition we are planning to set up two glass mirrors of 61-inch diameter which were brought here from a bombed-out laboratory in the French Zone of occupation in Germany through the efforts of the Office of Naval Research.

The actual procedure employed in a heating test in a sun furnace is as follows. First a satisfactory sample of the substance we want to melt must be prepared. Suitable dimensions are, for example, 1/4" x 1/4" x 4" or 3/8" diameter x 4" length. Samples may be cut from bricks or minerals by means of abrasive wheels or a diamond saw, or they may be produced by casting, molding or extrusion in the plastic form.

The sample is placed in the sample holder of the furnace near the focal area. Then the mirror is adjusted in declination, with the lever arm of the polar axis in its highest position. The controller is started, the final adjustment of the mirror relative to the sun is made (by means of a sighting device and a telescope), and the sample is brought into the focal area. The rate of heating is controlled by adjusting, by means of shutters or shades, the area of the mirror receiving radiation from the sun. Temperatures are measured with an optical pyrometer which is calibrated to read temperatures up to 6000° C.

An experiment with a sun furnace is an impressive spectacle. When the sample (perhaps a fire brick melting at 4000° F) is brought into the focal area it suddenly becomes white hot and starts to radiate like a miniature sun. Within a short time it begins to boil like butter on a griddle, vapor develops, and finally a drop of liquid forms and falls into the crucible. While this is happening, great care must be exercised to protect the eyes of the observer and to remove poisonous products obtained in heating certain samples.

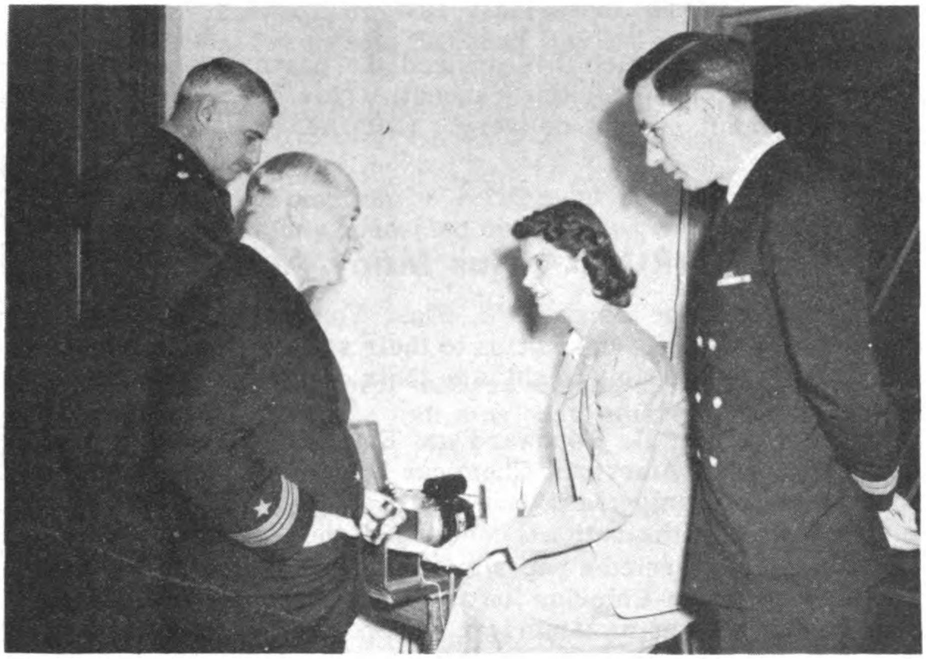
All our experiments so far have been carried out in an oxidizing atmosphere. We have been able to melt, by solar energy, all solid materials which can be heated in air, including the so-called super-refractories, porcelain, and oxides including zirconia. We have produced many glasses and well-developed crystals of exceptional hardness. In addition, X-ray diffraction tests and physical tests have been carried out in order to study materials which can withstand very high temperatures. We are now installing the attachment described previously (p. 16), which will permit the heating of samples in a neutral atmosphere, in vacuum, or at pressures of more than 1 atmosphere.

How high a temperature can one reach in a sun furnace? Final limitations of the furnace are undetermined, since we do not have sufficient knowledge about the sun. We do know that the sun is not radiating as a black body, but we are ignorant of the depth from which radiation reaches us. Much work, of course, still lies before us, and we hope that such research will aid in solving some of the unanswered questions in this interesting field.

* * *

On the Naval Research Reserve

VRRU 1-3 Tours Mt. Holyoke Project



VRRU 1-3, University of Massachusetts, recently toured the Navy's special devices psychophysical research project at Mount Holyoke College in South Hadley, Mass. The tour was made jointly with the University's Army Research Reserve unit. Shown above are Lt. Col. Carl R. Fellers, Commanding Officer of the Army Research Reserve unit; LCDR Edward D. Emerson, USNR, Commanding Officer of VRRU 1-3; Miss Eleanor Reed, research associate with the Navy project; and LT Robert S. Burpo, Jr., USNR, executive officer of VRRU 1-3.

Sales to Naval Reserve (Inactive)

"Officers and enlisted men of the Naval Reserve (inactive) may purchase items of clothing and small stores for cash while performing training duty under orders issued by competent naval authority. Such purchases are subject to the same restrictions as those by regular personnel. Officers and enlisted men of the Naval Reserve who are in a drill pay status or who are members of an authorized drilling organization may purchase items of clothing and small stores when the commanding officer of the Reserve unit considers the purchase necessary. Purchases may be made from any clothing and small stores issuing activity when authorized by letter request signed by the commanding officer of the Reserve unit. If purchased by mail, postal money order for the exact amount of the items should be mailed with the letter request. When the package is ready for mailing by the issuing activity, stamps from the official stamp account (for parcel post shipment) of the station will be affixed to the package to cover the postage cost, plus the post office C.O.D. fee to cover cost of handling. When the post office remits the amount of the C.O.D. (postage plus fee) to the activity which mailed the package, the value will be taken up in official funds to the credit of the appropriation, Transportation of Things, Navy. Purchases may be made for cash upon presentation of the letter request to any clothing and small stores issue room." (Article 42306 (6), BuSandA Manual.)

The address to which it is desired the package be mailed should be clearly stated in the letter request. This address should be one which will permit prompt delivery. (NRMAL No. 14-50 dtd 7 April 1950.)

VRRU 6-4 Has Many Authors

Members of the Gainesville, Fla., Volunteer Research Reserve Unit are busy people. In addition to their work on three Navy projects members of 6-4 find time to shine in their own fields.

In February R. B. Woodward and E. G. Kovach were in print in the Journal of the American Chemical Society with an article on "The Structure of the Santonides." In March Commanding Officer E. G. Rietz travelled to the national meeting of the American Chemical Society where he presented a paper on the topic, "A New Method of Analysis of Mercuric Ion-Chloride Ion and Mercuric Ion-Bromide Ion Mixtures." In April at an American Medical Association meeting in Gainesville Alvin J. Owens presented a paper entitled, "Effect of a Rigid Elliptic Disc on the Stress Distribution in an Orthotropic Plate."

Correspondence Courses

The following questions and answers add more information to that given in the June issue on correspondence courses.

Q. How many courses may I enroll in at one time?

A. Only one, in most cases. In certain cases, however, individual permission may be granted for enrollment in two courses if the enrollee's circumstances justify it.

Q. What is the minimum grade acceptable to the Naval Correspondence Course Center before a Reservist is granted promotion or retirement credit for satisfactory completion of a correspondence course?

A. An average of 3.4 for the entire course.

Q. If my average grade for a course is less than 3.4, will I get any credit for the course?

A. No, and no completion letter will be issued by the Center.

Q. If I fail to complete a course, will I receive credit for the portion I completed?

A. No. You will receive neither promotion nor retirement credit.

Q. If I am disenrolled, will a notice of the disenrollment be placed in my official records in BuPers?

A. No. Disenrollment notices are no longer sent to BuPers.

Q. Is Reserve promotion or retirement credit granted for completion of courses of study conducted by non-Government agencies?

A. No.

Q. If I earn 100 Reserve retirement points in one year, may I apply 50 of these points to the following year, thereby making it also a year of satisfactory Federal service?

A. No. Points must be earned in the year to which they are credited.

Q. Under BuPers Circular Letter No. 33-50, USNR alphabetical classifications have been changed to numerical designators. How will this affect the correspondence-course promotion requirements for Reserve officers as set forth in NavPers 10840?

A. Pending announcement of a long-range promotion plan, the change of designators will not affect promotion requirements. Officers will be required to complete the courses appropriate to the classifications they held prior to the conversion to numerical designators. The long-range promotion plan will insure that correspondence-course work taken in accordance with NavPers 10840 will receive appropriate credit.

Q. Can SL Reserve officers (now designated 1625) receive promotion credit for any other correspondence courses than those listed in NavPers 10840, many of which are not yet available?

A. Yes. SL and WL officers may earn specialty promotion units, in the amounts prescribed in NavPers 10840, for the following courses: Military Law, NavPers 10716; International Law, Regular Course (War College) or NavPers 10717 (but not both); International Law, Advanced Course (War College).

Q. Can SE or SE1 through SE4 officers (now designated 1405) receive promotion credit for any other correspondence courses in addition to those listed in NavPers 10840, many of which are not yet available?

A. Yes. Officers so classified may substitute any other engineering course as a specialty course for promotion credit.

Q. Are Reserve promotion and retirement credits granted for Army or Air Force correspondence or extension courses?

A. Retirement credit, yes, in the amount prescribed by the administering service, if the officer completes the course to the satisfaction of that service. Promotion credit, no, as no Army or Air Force courses have been specifically approved for that purpose.

Q. My Reserve classification was DE (now 1105). To earn promotion credit, should I take the correspondence courses prescribed in NavPers 10840 for D classification, or for E classification?

A. Select either one and qualify in that one classification. Reservists with multiple classifications are not required to qualify in all. However, don't confuse this multiple classification with the R, X, N, and T designators, which are covered specifically in NavPers 10840.

Seminars Deferred

Because of the present international situation, all the seminars that were scheduled for the first quarter of the fiscal year 1951 have been deferred. Any further changes in plans will be announced in future issues of Research Reviews.

"A busy time was had by all" seems to be the theme of reservist's version of the 3rd ONR seminar held 7-20 June 1950. The cartoon was drawn "in appreciation of a most informative training duty tour" by LCDR Viktor Schreckengost (USNR) Commanding Officer of VRRU 4-8, Cleveland, Ohio. LCDR Schreckengost, who is Head of the Department of Industrial Design at the Cleveland School of art, is widely known in many artistic fields. His work has been exhibited at the New York, Paris and San Francisco World's Fairs and his ceramic designs have appeared in the Encyclopedia Britannica. During World War II he was head of the Visual Design Section of the Special Devices center.

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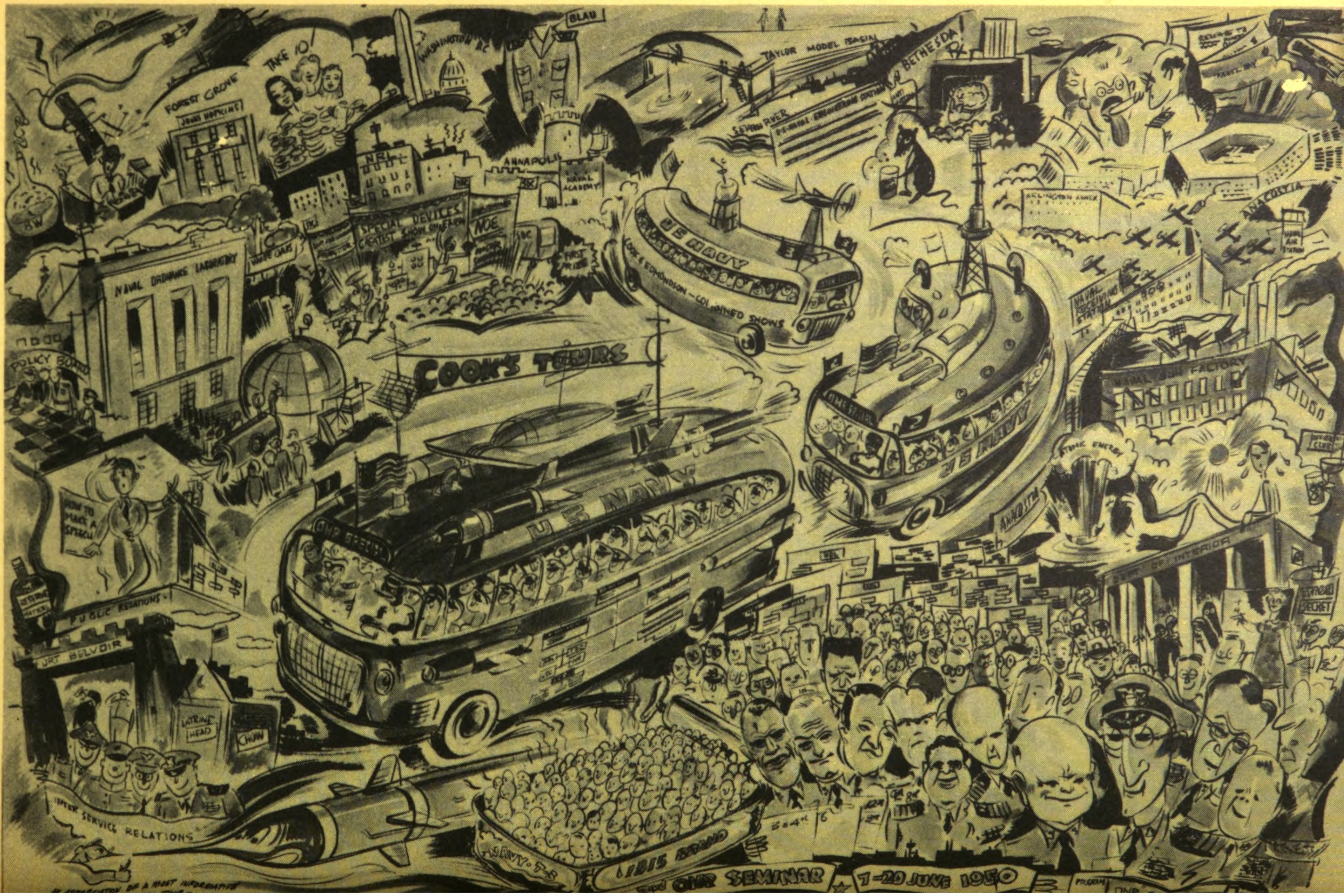
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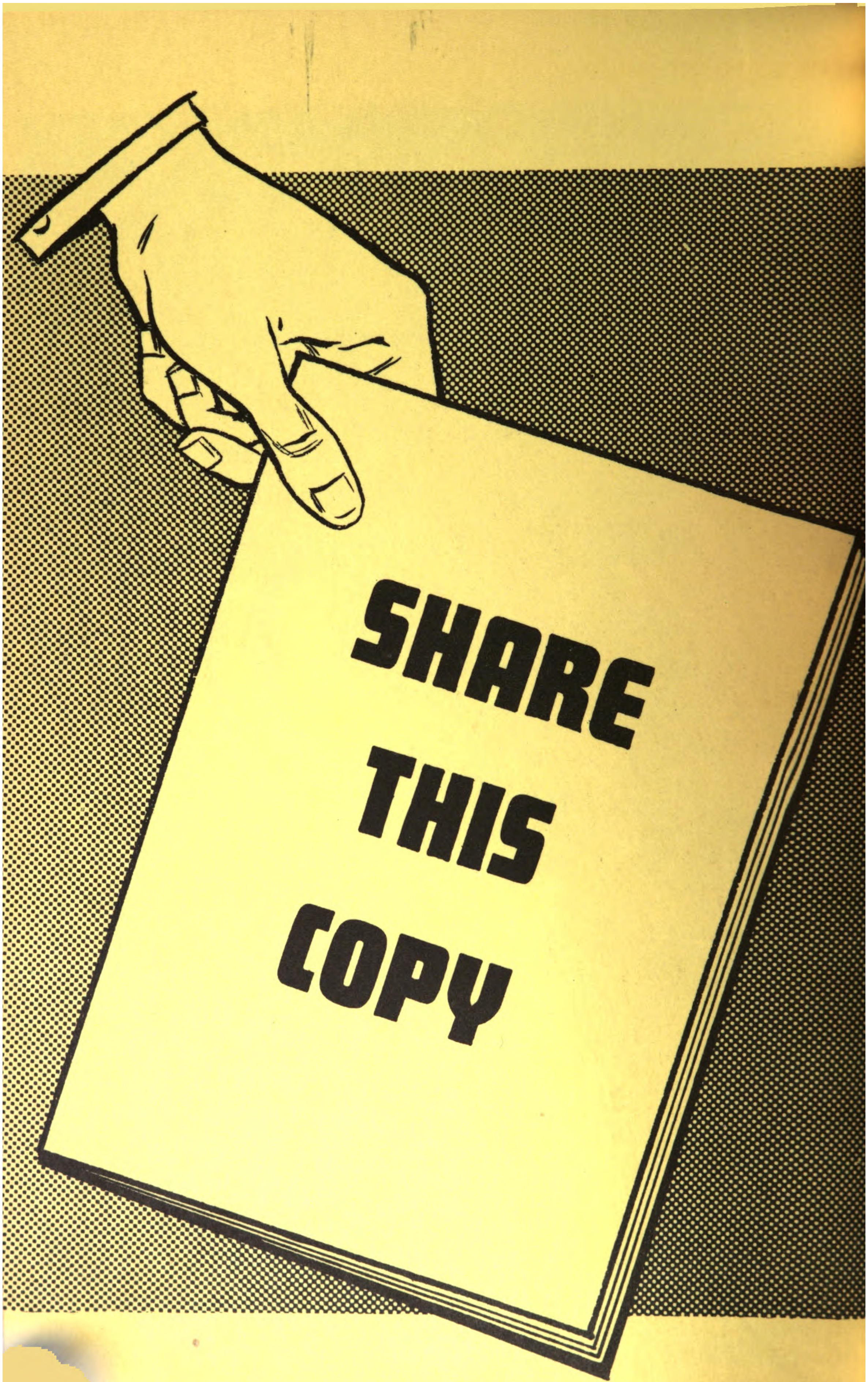
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