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RESEARCH REVIEWS

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WASHINGTON, D. C.

COVER PHOTO: This sailor, trying to get his 40-mm gun on-target during "general quarters", faces some complex problems of two-hand coordination. Similar difficulties are faced by radar operators and others who have to turn various knobs and cranks with swiftness and precision under emergency conditions. Since the Navy wants to make sure its equipment is set up for the maximum efficiency of operation, the Special Devices Center, through the University of Rochester, has undertaken a project to find the factors which make two-handed coordination easier. Some of the things they have found out are described in "Engineering for Better Marksmanship", by Roy L. Pepperburg, pp. 9 to 12.

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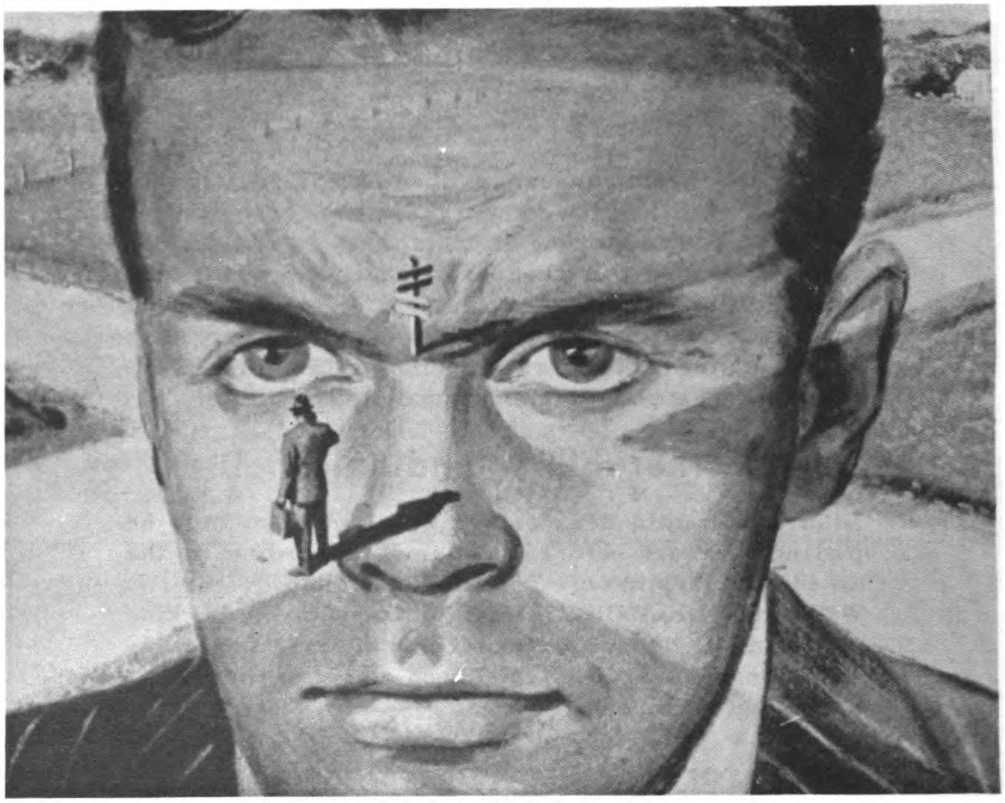

Two photographs typical of those used in projective tests. **Picture at** top is reproduced through the courtesy of the Alexander Hamilton **Institute.** Picture below is reproduced through the courtesy of the **John** Hancock Life Insurance Company.

What's in a Picture?

by

Henry H. Morgan
Wesleyan University

"Look at the two pictures on the opposite page. Try to imagine what is going on in each picture. Imagine what led up to the situation, what the people are thinking and feeling, and what they will do. In other words, make up a short story."

What you see here are sample pictures and partial instructions for a new psychological test being developed under the sponsorship of ONR and the Bureau of Naval Personnel. This test, entitled "Picture Interpretations," is one of a number of so-called "projective" tests being used more and more in various kinds of psychological work today. In any "projective" test you are asked to look at something rather vague or ambiguous and then to say something about it. In doing this you "project" or cast something of yourself into your statements.

In such interpretations you will find that whatever stories you create will differ from those that anyone else creates. Since each person relates a story uniquely his own, his story will tell something about himself as well as something about the picture that he sees. In "projective" tests the things that you look at may be pictures like those shown, or they may be ink blots, or words, or cartoons with dialogue to be completed. Many kinds of items have been used in projective tests, but all items have in common an ambiguity which offers a chance for many varied interpretations.

The job of making psychological sense out of such interpretations is a difficult one for the psychologist. Using his background in personality theory, he can make pretty good sense out of many statements, but there is always a danger that he will "project" himself into the statements he makes about other people's statements. For this reason, the psychologist experiments with projective tests to be sure that his analyses of them are correct. In these experiments a person's behavior in some situation is predicted on the basis of the test scores, and the psychologist then checks to see if his predictions are correct. In other words, the psychologist must do more than the tea-leaf reader, the palmist, or the astrologer. Anyone can make predictions about human behavior, and most people do so freely. But the soothsayer seldom checks the accuracy of his predictions and seldom makes the predictions under controlled experimental conditions.

A number of such experiments, aimed at finding out why people gave certain responses on projective tests, have been largely responsible for the development of "Picture Interpretations." Dr. David C. McClelland, Dr. Russell A. Clark, Dr. John W. Atkinson, and others

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Henry H. Morgan received his Ph.D. in psychology from the University of Minnesota in 1951 and is currently working on an ONR contract at Wesleyan University. Previously he served with the Air Force as a Link Trainer Instructor and as a Fighter Control Officer.

working at Wesleyan University began their experiments in order to discover how motivational states or "drives" influence the statements made. By varying experimentally the attitudes of men taking the test they found that temporary motivational states were reflected in the stories written. One of their interesting findings, for example, was that very hungry men wrote stories that differed significantly from stories written by men who were not in a state of hunger. Other experiments revealed story differences between men strongly influenced by various social or learned motives. These changes in motivational states were registered objectively by systematically analyzing the stories to secure scores for all men.

An interesting fact developed when some of the story analysis techniques were applied to new groups of men: It was found that men with higher scores on the stories tended to work harder on standard laboratory tasks. Although the initial interest in these psychological experiments was purely theoretical, these findings were thought to have practical applications. For this reason work was started to create a standardized psychological test known as "Picture Interpretations" which might be useful in identifying men who are hard workers.

"Picture Interpretations" began as a short version of a picture-story test developed by Dr. Henry A. Murray of Harvard whose test, called the "Thematic Apperception Test" or TAT, has been widely used as a diagnostic tool by clinical psychologists. Dr. McClelland and his associates were interested in certain kinds of information that were obtainable from Murray's TAT and so adapted Murray's technique to fit their experimental design. The resulting test, "Picture Interpretations," uses fewer pictures than the TAT and uses only those carefully selected to yield specific kinds of information of importance in predicting a man's performance on a job or task. A scoring system was devised which makes it possible for any trained story-reader to compute story scores which are approximately the same as those computed by another trained reader.

Using this scoring system, a number of psychologists have used "Picture Interpretations" in experiments where scores were related to school grades. The evidence obtained confirmed the belief that "Picture Interpretations" may help separate the busy bees from the drones. In one study, for example, a group of honor students in college were found to write stories yielding significantly higher scores than a group of students of equal intellectual ability who were doing average college work.

In the current test development work, "Picture Interpretations" is administered to small groups of men who view the pictures projected upon a screen in a darkened room. After viewing a picture for a few moments, the men have a brief period in which to write their stories. Usually, a total of 12 pictures are shown, which portray people in a wide variety of situations and activities.

Study has shown that some pictures call forth an infinite variety of dramatic stories containing valuable clues about the authors. On the other hand there are pictures which fail to yield stories containing information of much value, and these less useful pictures are eliminated from succeeding versions of "Picture Interpretations." Information from these analyses is used as a basis for further revisions of the test and also as a basis for further revision of the scoring method. Statistical studies are made to determine other kinds of information about "Picture Interpretations." One important thing to know is whether or not different readers are obtaining comparable scores from the records, and so checks on scoring accuracy must be part of the program. Studies are also being made to determine to what extent the same people will write the same kinds of stories upon two separate occasions. In order to find out how consistently "Picture Interpretations" measures the factors that are scored, two very similar series of pictures have been assembled. These equivalent forms of the test can be administered to the same group upon two separate occasions to measure changes due to the lapse of time or to different conditions of administration.

In order to insure objectivity in the analysis and scoring of stories, men's names are eliminated from the records and are replaced by code numbers.

One important bit of information that must be considered in the analysis of material is the intellectual ability of the men taking "Picture Interpretations." Scores on some measure of intelligence are available for all men tested, and this information is considered in evaluating the relation of "Picture Interpretations" scores to the record of job performance.

As with many psychological tests, the results of this one must be kept confidential. Thus one obvious reason for not describing the test or its scoring system in greater detail in this article is that spread of such information might enable individuals to "fake" high scores.

With ONR support "Picture Interpretations" is being changed from an interesting experimental device into a standardized personality test. After an extended research program, the test will be ready for use in personnel selection and placement. It should have considerable value in such applications since a man's effectiveness on a job is a function not only of his ability to do the work, but also of his attitudes toward the work, his fellow workers, and himself. Information from projective tests may be combined with information from interviews, aptitude and interest tests, and detailed personal histories to yield a pretty good picture of a job applicant or of a man seeking vocational guidance. In this way, an overall evaluation can be made that helps place a man in a job for which his abilities, aptitudes and interests appear well-suited. That is the ultimate goal of developing projective tests such as "Picture Interpretations."

Dr. D. D. Smith Heads Personnel and Training

ONR's newest branch head is Dr. Denzel D. Smith, who has taken over direction of the Personnel and Training Branch. Miss Marguerite Young, who had been serving as Acting Head, has accepted a position in the Biological Sciences Division of the National Science Foundation.

Dr. Smith's previous work included a Professorship of Psychology at the University of Maryland and four years (1942-46) with the Navy's Bureau of Medicine and Surgery.

Weighing in. Physical condition of rats is recorded as part of the experiments designed to uncover the causes of alcoholism. Note the cages with the double beverage supply.

"went on the wagon" for several days before returning to the alcohol bottle.

A search for the reason why the individual animals behaved so differently from one another when they were being fed and treated alike in every way led to only one possible answer—inheritance. The inheritance of the individual rats was not the same; in fact each was distinctive. Since the original experiments were performed we have studied hundreds of rats of different breeding. All the evidence we have gained has indicated that the inherited patterns of the individual rats is the key to the differences in their drinking behavior.

Experiments subsequent to the initial ones involved changing the diets of the rats to see whether this made a difference. It did, and a remarkable one! When placed on diets of marginal adequacy, all of the rats drank alcohol rather promptly; when they were placed on fortified diets containing an abundance of everything that rats are known to need, none of them drank substantial amounts.

Furthermore, when rats were drinking rather heavily on a marginal diet and were supplied with an abundance of the nutrients missing in their diets, their alcohol consumption often dropped to zero overnight and they left the alcohol alone for as long as they were supplied plenty of the missing food elements.

The reason why dietary deficiencies cause the animals to drink more alcohol is not perfectly clear; the fact that deficiency definitely causes an increase in alcohol consumption is indisputable because we have observed it hundreds of times. Actually the fact that nutritional deficiency generates an appetite for alcohol is more important from the practical standpoint than exactly how this fact may be explained.

It should be clear from the experiments described that individual rats vary in their nutritional vulnerability. Some of the original groups, when fed the stock diet, were completely free from deficiency and showed this by not drinking an appreciable amount of alcohol; others were appreciably deficient and demonstrated it by consuming alcohol at high levels. In the extension of our work we have brought many new strains of animals into the laboratory. Some of these, we find, are more vulnerable than any in our original group. They demonstrate this by heavier alcohol consumption on diets which would not create deficiency in any of our original group of rats.

We had next to apply this idea of nutritional vulnerability to human beings.

About the time when these ideas were "popping" a man came to us who was desperately in need of help. He had been a heavy drinker for 20 years, an "alcoholic" for 10, had not been helped by psychiatry, and the Alcoholics Anonymous program had not been successful in his case. Even his family had given him up. "Surely", we thought, "if our ideas are sound, this is a person who was born with nutritional vulnerability; we will try to correct it." We gave him a carefully concocted mixture of vitamins and other nutrients that we could get into capsules, and told him how to take them, hoping that we would succeed in filling the gap so far as his individual deficiency was concerned.

To make a long story short, this individual lost his alcoholic tendency in a few months; he became so sure of himself that he insisted on demonstrating to us that he could drink a few beers (his favorite starting beverage) and come back to us sober the next morning. This he did, just as he said he would, and in fact he has been a moderate beer drinker since this time, which is now three years; as long as the nutritional supplements are taken, he is free of the terrible craving that bedevilled his life for so long. Other cases have responded even more dramatically and in a much shorter time. One young man, after 18 months experience, told me he had had <u>absolutely no trouble</u> since he took the supplements; it was like a miracle in his life. Another—a prominent lawyer—found he now had no craving for liquor at all. Occasionally he would take a cocktail for social reasons but he had no particular liking for them and had no tendency whatever to drink one after another.

Unfortunately we have found occasional individuals who did not respond at all to our mixture, or at best responded in a dubious manner. The record with human beings has been not wholly unlike that with rats (when all strains are considered). About half have responded in a very satisfactory manner; the other half usually have been helped somewhat, but not enough. Yet everything we have found out agrees with our nutritional vulnerability idea and points to the probability that some day when we know more about nutritional factors, we will be able to help all alcoholics.

How does psychology enter into this problem, and how does frustration contribute to the production of alcoholics? This is a complicated question and we do not profess to know all the answers. It seems probable, in fact certain, on the basis of very recent experiments, that stress causes an increased need for some vitamins. This may mean that some individuals remain invulnerable as long as life's stresses are not too great, but that when an obnoxious mother-in-law or a nagging wife enters into the picture, the nutritional needs step up and a vulnerability to deficiency arises.

The use of nutritional supplements in the treatment of alcoholism is in any case a most promising attack. Large scale experiments are

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underway at the Harvard School of Public Health and if the final reports are similar to the preliminary ones, these experiments will establish the principle that nutritional supplements can, in a substantial number of cases, cure alcoholism.

The hope of preventing alcoholism by the use of nutritional supplements is even greater than is the prospect of cure. It is an almost universal experience that prevention is easier than cure. When an individual has had his whole life complicated for years by a problem like alcoholism, it is indeed difficult to remove the scars and induce him to live a healthy and productive life. Too many associations of the past cause entanglement. The prevention of progressive alcoholism, however, when it is in its incipient stages should be relatively easy, and we hope that nutritional supplements may salvage many lives which would otherwise be ruined. This is highly important to our society because it is often people of the highest grade—sometimes exceptionally able and fine people—who are afflicted with the disease.

It seems an extraordinarily good bet that if each individual's nutritional needs can be satisfactorily met, the scourge of alcoholism will be routed.

Cause and Treatment of Diabetes Found Through "Impractical" Research

Many research endeavors, at first considered of theoretical interest only, have eventually become invaluable to the world. One of the most important cases of this kind in medical research—the discovery of insulin as a treatment for diabetes—was cited recently by CAPT Charles Wesley Shilling, ONR's Deputy for the Biological Sciences, in a speech before the Worcester Foundation for Experimental Biology.

Diabetes—once inevitably disabling or fatal—can now be treated with this hormone, obtained from the pancreas of animals slaughtered for meat. At one time, although diabetes had been recognized for hundreds of years, its cause and treatment were still mysteries; even the organ involved was unidentified. Two investigators, von Mering and Minkowski, were interested in studying the relationship of the pancreas to digestion. They had no real interest in diabetes. During the course of their studies, they removed the pancreas from animals in order to see what effect this would have. A few days after the operation was performed an animal caretaker came to the two professors and reported that the cages of the postoperative animals seemed to be particulary attractive to flies. Von Mering and Minkowski investigated, and found that the reason for the attraction of flies to the cages was the excretion by the animals of large quantities of sugar in their urine. Knowing that this also occurs in diabetes, they immediately sensed some association and set out to study the relation of the pancreas to the disease. This was the first indication that the pancreas is the organ which controls the utilization of sugar and which, when its function is abnormal, causes the disease we call diabetes. Today there are 3,000,000 diabetics in this country who, through treatment with insulin, are leading normal lives. All of these people owe their very existence to this inadvertent observation by the humble caretaker who worked for von Mering and Minkowski and to the scientists who had the vision to understand its significance.

Engineering for Better Marksmanship

by

Roy L. Pepperburg
Special Devices Center

Ever try to twirl your thumbs in opposite directions at the same time? Most of us have tried to at one time or another and have been perplexed, not to say nonplussed. How well we succeeded was of small consequence, of course. Many Navy men, on the other hand, must perform comparable tasks—twirling knobs instead of thumbs—on which their lives and the lives of others may depend.

Fire-control men, for example, must keep crosshairs on the target. Tracking the target is done by turning two cranks, knobs, or wheels—one controlling bearing, and the other elevation. In other words, one control moves the crosshairs to port or starboard, while the other control moves the crosshairs up and down. Usually both controls must be operated together.

Navy officers, engineers, equipment designers, psychologists, manufacturers, and others wondered whether the ability to perform such tasks was affected by the position or size of the knobs or cranks, the direction of their movement in relation to the movement of the crosshairs or other device, the amount of movement, the force required to make the movement, and other conditions. If a man could get on-target quicker and stay on-target longer because a knob turned to the right instead of to the left, many beneficial changes could be made in vital equipment.

Navy officers and engineers could speculate about the problem, but it was up to psychologists to find the answers. To psychologists of the Human Engineering Division of ONR's Special Devices Center fell the task of conducting the research.

The psychologist places our knob twirling problem under the heading of "human motor abilities"—in plain language, the ability of the human to move his parts.

The Special Devices Center assigns as many tasks as possible to private organizations, which frequently saves the Government money, encourages private organizations, keeps the Government establishment within reasonable bounds, personnel-wise, and assures performance by persons or institutions best equipped to carry out the task. The investigation into human motor abilities (Human Engineering Project 20-M-1-d)

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was assigned to the University of Rochester's Department of Psychology. Laboratory work was carried out by that department's S.D.S. Spragg, D. B. Devoe, A. L. Davidson, Eugenia B. Norris, and others. Our six technical reports summarize and present the findings of this research.

Project 20-M-1-d is a large one. It had to be divided into several parts for laboratory purposes. Many of these parts were highly technical aspects of human motor abilities—coordination interference, and the like. If we examine one facet of the project it will illustrate the kind of work performed and the results achieved.

The problem was to find the best position and direction of turning for the two cranks on our target-tracker or any similar device. The equipment used was a modified SAM Two-Hand Coordinator, designed to measure one's ability to keep, by means of two cranks, a target follower on a target moving at different speeds along an irregular path. The selection battery at Air Force classification centers used this gear unmodified during the war. The present modification consists of mounting the control handles on pivoting stands, a change which made it possible to place the controls in either the horizontal or vertical plane. The "guinea pigs" were 96 students at the University of Rochester who were paid for their services.

SAM, as shown in Figure 1, is a simple machine. Turning one handle (A) moves a small button (C) from side to side. Turning the other handle (B) moves the button (C) forward and back (toward and away) from the operator. Either handle can be arranged to control either motion. The effect of turning the handles can also be reversed—that is to say, the handle controlling side-to-side motion can be arranged to move the button to the right when the handle is turned to the right (clockwise) or to the left (counter-clockwise).

The modification of SAM also enables the psychologist conducting the experiment to change the position of the cranks. Ordinarily the cranks face the operator and turn in a vertical plane parallel with the front of his body. Either crank, however, can be pivoted so that the handle turns in a vertical plane perpendicular to the operator's body.

A Standard Electric clock calibrated in thousandths of a minute recorded the score in milliminutes on target.

Not all conditions were tested during this experiment. Previous research strongly suggested that the "expected" or "natural" set-up between the motion of the crank and motion of the target-follower button gave the best performance. In the "natural" or "expected" movement, clockwise motion of the control causes clockwise motion of the target-follower. The earlier tests, however, dealt only with one-hand tasks, two-hand tasks with discontinuous movement, or tasks in which only the speed of movement was considered. None of them dealt with a condition involving "complex continuous two-hand coordination."

Part 5 of Project 20-M-1-d was therefore set up to test the accuracy of performance of a "complex two-hand coordination task"—the turning of two cranks at the same time at speeds and directions required to keep a target-follower on the target.

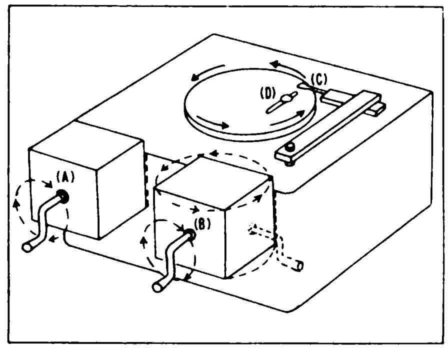

Figure 1. A modified SAM Two-Hand Coordinator with certain mechanisms omitted for simplicity. Crank (A) controls side-to-side movement of target-follower (C). Crank (B) controls fore-and-aft movement of (C). The subject turns cranks (A) and (B) and seeks to keep target-follower (C) over target (D). Target (D) travels back and forth in slot while circular plate containing slot revolves, causing (D) to describe an irregular path at varying speeds. The modification consists of gears which permit cranks (A) and (B) to be rotated 90° as indicated for crank (B) by dotted lines.

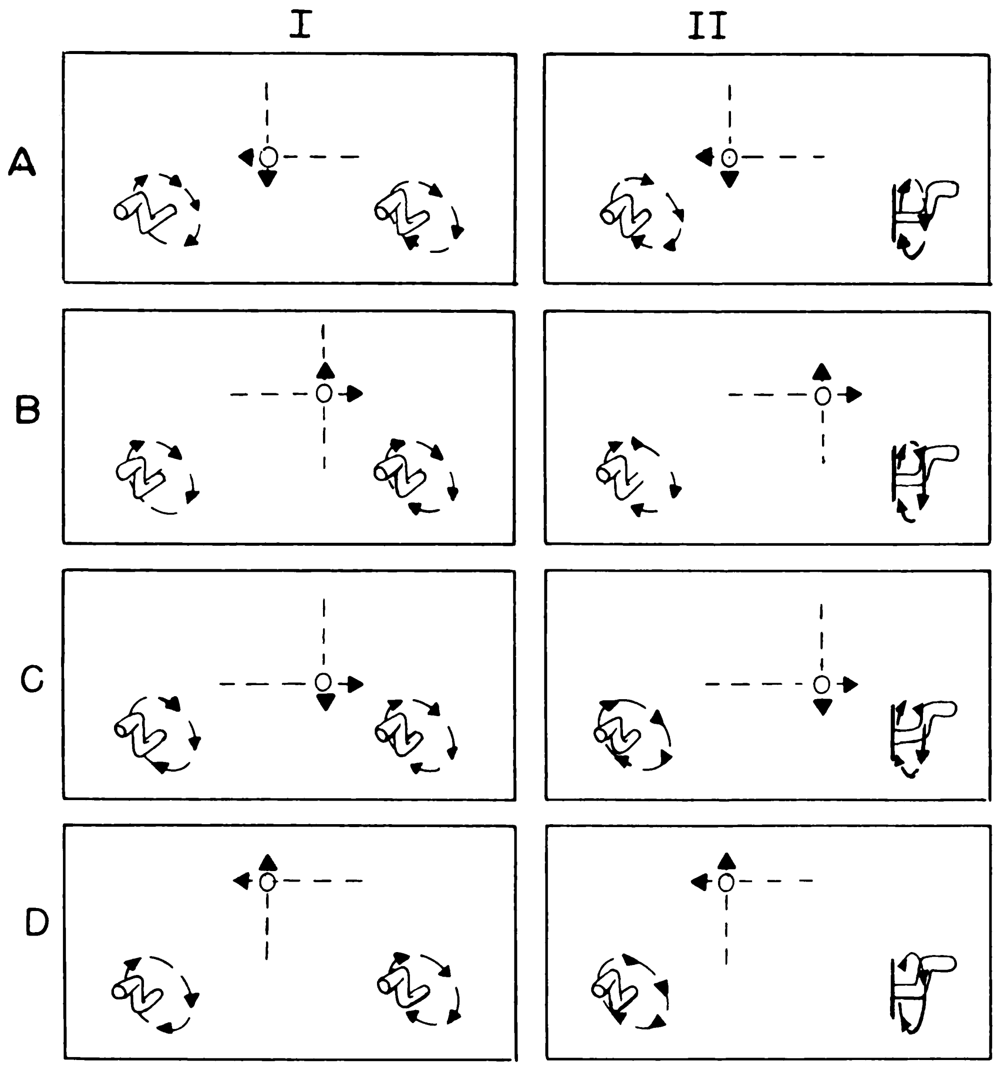

Figure 2. Conditions in which the SAM Two-Hand Coordinator was operated for this experiment. Group I operated the device in conditions A, B, C, and D under I. Group II operated the device in conditions A, B, C, and D under II. In each instance the left crank controlled side-to-side motion, and the right crank controlled fore-and-aft motion of the target-follower, as indicated by arrows. (The target is not shown.)

Students who were to take the tests were divided into two groups of 48 each. Members of Group I operated SAM in positions A, B, C and D (Column I in Figure 2). Group II performed on SAM in the same way with SAM set up as in Column II, Figure 2. Significantly better scores were tallied by both Groups I and II in position B than in positions A, C, or D. No significant difference appeared between the scores of Groups I and II for position B. In other words, Part 5 of Project 20-M-1-d revealed the most desirable position and direction of movement for controls on devices requiring complex two-hand coordination. The left control should be on the front of the device, rotate in a plane parallel with the front of the operator's body, in the direction corresponding with the desired movement of the target-follower. The right control should be located either on the front of the device in the same way as the left control or on the right side of the device so that the control turns in a plane perpendicular to the front of the operator's body, and likewise turns in the direction desired of the target-follower. SAM's operators stayed on the target 20 percent longer after an equal amount of training when the controls were arranged in this way.

Other phases of Project 20-M-1-d revealed equally significant data about such factors as coordination, motor control, judgment, interference, and other factors. Many machines and instruments require adjustment by the turning and setting of knob controls. Such tasks include tuning a radio, adjusting its volume, adjusting radar and sonar controls, focussing a camera with a ground-glass back or viewer, focussing a projected image on a screen, and setting a range-finder.

The studies revealed that knobs measuring from 2" to 2-1/2" in diameter provide the best control. Adjustments requiring knob rotations of 60 to 110 degrees are satisfactory, but adjustments limited to a rotation of 80 degrees give superior results. The amount of torque or friction desirable for optimum control was also determined.

New knowledge about human motor abilities, revealed by these Human Engineering studies, will be reflected in better equipment design for the Navy in many fields. Radio, sonar, loran, computer, and fire control devices for better marksmanship—all of which require setting or adjustment by knobs or cranks—are among the instruments that will be improved as a result of this psychological research.

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NOTE: Personnel who are in a position to apply data developed by the research described here, or who would like more complete information for any reason, should request Technical Reports SDC 241-6-1 to 241-6-6 from the Commanding Officer and Director, Special Devices Center, Port Washington, New York.

Research Reviews

Research Reviews endeavors to report briefly highlights of technical progress in research by naval laboratories and contractors and the development of important naval research facilities. Articles which meet these broad criteria and possess a good degree of readability are welcomed. Manuscripts and changes of address should be sent to Code 250, Office of Naval Research, Washington, D. C.

Who's Who in Naval Research

CAPT Thomas Bradley Haley, CO and Director of the Special Devices Center, has his feet firmly on the ground for the first time in about twenty years. For since 1932 the quiet, pleasant officer who heads the big installation at Sands Point has always had duty involving flying. This record undoubtedly comes in handy on his present assignment, for a large part of the program of SDC aims at making the unbelievably complex modern military craft easier to fly. First-hand experience of the difficulties involved—in which the scientists or engineers who design military equipment are occasionally sadly deficient—is something the Captain has aplenty.

CAPT Haley's appointment to the Naval Academy was made by Cordell Hull. After that he had one of his few purely sea-going assignments—to the USS ARKANSAS, flagship of BatDivTWO, the Scouting Fleet. The following year his flying career began with his orders to the U. S. Naval Air Station, Pensacola, where he was designated Naval Aviator in 1932. Duty with Fighting Squadron ONE and Bombing Squadron TWO in the USS SARATOGA; with Patrol Squadron EIGHT operating out of Pearl Harbor; as a student at the Postgraduate School, Annapolis; and as a student at the Philadelphia Naval Aircraft Factory, all broadened his knowledge of the various aspects of military aircraft problems. This knowledge was further extended when a course at the Massachusetts Institute of Technology earned him a master's degree in aeronautical engineering.

During the war, CAPT Haley's services with Patrol Squadron EIGHTY-ONE brought him the Air Medal "for meritorious achievement in serial flight as Patrol Plane Commander of a PBY-5 plane...during rescue operations off the coast of Key West, Fla." The citation credits the Captain, while engaged in anti-submarine patrol, with preventing torpedoing of life boats by the enemy and possibly attack of personnel, as well as rescue of a lone survivor.

CAPT Haley's return to the United States brought him duty in the training Division in the Office of the DCNO—and incidentally first-hand knowledge of some of the problems which are of particular concern to the Special Devices Center. By May 1945 he had completed the course at the Army-Navy Staff College and reported for duty in the staff of Commander Amphibious Group THREE, Amphibious Forces, Pacific Fleet. His postwar duty included service as Executive Officer of the USS BOXER (CV-21) and a return to Washington for duty in BuAer. His assignment previous to coming to SDC was Head of the Overhaul and Repair Department, NAS, Norfolk.

One of CAPT Haley's spare-time activities reflects his engineering bent—he loves to repair things; not at all interested in new construction, he turns into a "Mr. Fix-It" when any kind of gear breaks down. His other interests are less technical—baseball, hunting, golfing, and his family. A quiet man, whose silent efficiency on the job have become well known, he is nevertheless—in appropriate circumstances—capable of doing justice to an entertaining anecdote, and like any good story teller he knows a million of them.

Biological Research and the Navy

The aim of the Biological Sciences program of the Office of Naval Research has been to support research which shows promise of making a significant contribution to the scientific fields which underlie developments in present and future naval operations, without particular attention to the sharp definitions of basic, applied, etc. The scope of the Navy's research responsibility is almost unlimited because Navy men operate in virtually every environment, natural or artificial; however, clear delineation of the Office of Naval Research program is permitted because of the well-defined programs of other government agencies. For example, the research grants of the National Institute of Health, U. S. Public Health Service, are concentrated on investigation of the principal diseases of the civilian population. Thus the Office of Naval Research can well afford to omit consideration of such fields as cancer research and venereal disease control. On the other hand, the Navy must give attention to disease characteristics of large numbers of men in close quarters, such as streptococcal, respiratory infections and dysentery, since the program of the Institute does not provide sufficient emphasis relative to the overpowering military importance of these diseases.

Even more important in the ONR program is the concept of factors governing the functions of the normal man. The principal problem of military medicine is not the care of the sick and wounded; it is rather, the prevention of disease and injury and the maximal utilization of the physical and mental abilities of the Nation's manpower. This is partially expressed by the "Mission" of the Navy's Medical Department: "To keep as many men at as many guns as many days as possible". This primary objective will depend on new physiological knowledge and concepts of problems of fatigue, individual differences, and responses of environmental stresses. It demands research involving such basic explorations as that of enzyme chemistry in cellular function, comparative physiology, the fundamental basis of the nerve impulse and its propagation and transmission—in short, virtually the whole spectrum of experimental biology.

(Excerpt from article, "Support of the Biological Sciences by ONR," in April issue of the Bulletin of the American Institute of Biological Sciences, by Dr. Orr Reynolds, Head of ONR's Biological Sciences Division.)

Microwaves and Matter

by

W. D. Hershberger
University of California, Los Angeles

Mention microwaves to the usual expert in electronics and he has visions of Imogene Coca and Sid Caesar using a long technological crutch to help them in hopping one of the gaps, say from Lincoln to Denver, on the television microwave link. If our electronics expert has had experience with aircraft, however, he may think of radar with its magnetrons, klystrons and rotating dishes spewing trains of microwaves—perhaps to help a friendly airplane make a safe landing or else to help an unfriendly airplane make an unsafe landing.

These uses of microwaves are no doubt here to stay, but recently, especially since the war, researchers have been using microwaves in studies on matter itself. Those who like ponderous phrases insist that we now use microwaves to Wrest Secrets from Nature and perhaps even to Interrograte the Fundamental Building Blocks of the Universe! Be that as it may, studies on interactions between short radio waves (from about 0.1 to 10 cm in length) and materials are fascinating and are leading to new results having both scientific and technical interest.

The program at UCLA on microwaves and matter can be conveniently divided into two phases. The first is the interaction of microwaves with certain gas atoms and molecules. The second phase is the interaction of microwaves with certain substances known to chemists as paramagnetic solids. Included among paramagnetic solids are phosphors, interesting substances which are used in television screens and fluorescent lighting tubes.

The first phase of the program—namely absorption of microwaves in gases—will be passed over very lightly. The fact that water vapor in the atmosphere absorbs 1.25-cm waves has had a twofold effect: (1) it wrecked an otherwise promising radar development program during World War II and (2) it placed a quantity of surplus 1.25-cm equipment in the hands of eager experimenters. Since the 1.25-cm waves do interact with atmospheric and other gases, the measurement of these effects can be used to explore the internal rotations and vibrations (as well as rotations as a whole) of molecules. Data of this kind have been obtained on a hundred or more molecules and the information provided

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W. D. Hershberger, Professor of Engineering at UCLA, received his Ph.D. degree from the University of Pennsylvania. From 1927 to 1931 he served in the Sound Division at the Naval Research Laboratory and from 1931 to 1936 in the Signal Corps Laboratories where he laid out the first experimental radar equipment used by the Army. From 1937 to 1949 he was employed by RCA, where he was active in developing a 500-Mc altimeter, and since the war he has been studying interactions between materials and microwaves. He has published papers on supersonics, microwave spectroscopy, frequency stabilization using microwave lines, and has filed some 50 patent applications.

on their geometry is astonishingly accurate. Frequency stabilization with the molecule of ammonia was accomplished prior to 1948 when methods were developed for coupling the molecule to the Klystron generator. The earlier method of frequency stabilization, which involved use of the quartz crystal, may be replaced in the microwave range by this molecule. (Unlike the quartz crystal or a ship's chronometer, it may be dropped on the deck without impairing its accuracy!) Stabilization frequency to 1 part in 10,000 has been attained (not as good as the quartz crystal) and presently the ammonia pendulum was suspended to swing in the so-called "atomic clock". This field has been exciting and has led to new information for the scientist, and several engineering applications.

Since there are those who feel that electrons are more interesting than molecules, let us go on to the second part of our research program—that dealing with the interaction of microwaves with paramagnetic solids. Today practically everyone knows that an electron has an electric charge of about 10^{-19} coulombs and that 10^{30} of these electrons weigh about one pound avoirdupois. In fact countless people know these simple facts who have never weighed an electron or measured its charge. If they are willing to accept these small matters on faith they should have little reason to object when told that the electron also has spin and magnetic moment and behaves very much like the earth, spinning merrily on its axis and displaying magnetic polarity.

The microwave method can be used to see electrons only in certain rather unusual substances, however. The usual or working-class electron ordinarily teams up with a second electron and the pair usually succeed in concealing their joint magnetic properties from external observations. These working-class electrons—hewers of wood and drawers of water—are usually kept busy holding bones, crystals and houses together and are known to chemists as valence electrons. Other low-class electrons busy themselves in making the trip from power station to consumer (getting counted in your meter as they go by) while others work for the telephone companies. The point about all these run-of-the-mill electrons, however, is that they are arranged in such a way that their magnetic properties cancel each other out. But there is an elite among the electrons, which do the startling tricks basic to the electronics industry and on occasion are found unpaired. It is with these odd electrons that we are concerned in our work on microwaves. Sometimes they are found in organic compounds, for although Nature generally placed an even number of electrons in molecules even Nature makes mistakes. Substances which contain these unpaired electrons with their undiminished magnetic properties are known as paramagnetic solids.

At this point we need an answer to the question: What happens to a spinning body having a magnetic moment when it is placed in a strong magnetic field and thus is subjected to a torque? The mechanical analogy is the gyroscope, spinning in a frame to which we hook a weight. The gyroscope immediately solves a couple of differential equations and begins to precess, not in the direction of the force but at right angles to the applied force. Children (and adults who do not play golf) are often delighted by this behavior since they normally have found that a chair or other object, when given a push, moves in the direction of the push and not at right angles to this direction.

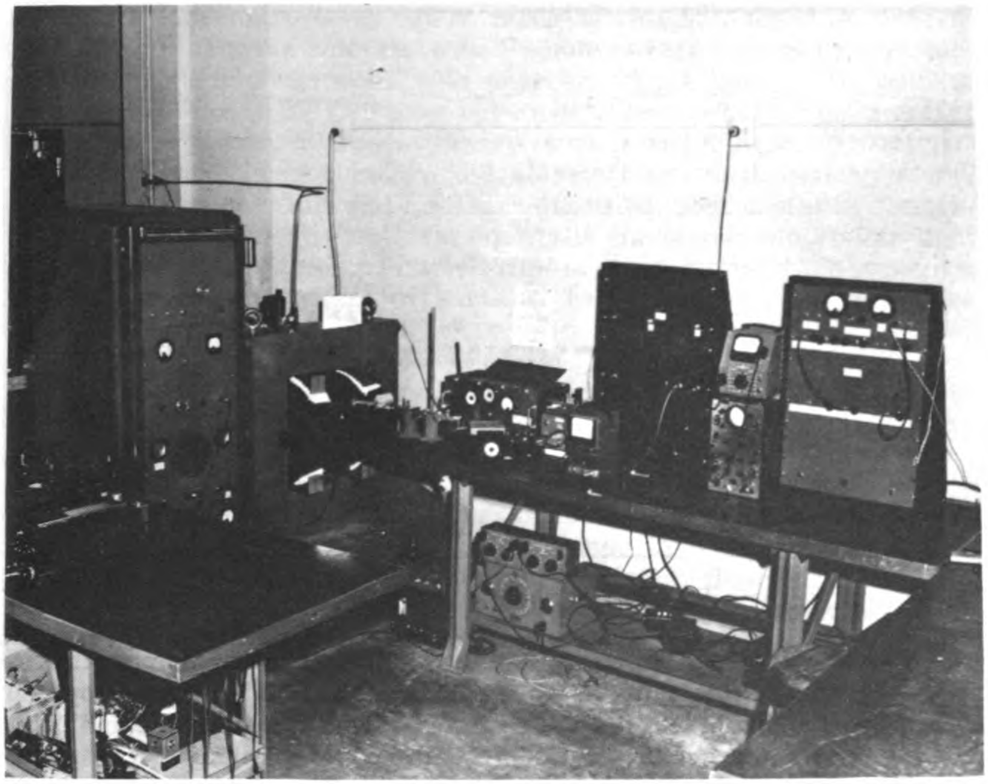

Figure 1. Electromagnet on Los Angeles campus of University of California

Some of the equations used to describe the precession of a gyroscope look on the surface like some of the equations used to describe the motion of a spinning electron in a magnetic field. The electron tries to line up with the magnetic field but instead its axis spins around a line of force at a frequency we choose to call the gyromagnetic frequency. Fortunately for the microwave experiments, the gyromagnetic frequency for an electron is 9400 Mc or X-band when the field is 3400 gauss and K-band when it is 8500 gauss. Now we have a tool, a magnet, to make electrons spin, and a second tool, obsolete radar equipment, for observing their gyrations in the magnetic field.

In the experimental set-up on the Los Angeles campus of the University of California the first tool is an electromagnet weighing 3500 pounds and having pole pieces eight inches in diameter. Figure 1 shows a photograph of this equipment. The sample is perhaps one half the size of a matchhead! This is considered a reasonably well balanced design, but the present one is not the airborne model. The sample is placed in a resonant cavity about the size of a demi-tasse and placed in the magnetic field. The second tool, a microwave transmitter, is used to drive power through the sample and this transmitted power is recorded as one slowly changes the magnetic field strength. When a critical relationship is reached, so that the gyromagnetic frequency of certain specialized electrons in the sample is the same as the frequency of the obsolete radar equipment, a sharp drop in power is noted and, in the present equipment, automatically recorded. Such records are called "paramagnetic spectra."

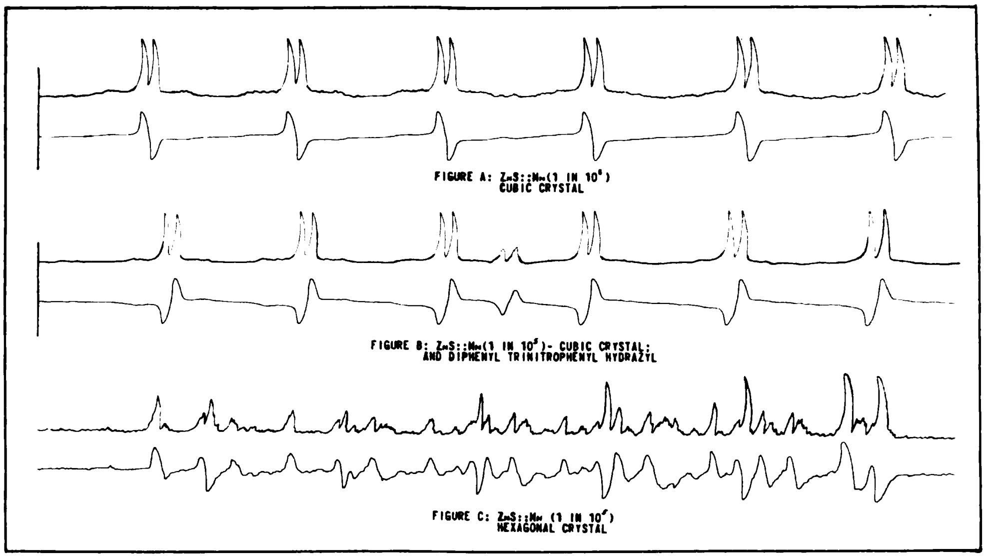

Figure 2. Paramagnetic spectra

One material which produces such an effect is diphenyl trinitrophenyl hydrazyl, of which a sample was furnished for this work by Bell Telephone Laboratories. A careful count reveals that the molecule contains 41 atomic nuclei. This is not important. Further, it contains 193 electrons. Of these the first 192 are not important; it is that last odd one that makes things hum. Because it is unpaired its magnetic properties are not cancelled out and they produce some interesting results in our equipment. When a pinch of the substance is placed in the resonant cavity in the gap in the magnet and the magnetic field is adjusted to the critical value, power transmission is reduced one third. The central line found in Figure 2A and not found in Figure 2B arises from a microscopic sample of the hydrazyl used to calibrate the field.

In some phosphors the electrons are the kind which may be seen by the microwave method, so they are studied as part of the second phase of our program. Actually phosphors contain no phosphorous at all, as this would be all too rational. To make one you can start with the purest zinc sulphide known to man. At RCA Laboratories, where the phosphors used in this study were made, even the rugs on which the chemists wipe their shoes are washed in distilled water. In this highly sanctimonious state (referring to the chemical, not the chemist) the material is not a phosphor and cannot do the thing which characterizes this class of compounds—turn electric energy or ultraviolet light into visible light. To accomplish this, the zinc sulphide has to be contaminated by some base material such as manganese. The latter is introduced in minute quantities and the mixture brewed with as much care as the three witches in Macbeth used on their strange concoction. Microwave methods can then be used to find out more about the internal workings of the phosphor. The spectra shown in Figure 2A-C are found for a phosphor in which the host crystal is zinc sulphide while the manganese is present to the extent of 1 part in 10,000. Manganese in cubic ZnS gives us a spectrum with six sharp peaks and in hexagonal ZnS one finds 30 peaks.

Work with microwaves can do much to enlighten us on phosphors, which still present the scientist with a number of unexplained mysteries. Actually the people who work with phosphors have been pretty good at making them—about 100,000 have been synthesized—but they are rather weak on theory. In fact present theory is quite incomplete. The microwave technique will undoubtedly yield information as to the energy states of the electrons in solids and may turn out to be most useful in clarifying the process whereby electrical energy is converted into visible light in our fluorescent lamps. In brief, this is the purpose of the research on phosphors. The spectra of some 27 have been explored and there seems to be a long trail ahead.

It is clear that physicists working in this field are not going to find themselves with time on their hands. There are plenty of fundamental facts waiting to be discovered by microwave methods and eventually there will be utilitarian applications for many of them. Already much has been learned about the structure of a number of compounds and already work with microwaves promises to teach us much about the workings of such varied items as television, fluorescent lighting and transistors. All in all the prospects are bright for advancing fundamental science and its practical applications through work in this field.

Lubricants from Pine Trees

For many generations an appreciable number of Southerners have made a livelihood by extracting turpentine from pine trees. But since the War, cheaper solvents synthesized from petroleum hydrocarbons have made competitive inroads into the sale of natural turpentine. This would seem primarily a concern of the Department of Agriculture. But a concurrent situation—an increasing demand for aliphatic dibasic acids to use in making synthetic lubricants—aroused the interest of the Navy as well. So the Department of Agriculture and NRL entered into a joint search for new uses of turpentine. They came up with a pat discovery: Pinic acid (made from α-pinene, a major constituent of turpentine) can in many cases replace the adipic and sebasic acids previously used as a base for synthetic lubricants. This will free these acids for other employment (they are badly needed in the production of nylon and plasticizers) and will also provide, in large quantities and at substantially lower cost, special lubricants for military and industrial use.

As a matter of fact, a plentiful source of cheap dibasic acids has been needed ever since 1942, and products obtainable from native raw materials would of course be especially desirable. The aliphatic diesters were being used more and more as extreme low-temperature lubricants in turbojet engines, instruments and machine guns; as aviation and ordnance greases; and certain ones as low-temperature plasticizers. In addition, a variety of other end-products were competing for the dibasic acids, the branched-chain alcohols, and even the diesters themselves. Thus the discovery of a source in readily available turpentine is a happy outcome for industry, the Navy, and the Pine-Belt South.

On the Naval Research Reserve

New Type of Seminar Scheduled Next Month

San Francisco will be opening its golden gate next month to reservists who will be participating in one of the most unusual seminars ever held by the Volunteer Naval Research Reserve. Starting from Treasure Island the visiting officers will swing through California by air, visiting a large proportion of the scientific and military installations which are of interest to the United States Navy. This type of expedition, unique in VNRR annals, is called a "caravan" seminar.

After hearing talks by line officers, bureau and ONR representatives, the reservists will leave Treasure Island on the first lap of their grand tour. The first stop-off scheduled is the University of California, Berkeley, where leading scientists of the Radiation Laboratory will explain their work and show the reservists some of the powerful tools of nuclear physics—the cyclotron, betatron and synchrotron. Returning to Treasure Island, the officers will be briefed on mobilization plans, scientific personnel needs in the Navy Department, VNRR training plans and various unit research projects. A field trip to the U. S. Naval Biological Laboratory in Oakland will follow, with talks by leading scientists at that installation. Two more laboratories will be visited in as many days: the Radiological Defense Laboratory at Hunters Point and Stanford University's Microwave Laboratory and its Research Institute.

After time off for Labor Day, the reservists will start their second week of visiting—this time at the principal testing centers in the area: The U. S. Naval Air Missiles Test Center (Point Mugu), the BuDocks Research and Evaluation Laboratory (Point Hueneme), and the Naval Ordnance Test Station (Inyokern).

Member of VNRRU 9-22 Recognized For Achievements in Soil Conservation

The second highest award granted by the Department of Agriculture was presented to LCDR Adrian C. Fox, member of VNRRU 9-22 (Lincoln, Neb.) in special ceremonies held recently in Washington D. C. A member of the regional office of the Soil Conservation Service, LCDR Fox was given a superior service award for furthering conservation practices through aid to schools and colleges in Kansas, Nebraska, Montana, Wyoming and North and South Dakota. He is head of the Educational Relations Section of the Soil Conservation Service. Commending Mr. Fox, George E. Rotter of the Nebraska Department of Public Instruction said: "His influence is a basic one to the character of our young people, as well as a lasting contribution to the conservation of our national resources."

LCDR Fox, who entered the SCS in 1935 as an assistant forester, received degrees in general agriculture, botany and entomology at North Dakota State College. He also attended the School of Forestry at Iowa State College.

His naval career included 33 months of duty during World War II and he has been a member of VNRRU 9-22 for more than a year. He has gained widespread recognition through a large number of articles for state and national publications and several technical articles dealing with biology and wildlife.

VNRRU 9-2 Studying Problems of Warfare in the Arctic

In World War II extremes of heat and cold played havoc with the fighting forces of almost all the nations involved. From the icy Russian plains to the steaming jungles of the South Pacific military personnel were confronted with countless problems arising from severe climatic conditions. Maintaining equipment and men under such conditions is obviously an important problem to our Armed Forces.

VNRRU 9-2 (Urbana, Ill.) last year became interested in one phase of this problem. It started a program (which is still in progress) aimed at unearthing as many facts as possible about the problems of maintaining military personnel and equipment under Arctic conditions.

The proposed project was divided into four parts:

(1) Basic instruction on the Arctic and its problems.

(2) Division of the unit into groups, each to work on a specific research problem on Arctic warfare.

(3) Discussion of the results of the work of the individual groups by the unit as a whole.

(4) Submission of significant results to ONR for consideration by the Navy.

Qualified lecturers were obtained who summarized for the reservists a large amount of general information about the Arctic regions: regional geography; travel conditions; food and clothing requirements; physiological effects of the weather; and the geopolitical set-up in the polar lands.

In regard to Phase 2 of the project it was decided that more tangible and practical results would be obtained if the group projects were directed toward a coordinated unit problem. It was further decided that the project should be practical and similar to the type that unit personnel might have assigned to them if they were attached to a staff for advance planning.

The plan finally decided upon was to prepare and furnish advance operation information and data for the assault, capture and occupation of an Arctic objective on a theoretical "W-Day". The port was assumed to have 2000 enemy personnel who would be supplemented by 2000 garrison troops and 500 civilian technicians. No assumption was made as to the season of the year when W-Day would occur. It was assumed that the "enemy" was supported by submarines, planes and small and medium arms fire.

To obtain the required operational information, the unit was divided into groups dealing with five different categories: intelligence, operation of ships, operation of planes, land operations and personnel survival. Each group will file an interim report on its work at the end of this month and final reports will be discussed at the August 7 meeting of the unit.

VNRRU 9-2 is headed by CAPT C. M. Louttit. CDR Charles H. Bowman organized the Arctic warfare project.

LCDR J. L. Maxton Reports on U. S. Farm Resources

A report on the resources of agriculture as a part of total U. S. resources has been compiled by LCDR Jacob L. Maxton, Agricultural Economist and member of VNRRU 5-2 (Blacksburg, Va.). Mr. Maxton's report touches on the distribution and characteristics of farm people, trends in output and input expected in 1952, field farm products and livestock expected in 1952, and miscellaneous agricultural resources. Mr. Maxton is engaged in teaching and research at the Virginia Polytechnic Institute.

He points to the need for greater utilization of mineral plant foods and the conservation of animal and vegetable plant foods in order to increase the soil's productivity. He feels that this increase in productivity should then be used for sustaining an increased livestock population and increasing American living standards.

Mr. Maxton's report also stressed the need for conservation in another area—our fishery and timber resources. The trend in recent years has been toward depletion of these vital reserves.

Although the trend toward the use of modern farm machinery has been greatly accelerated in the past decade, there is a need for still greater use of larger equipment to increase the output per worker and decrease the cost per unit of product. Actually, Mr. Maxton points out, most of the dollar gains in physical and financial values of farms and farm products are inflationary.

Reservists Came, Saw and Learned

One hundred Research Reservists (see photographs opposite) representing many different fields of science and technology, have departed Washington much the wiser in the ways of Navy research as a result of the Fifth annual seminar which ended June 23. In two weeks the officers heard lectures by such Navy notables as Rear Admiral Calvin M. Bolster, Chief of Naval Research, Dan A. Kimball, Secretary of the Navy, and many others; they also toured almost every important naval activity in the Washington area.

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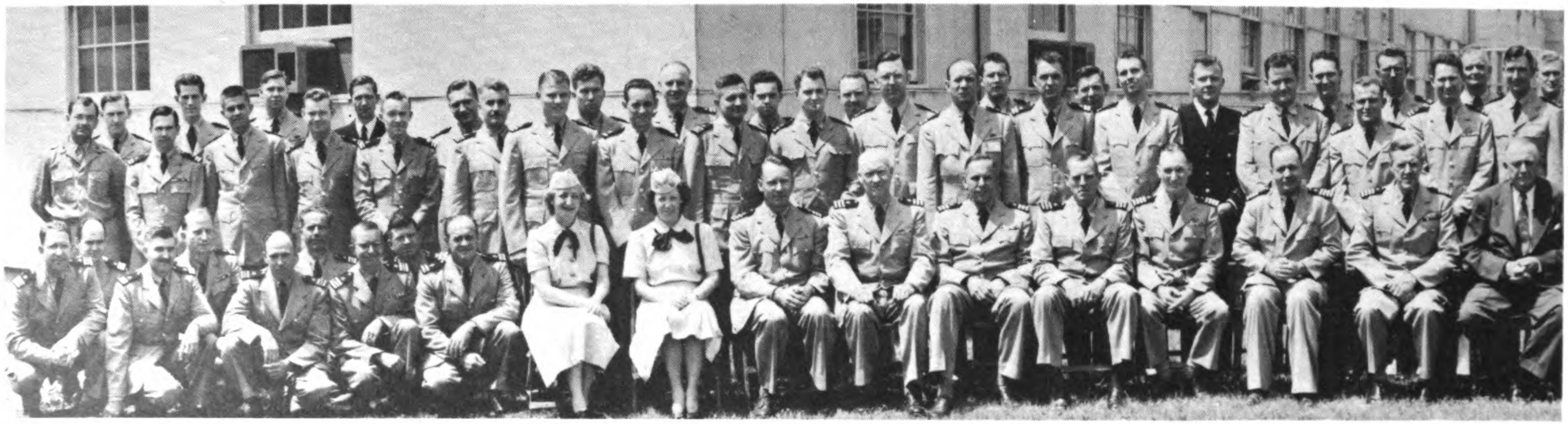
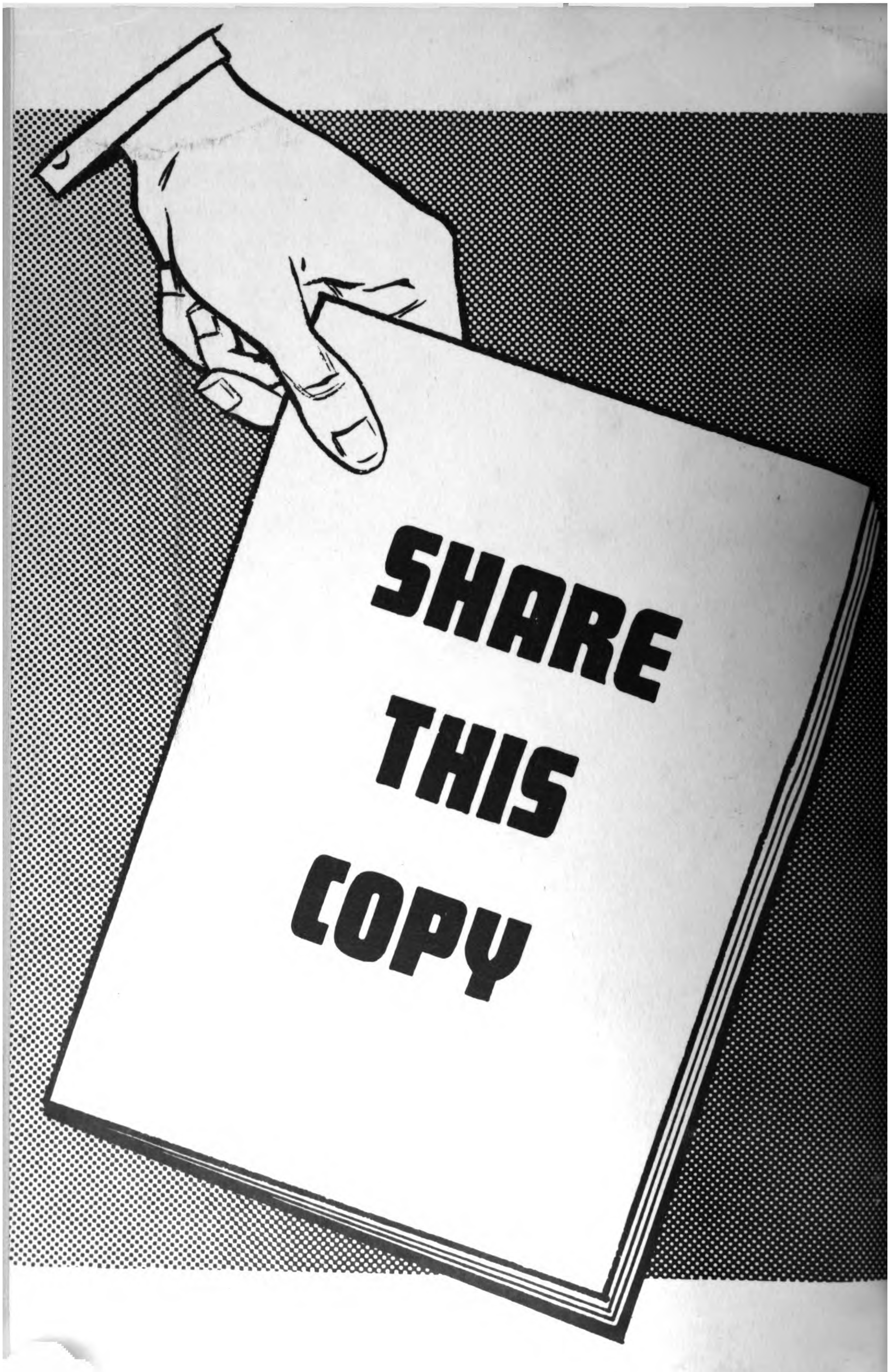


FIFTH ANNUAL ONR WASHINGTON SEMINAR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