RESEARCH REVIEWS

15 NOVEMBER 1948

OFFICE OF NAVAL RESEARCH

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NAVEXOS P-510

COVER PHOTO: V-2 rocket in flight. The V-2 rocket, developed in Germany during World War II, travels at velocities up to five times the speed of sound. One method of studying phenomena associated with objects traveling at supersonic velocities is described in the article beginning on page 1.

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Approved by Bureau of Budget, 13 April 1948

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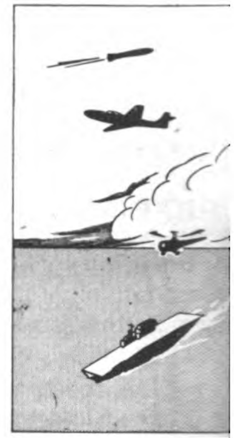

It is the opinion of some persons that the reason for the great versatility of Leonardo da Vinci, the remarkable fifteenth century Italian painter, sculptor, musician, engineer, scientist, inventor, et al., lies in the meager knowledge of the day in all these fields. It hardly detracts from Da Vinci's genius to acknowledge some truth in the opinion. We cannot find among the world's greatest men of our day anyone who has achieved comparable eminence in so many and widely diverse fields. Nor do we expect to find anyone. Knowledge has undergone a chain reaction.

With the expansion of knowledge there has been a relative contraction of the boundaries of the individual scientist's field of endeavor. As the growth of science brought successive divisions of effort into various separate branches, the scientist became further removed from an increasing number of his fellows. The modern scientist cannot be a jack of all trades; the specialist in one field is a layman in another. The scientist, too, must keep abreast of science. He, too, needs reports which are convenient and clear and which require a minimum of reading time.

Beginning with this issue *Research Reviews* adds to its readers the scientists engaged in Naval research under ONR contract. The mission of *Research Reviews* to inform the Fleet of current research makes it advisable to keep the scientists doing the research informed of work going on in all fields of Naval research.

To issue a publication which serves the Fleet and the scientists requires a knowledge of their needs, desires, and opinions. The easiest way to obtain this knowledge is through correspondence. *Research Reviews* welcomes comment from the scientists as it does from Fleet personnel. With our readers' help, *Research Reviews* can become an effective instrument for informing the Fleet-scientist team.

A PICTURE OF SPEED

Rudolf Ladenburg
Princeton University

For a long time it seemed that nature had set an upper limit to the speed with which a man can travel by airplane. This apparent limit was the velocity with which sound travels through the air, that is, about 770 miles per hour at 70° Fahrenheit and somewhat less at the low temperature in the stratosphere.

The speed of sound plays such an important role in the science of aerodynamics that it is used as the unit of velocity. Instead of measuring the speed of an airplane, projectile, or rocket in miles per hour one speaks of "Mach numbers" (M). This unit of velocity was named Mach in honor of the Viennese physicist and philosopher Ernst Mach, who was the first to study phenomena of speeds faster than sound.

"Mach number equals one" (M = 1) means a velocity just equal to sound velocity at the local temperature. Up to about that speed the air resistance, drag, and lift of an airplane, for example, behave quite regularly; they increase in a smooth way with increasing speed. When the Mach number reaches unity anywhere on the wings or body of the airplane, however, the regular behavior of the air resistance breaks down and new phenomena occur which endanger the flight.

Only recently has anyone been able to penetrate the natural barrier and to enter the field of "faster-than-sound." The penetration of this barrier has given impetus to research in this field. Studies such as those undertaken at Princeton University under a contract with the Office of Naval Research are necessary to an understanding of the phenomena associated with objects traveling at "supersonic" speeds.

At supersonic velocity the compressibility of the air plays a decisive role. When the nose of the airplane, or of any object, hits the air with

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Rudolf W. Ladenburg, professor of physics at the Palmer Physical Laboratory of Princeton University, received his Ph. D. degree at Munich, Germany (1906) with W. C. Roentgen. After working with J. J. Thomson (1906-07) at Cavendish Laboratory, Cambridge, England, he held various positions in Germany as instructor, lecturer, professor, and finally as head of the Physics Department of Kaiser-Wilhelm Institute for Physical Chemistry at Dahlem/Berlin, where he remained until 1931. At that time he came to Princeton University as Brackett Research Professor of Physics.

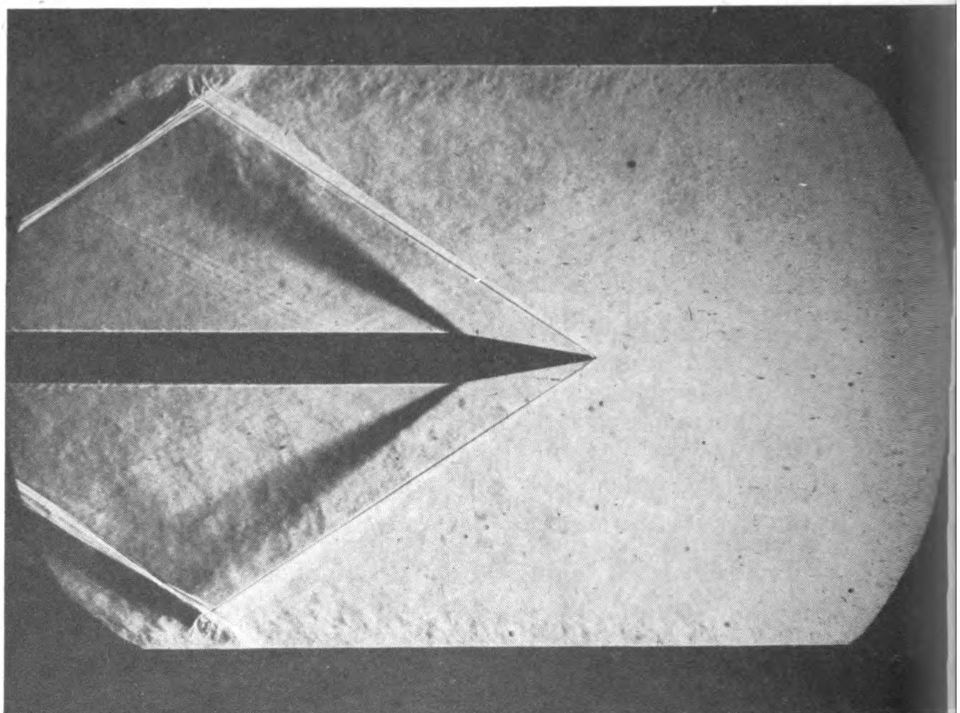

Figure 1. At nearly 1800 miles per hour relative speed, this wedge-like object is in reality standing still while the high speed air of the wind tunnel passes around it. The direction of the air is from right to left. This photograph tells scientists where the shock waves are produced and where the air density changes.

supersonic velocity the air is highly compressed and forms "head waves" or "shocks," similar in many respects to the conspicuous bow waves which a fast boat produces on the surface of the water. These bow waves are a familiar sight. The shock waves in air are also easily visible. The density increases abruptly in these shock fronts and deflects the light waves from their straight path. That these shock waves can be photographed was shown 80 years ago by Mach.

Figure 1 is a photograph of a wedge-like object at M = 2.3, obtained by the "schlieren method." Light deflected in the compressed air near the shock and in the expanded air at the shoulder of the object produces brighter and darker regions on a sensitive photographic plate. In figure 1 the object was not moving, but was held fixed in position and the air was blown against it with the high speed--an elementary application of the principle of relativity. This principle is used in most cases where one wants to get information about aerodynamical behavior, about lift and drag of a special object such as an airplane wing or a projectile at high speed.

For such studies large wind tunnels have been built where the airflow around a real airplane or around a large rocket of natural size may be investigated by measuring lift and drag. These enormous wind tunnels cost millions of dollars. They are especially costly if built for the study of speeds faster than sound, and it is nearly impossible to build the tunnel large enough to have space for modern large rockets which reach M = 5, like the German V-2. So one is obliged to work with a smaller wind tunnel, using smaller, geometrically similar models of aircraft and rockets; but the Mach number and other conditions must be right to give reliable results which are valid for the actual object. Such smaller wind tunnels of perhaps a few inches in cross section are within the scope of a university laboratory.

Wind tunnels are also cheaper to build and easier to handle if they need not run for many minutes. Mechanical measurements of pressure, lift, and drag on a large object, however, demand that the tunnel operate for many minutes. In the intermittent wind tunnel for optical studies of supersonic speeds, built recently in the Palmer Physical Laboratory of Princeton University, only very short periods of operation are necessary. Less than a second is sufficient time to establish the air flow and to

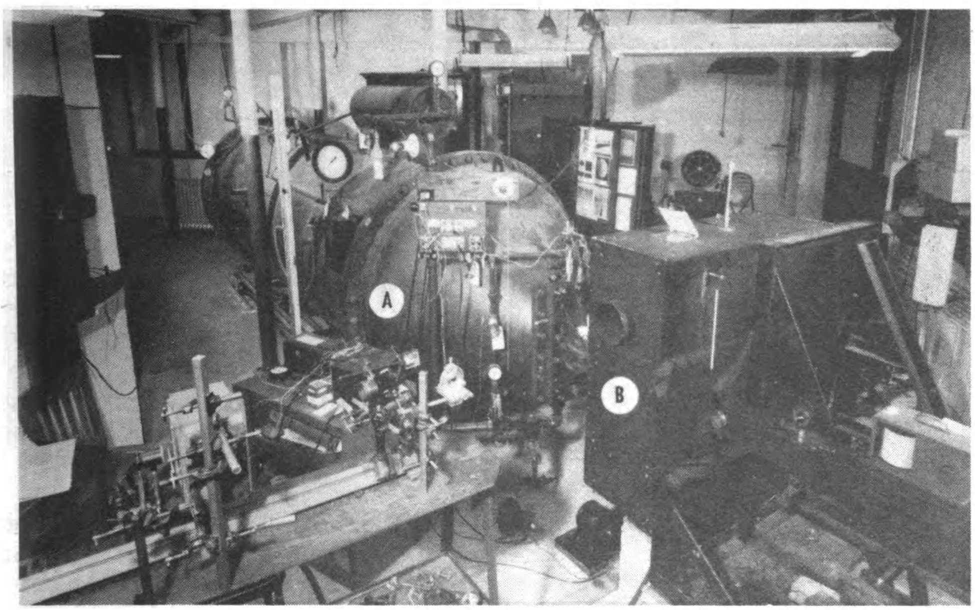

Figure 2. The laboratory in which the optical studies of faster-than-sound phenomena are carried on. A indicates the tank in which compressed air is stored prior to its passage through the channel. The optical apparatus and test section of the channel are hidden by the box (B).

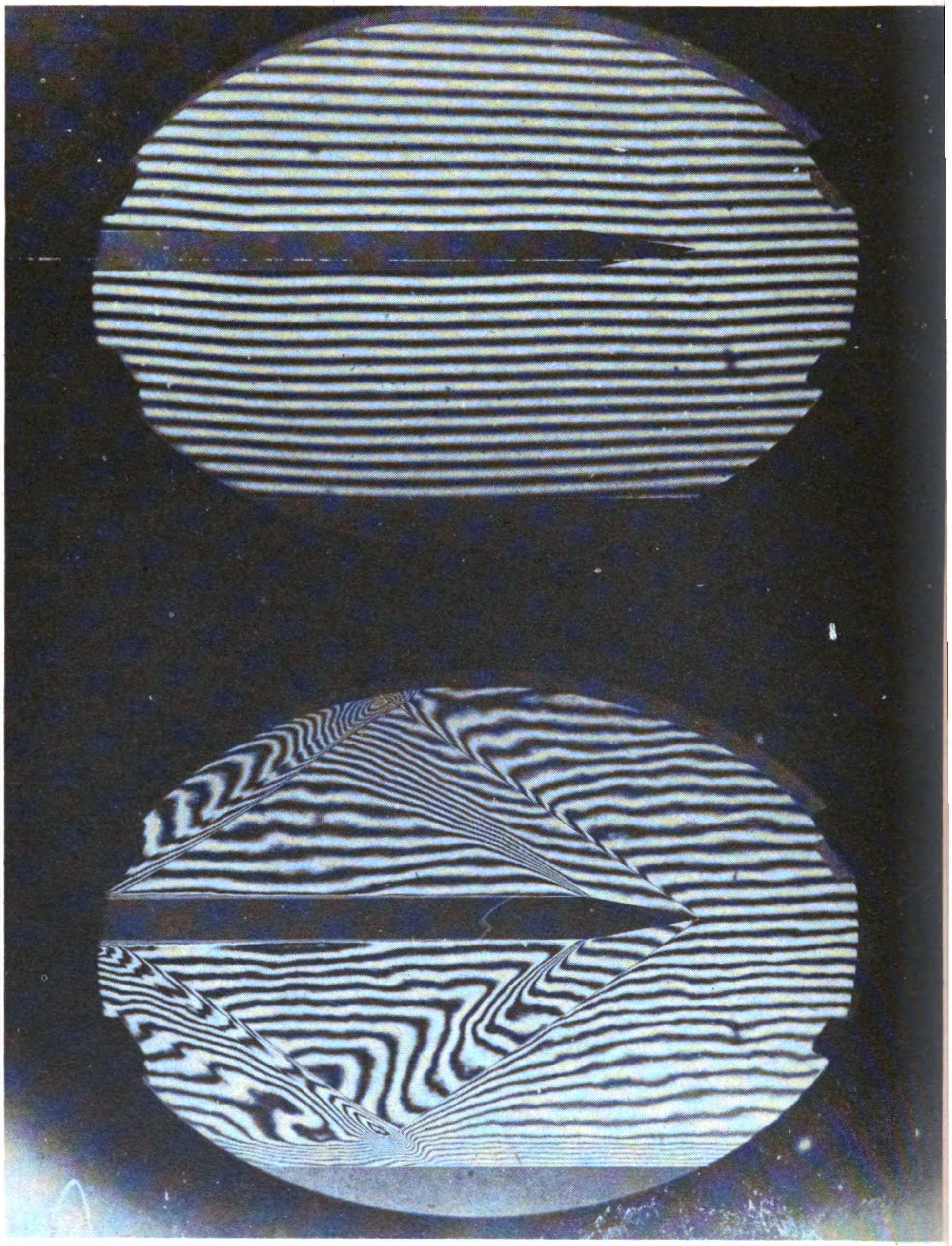

Figure 3. "Interferometer" photographs. A special optical instrument produces straight, parallel lines when the air is at rest, as shown in the upper photograph. The flow of air in the lower photograph (from right to left) causes the lines to shift in accordance with the air density. Scientists are able to make quantitative computations on air density, pressure, temperature, and velocity from these interferometer photographs.

photograph the object and the surrounding air waves. Supersonic speeds up to M = 4 may be studied in this wind tunnel, in which the experiences of Mach are utilized to such an extent that only optical means are applied for obtaining all the information wanted. This method avoids any disturbances which mechanical gadgets inside the supersonic working section would produce.

Figure 2 shows the laboratory with the necessary instrumentation. Compressed dry air is stored in the large tank (A). When a pressure-operated sliding valve is opened for a moment the air escapes into an evacuated rectangular channel connected through pipes with a second large tank outside the laboratory. The channel converges first to the "throat," the narrowest part, where the air speed reaches just sound velocity; then the channel widens up and the air, expanding and getting thinner and cooler, speeds up more and more and reaches the "test section," carefully constructed in such a way that the gas obtains the supersonic speed desired. This speed is determined only by the size of the "throat" and of the "test section" of the channel and does not increase or decrease when the pressure in the tank changes; only the density and the amount of the flowing gas is subject to change. The speed of the air always just reaches sound velocity in the throat and is then speeded up according to the size of the test section. For other speeds and other Mach numbers one has to construct other wind tunnels.

The channel carries optically ground and polished windows through which light from an illuminating electric spark can pass to produce the schlieren picture mentioned before. The optical arrangement used and the essential part of the channel are hidden in figure 2 by the box (B) which includes the mirrors and lenses.

An opening valve or a special pressure switch releases the spark which illuminates the object in the channel and the surrounding air waves for a millionth of a second so that their momentary conditions are "frozen" in the picture. In the next moment the valve is closed again. The whole operation lasts less than a second and 10 or 15 minutes later the next picture can be taken after the tank has been refilled and the tunnel evacuated again.

Neither the engineers nor the scientists, however, are content with nice looking pictures, such as figure 1, which tell only in a qualitative way where the shocks are produced and where the air density changes. They also want quantitative data, numerical values which permit computation of, for example, the pressure distribution around the object and which possibly lead to new information about the general laws of nature. Here a special optical instrument comes into play, the "interferometer" --contained in the box (B) of figure 2. This instrument produces black and white "fringes" on the photograph (fig. 3). These fringes are straight and parallel to each other as long as the air is at rest. When the air flows, the fringes are shifted due to the changed density; they are curved and "broken." Careful measurements under a microscope tell how much the fringes are shifted in the flow picture from those in the picture where the air is at rest. One is able to compute in a quantitative way how much the density has changed and, by the use of well-tested aerodynamical relations, to calculate pressure, temperature, and velocity in the whole field of view.

It is through studies such as this ONR-sponsored project at Princeton University that one acquires new information not otherwise obtainable, thus opening up new fields of knowledge.

Sparkplugs in Science

Roger Bacon showed the world, for the first time, the importance of scientific observation and experiment. This remarkable man was born at Ilchester in Somerset, England, in 1214. After studying at the University of Oxford and in Paris and Italy, he eventually returned to Oxford, and became a Franciscan monk in 1251. In an age when "science" was largely synonymous with the alchemists' search for the philosopher's stone and attempts to transmute base metals into gold, Bacon displayed a scientific vision far in advance of his era. He foresaw the possibility of mechanical flight, the use of explosives, the improvement of sight by lenses, and the propulsion of ships by engines.

In all his teaching he insisted on the importance of experiment rather than discussion, and on the necessity for first-hand practical experience, particularly of such chemical operations as distillation and calcination. He saw clearly that, without this practical foundation, natural science was little more than a collection of words. One result of his insistence on experiments was to enable him to show that air is necessary to sustain combustion. He has also been credited, but without adequate evidence, with the discovery of gunpowder. Some explosive mixture was undoubtedly known in Western Europe in his time, for Bacon complained of the annoyance caused by boys setting off fireworks outside his study. He died on 11 June 1292, leaving as his contribution to science a way of thought which still persists all over the world. Roger Bacon may justly be described as the first modern scientist.

TAKING THE "ANTI" OUT OF ANTIORGAN SERA

C. M. Pomerat
University of Texas

Antiorgan sera were originally developed in 1899 in the laboratory of Elie Metchnikoff, a Russian bacteriologist, at the Pasteur Institute in Paris. Recently Soviet workers under the leadership of the late Alexander Bogomolets have called attention to the use of these antiorgan sera, known also by the more technical name of antireticular cytotoxic serum (ACS). The sera were used in the treatment of a wide variety of diseases involving the connective tissues, those tissues which bind together the organs of the body and hold them in place.

Antiorgan sera are prepared to contain antibodies which act on cells of the spleen and bone marrow. High concentrations of these antibodies may produce injury to the cells. Very low concentrations, however, are believed to stimulate the mobilization of bodily defenses against infectious processes. They may also assist in bone repair and possibly aid in the treatment of malignancy and of mental diseases.

Research studies in this field have been carried on at the University of Texas. These studies have not yet uncovered conclusive evidence

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C. M. Pomerat, professor of cytology in the Department of Anatomy of the University of Texas--Medical Branch, is also director of the University's Tissue Culture Laboratory which he and Dr. C. D. Leake, vice president of the University of Texas and head of the Medical Branch, set up about five years ago. The main objective of the Laboratory is to intergrade the work in preclinical and clinical fields. Dr. Pomerat, whose teaching is in the field of anatomy, encourages students to take part in studies in dynamic morphology so that they may collaborate in group projects under investigation with members of the departments of surgery, medicine, dermatology, obstetrics, and pediatrics. This development is an exciting experiment in medical education. Dr. Pomerat received his A.B. degree from Clark University (1932) and his A.M. (1934) and Ph.D. (1937) degrees from Harvard University. He was a Rockefeller Foundation Traveling Fellow (1937-38) at the University of Buenos Aires, Argentina, and at Cambridge University, England. He has also studied at Oxford, England, and lectured at medical schools in Mexico. His professorial appointments include positions at Clark University, Rutgers University, the University of Alabama, and the University of Texas. He is a member of some ten scientific societies and contributor to professional journals and other scientific publications. Dr. Pomerat's studies have taken him on an expedition to Hudson Bay, Canada, to West Indian Islands, Venezuela, and British Guiana, and on six trips to Mexico. He has directed a subtropical marine laboratory at Miami and has conducted research for the Navy's Bureau of Ships under sponsorship of the Woods Hole Oceanographic Institute.

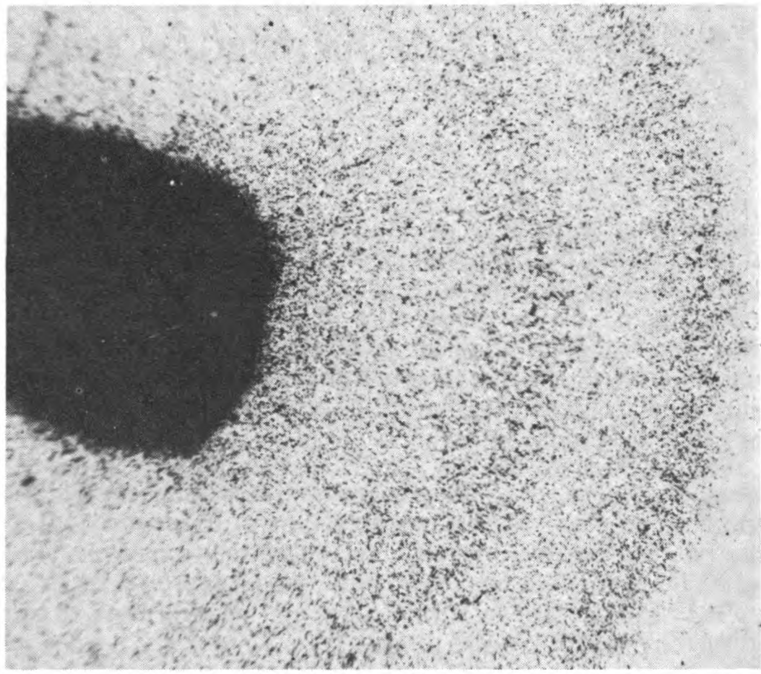


Figure 4. Photomicrograph at low power magnification of a tissue culture used as a test object in looking for a substance which may promote the formation of large macrophages. The dense black mass on the left is a small piece of chick spleen. The little dots are cells in the process of migration from the spleen 24 hours after incubation at body temperature.

which might lead to new remedies, but they have opened pathways believed fundamental in our understanding of the mechanism of infection and resistance. A dozen scientific papers have been published concerning these investigations. A key to this literature is provided in two recent popular reviews.*

Work now in progress under the sponsorship of the Office of Naval Research is devoted to finding out more about the biochemical mechanisms associated with the effects produced by antiorgan sera. In one study a complicated series of reactions known as the Warburg-Keilin system was studied. This is a chemical system involved in the oxygen-carbon-dioxide exchange of cells and tissues. It was found that antiorgan serum concentrations adequate to bring about much damage to cells in tissues produced no changes in cellular respiration. The biochemical mechanism of respiration, then, is not associated with the effects

*"A Review of Recent Developments on Reticulo Endothelial Immune Serum (REIS)," Quarterly of Phi Beta Pi, Vol. XLII, No. 4, January 1946, p. 203.

"Therapeutic Possibilities of Antiorgan Sera," Interne, Vol. 13, No. 10, October 1947, p. 449.

produced by antiorgan sera. The effect of antiorgan sera on other enzyme systems is being systematically explored.

One of the factors which might be involved in the favorable action of low concentrations of antiorgan sera is the production of special defense cells known as macrophages. Tissue culture studies, in which cells and tissues are kept alive and growing in a test tube, have shown that antiorgan sera have occasionally produced these macrophages. This is not a regular occurrence, however. Moreover, the blood serum of some rabbits which have not been treated with the antiorgan serum occasionally appears to have the same power of macrophage production.

The results of these investigations indicate that the factor responsible for macrophage production in the serum of some normal animals may be produced by bodily processes which parallel processes used in the preparation of antiorgan sera. Experimental results may eliminate the possibility that this factor is a naturally occurring antibody. It is hoped that work currently in progress will reveal the nature of the serum factor inducing macrophage formation, if not the specific factor; for example, whether the factor is choline or some other substance resembling quanternary ammonium compounds.

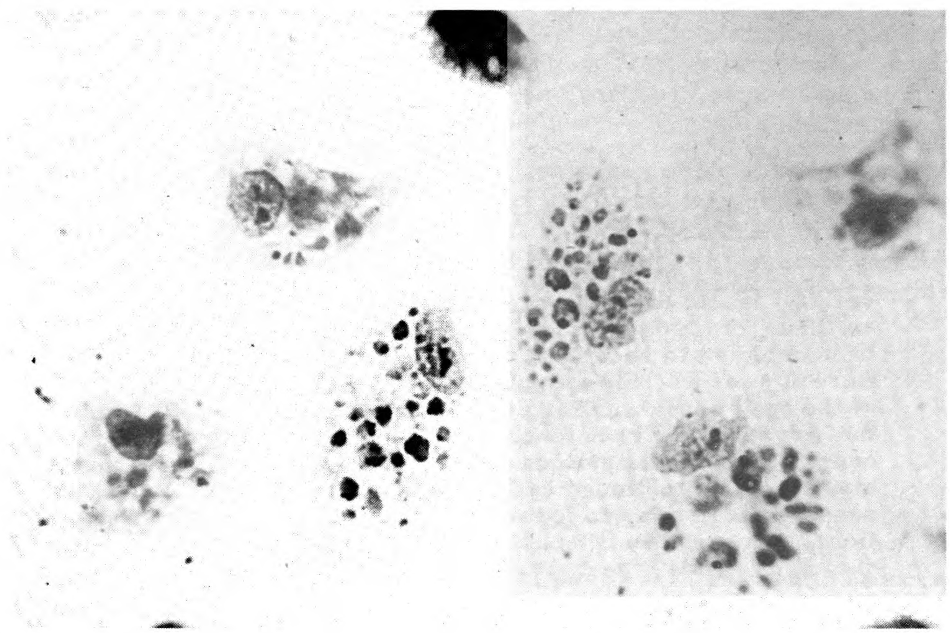


Figure 5. Photograph taken at approximately 660 times magnification to show macrophages in cultures of the type shown in Figure 4. Macrophages have a scavenger function in the removal of dead cells and debris. In the photograph 7 cells are represented. Each has an oval-shaped nucleus outside of which may be seen cytoplasm which is filled with devoured cell fragments. This culture had been treated with the serum of a normal rabbit, which contained a macrophage stimulating factor.

Besides inducing the formation of macrophages, antiorgan sera have been found to protect guinea pigs against inoculations of virulent strains of typhus and spotted fever. In these experiments, test serum is injected into the skin. One hour later an injection of the infectious organisms is made. If the serum affords adequate protection to the animal, no fever results.

The protective factor in antiorgan preparations has not yet been isolated. The mechanism of processes resulting from the action of this factor has not yet been explained. The explanation of this mechanism is the goal of the project under ONR sponsorship at the University of Texas. Several approaches to the problem are being made. Certain biochemical tests on the nature of the compounds involved are being studied. The effect of choline-like compounds is being compared to that of antiorgan serum. The role of the enzyme hyaluronidase in the activity of antiorgan sera is being investigated. Further work is being done in preparations of the skin to show macrophage production. Results of these combined studies will help to explain how the unisolated protective factor in antiorgan preparations acts.

Among the ONR Contractors

W. T. Salter, professor of pharmacology at the Yale University School of Medicine, is the principal investigator on an Office of Naval Research contract in physiology. He has been selected to receive the first $1,000 Iodine Educational Bureau award. This award will be presented to Dr. Salter at the next annual meeting of the American Association for the Advancement of Science, when he will present a review paper on his investigations. Dr. Salter was recognized for his "long and continued basic research relating either directly or indirectly to iodine, and his impressive contributions of more than 30 publications on this general subject during the past 10 years."

A NEW APPROACH TO CORROSION

Pierre Van Rysselberghe
University of Oregon

In spite of the constant accumulation of an enormous technical literature, the field of corrosion is in serious need of new fundamental methods of experimental investigation and of new theoretical ideas supported by sound data. In particular, the resources of theoretical electrochemistry and of chemical thermodynamics should be drawn upon much more fully than has been the case in most of the corrosion research programs. Only in a few centers, and around a few individuals whose work is often insufficiently known, can it be said that the research point of view is truly "fundamental." The urgent and costly practical aspects of corrosion no doubt account for the predominance of applied research. It is, however, a frequently occurring fact that a modest research project of a fundamental nature can save considerable time and money by making large scale empirical research projects useless.

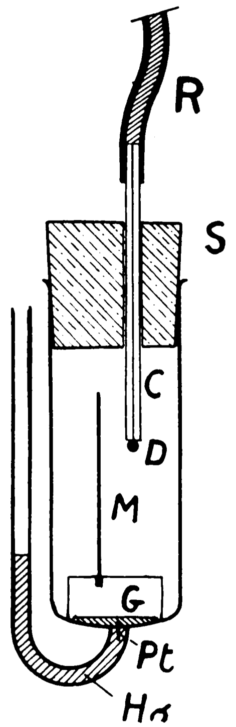
When it is realized that even such a familiar corrosion phenomenon as the rusting of iron is not yet understood in all its details, the need for more fundamental research is brought home in a striking manner. When it comes to explaining more obscure corrosion reactions, a brief look at the literature, even at elaborate treatises, shows that we are far from a comprehensive understanding of the whole field of corrosion.

As a possible contribution to the fundamental physical chemistry of corrosion our group at the University of Oregon suggested to the Office of Naval Research in the spring of 1946 that a fruitful approach to corrosion phenomena might be based on the systematic use of the instrument called polarograph, which had already proved itself extremely useful in a number of other fields.

Pierre Van Rysselberghe is professor of chemistry at the University of Oregon, Eugene, Oregon. He received engineering degrees from the University of Brussels, Belgium, in 1924 and 1927. He came to this country as a Research Fellow of the Belgian American Educational Foundation and obtained M. A. and Ph. D. degrees in physical chemistry at Stanford University (1928 and 1929). He taught at Stanford University from 1929 to 1941, at which time he joined the staff of the University of Oregon. In 1935-36 he was Visiting Lecturer in the Belgian universities, under the auspices of the Belgian American Educational Foundation. His research activities have been in the fields of solutions of electrolytes, thermodynamics, electrochemistry, and polarography. At present he is directing a research project under ONR contract on the application of the polarographic methods to corrosion phenomena.

In polarographic studies the object is not to watch a metal corrode and then weigh the product of corrosion, such as putting a piece of iron in a solution and seeing how much it rusts. The object of the polarographic study is to observe the effect of a metal on a chemical system, to determine how this system operates in the process of corrosion. The determination is based on certain reactions occurring in the system at various electrical potentials.

The polarographic equipment consists essentially of two parts--an electrolysis cell and an instrument to apply electrical potentials and record the resulting currents. Figure 6 is a diagram of the electrolysis cell. Increasing potentials are applied between the large mercury anode at the bottom of the glass cell and the very small cathode which is a constantly renewed drop of mercury hanging from the tip of a capillary tube with an internal diameter of the order of 0.01 to 0.03 millimeter. The head of mercury is so chosen that the drops succeed themselves at intervals of two to three seconds. The solutions electrolyzed in these cells consist, usually, of tenth-normal solutions of a "supporting electrolyte" to which the "reducible substance" to be studied is added. The supporting electrolyte is a solution which will conduct the current without affecting the reaction of the reducible substance. A supporting electrolyte might be potassium chloride, hydrochloric acid, or sodium hydroxide; a reducible substance might be oxygen or carbon dioxide. The reducible substance is added in amounts much smaller than the concentration of supporting electrolyte. The range of potential is from zero to the reduction potential of the positive ion of the electrolyte (about two volts for the commonly used potassium ion). The electrolysis of the reducible substance is first observed without the metal strip. Then the metal strip is added to



R Rubber tube leading from source of mercury
S Stopper
C Capillary tube
D Drop of mercury (cathode)
M Metal sample
G Glass ring
Pt Platinum
Hg Mercury (anode)

Figure 6. Polarographic cell used in corrosion tests. The cell is filled with a solution consisting of the supporting electrolyte and the reducible substance under study. The corroding metal sample is kept in a vertical position away from the mercury drops through a slit in a glass ring resting on the pool of mercury forming the anode. The function of the platinum is to insure electrical contact with the mercury of the anode.

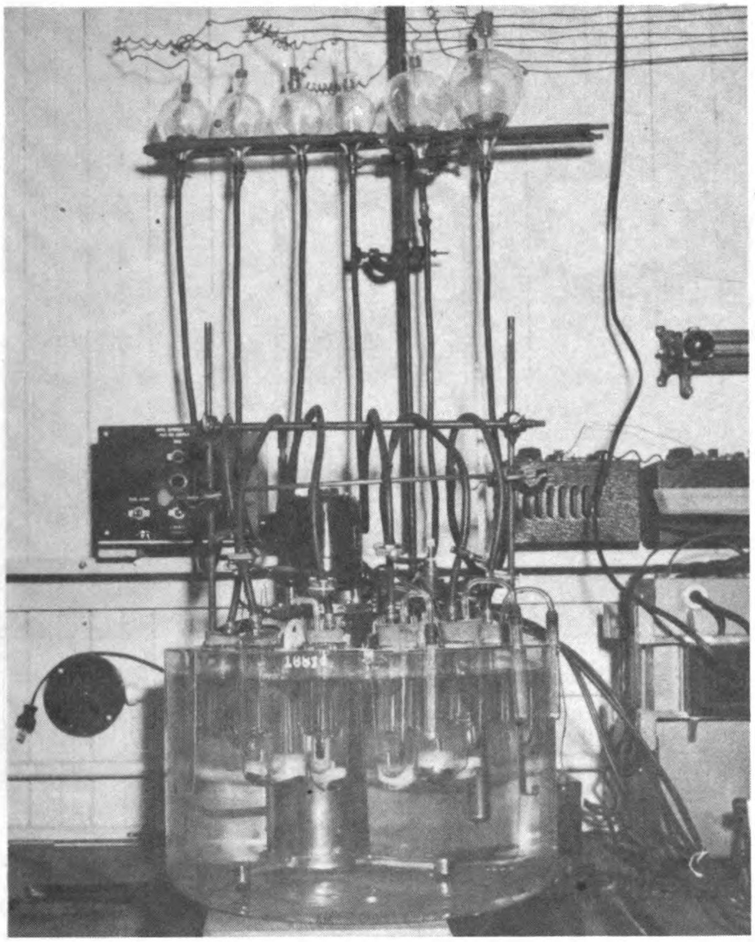


Figure 7. Apparatus for simultaneous study of several metal samples undergoing corrosion under controlled potentials. The current-voltage curves are registered by means of the portable polarograph shown in figure 8. With this apparatus corrosion can be followed as a function of at least three variables: potential of the corroding sample, pH of the medium, and oxygen concentration.

determine how it affects the reduction process. It is known that the metal strip corrodes, so the changes in the process are caused by corrosion, and something of the nature of corrosion is thus learned.

Figure 7 shows apparatus for simultaneous study of several metal samples undergoing corrosion under controlled potentials. The current-voltage curves are registered, for instance, by means of the portable polarograph shown in figure 8--the second part of the equipment. Other types of polarographs are shown in figures 9 and 10.

Figure 8. Portable polarograph designed and assembled at the University of Oregon by Dr. Paul Delahay.

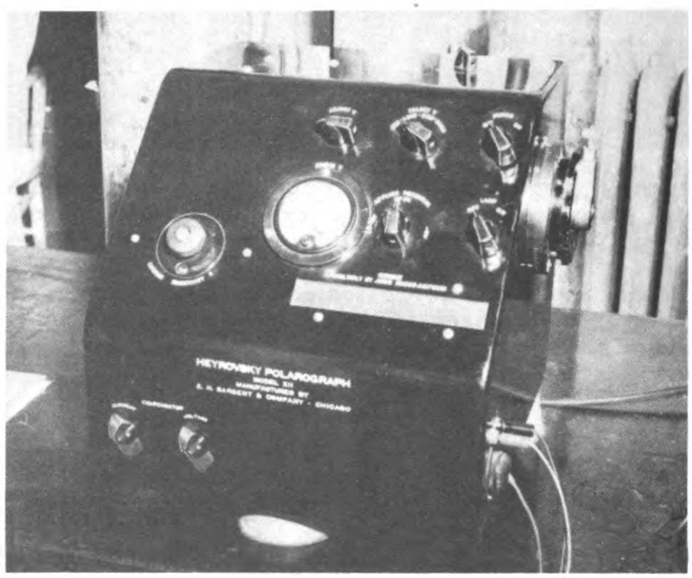


Figure. 9. Sargent Polarograph of the Heyrovsky type with automatic photographic recording of current-voltage curves.

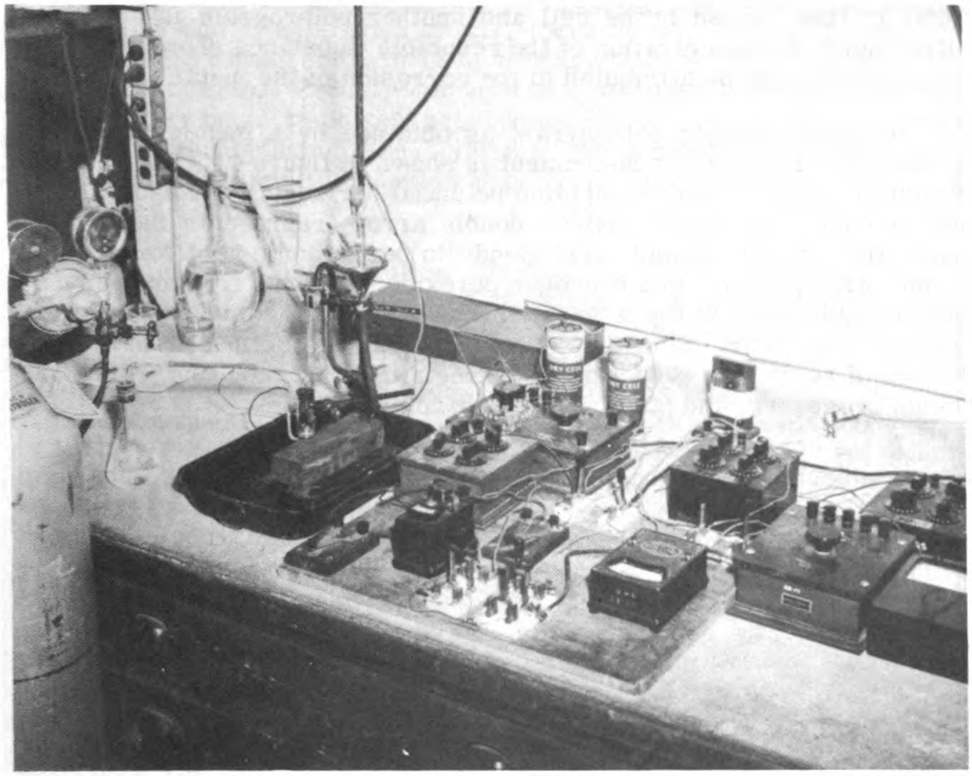


Figure 10. Manual polarograph assembled from standard physical chemical equipment.

Since the anode is much larger than the cathode, the minute electrolysis currents do not change the composition of the solution in contact with the anode, and its potential stays constant. The whole variation of applied potential therefore occurs at the dropping mercury cathode. Each reducible substance undergoes reduction when its own range of reduction potentials has been reached. The reduction causes a rapid rise of current followed by a leveling out which is the result of complete "concentration polarization" at the cathode; that is, the reducible substance in contact with the extremely small cathode has been completely exhausted--its concentration falls to zero. The reducible substance not in contact with the cathode must now arrive by diffusion, and the corresponding current (the flat portion of the curve) is called "diffusion current." The current-potential curve corresponding to a reduction is called a "polarographic wave," and the complete graphic record of successive polarographic waves is called a polarogram (see fig. 11).

The great usefulness of the polarographic method results from the fact that the height of a reduction wave is proportional to the concentration of the substance being reduced. A polarogram is first obtained for the reducible substances without the metal strip in the cell. The metal is then placed in the cell and another polarogram is obtained. Differences in concentration of the reducible substance shown by these polarograms may be attributed to the corrosion of the metal.

A typical oxygen polarogram as obtained by a photographic recording with the Sargent instrument is shown in figure 11. The current is plotted vertically and the applied potential horizontally. Reading from left to right, the first vertical double arrow represents the oxygen concentration, the second corresponds to percarbonic acid formed between carbon dioxide and hydrogen peroxide resulting from oxygen reduction, and the third represents the final step in the complete reduction of oxygen to water. Similar polarograms can be obtained with the reduction of acids, the reduction of the metallic ions resulting from corrosion processes, and other related phenomena.

In the corrosion of metals by aqueous solutions of salts, acids, and bases important substances are dissolved oxygen, carbon dioxide, and hydrogen ion, as well as water and the electrolytes themselves. Oxygen presents, in the polarograph, a very interesting succession of two waves, the first corresponding to the reduction of oxygen to hydrogen peroxide, the second corresponding to the complete reduction to water. When a metallic sample is placed in a polarographic cell its consumption of oxygen can be followed by measuring, at different time intervals, the height of the first oxygen reduction wave. With some metals and alloys there may be a certain amount of hydrogen peroxide formed through incomplete reduction of oxygen by the metal. This is easily detected through the fact that the second oxygen wave becomes higher than the first. In this manner we have been able to establish a proof of this often suspected phenomenon. Also, whenever

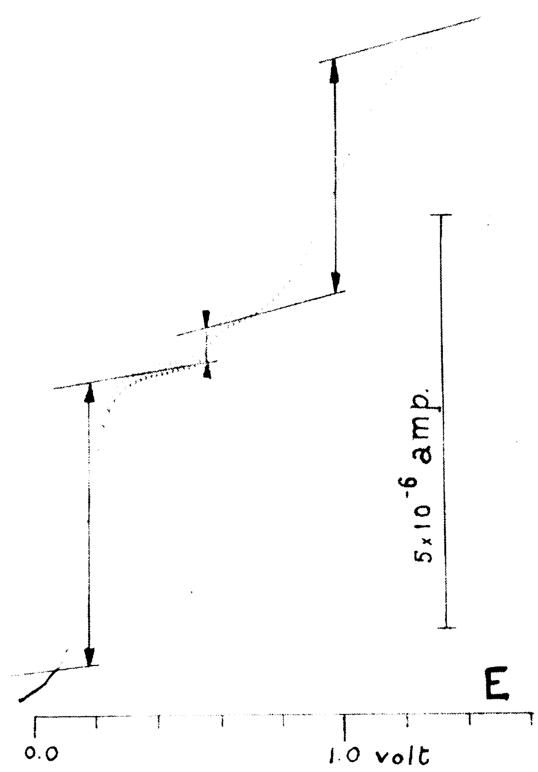
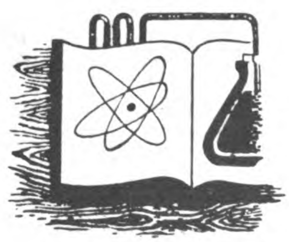


Figure 11. Typical polarogram obtained with oxygen and carbon dioxide in an air-saturated solution of potassium chloride.

a certain amount of carbon dioxide is present, even in the small concentrations due to saturation by air, there is formation of some percarbonic acid whenever there is hydrogen peroxide formed between the metal and oxygen. Percarbonic acid is a stronger acid than carbonic acid and may be an important accelerator of corrosion. The existence of percarbonic acid in these solutions was detected by means of the polarograph through its reduction at potentials intermediate between the two oxygen waves.

It is also possible to follow the consumption of carbon dioxide by metals through a wave occurring at potentials higher than two volts cathodic which, therefore, requires supporting electrolytes with higher reduction potentials than the potassium ion. Such electrolytes are quaternary ammonium salts which are important materials in this type of corrosion research. When the corrosion process results in the formation of dissolved metallic ions from the corroded metal, these ions can also be detected and their concentrations can be determined by means of their own polarographic reduction waves. Studies of this sort give us important information on the kinetics and mechanism of corrosion which it would be very difficult to obtain otherwise. The method also has the advantage of rapidity because some information about the corrosion tendencies of any metal can be obtained after only a brief period of immersion, thanks to the very great sensitivity of the polarographic method.

As a whole the polarographic method used in these ONR-sponsored studies at the University of Oregon promises to be a very valuable new tool in the extremely important field of corrosion research.



ON THE BORDERLINE OF PURE AND APPLIED MATHEMATICS

G. Polya
Stanford University

Some members of the department of mathematics of Stanford University are at work under Office of Naval Research sponsorship on a project entitled "Dependence of the Capacity on the Geometric Form of the Conductor." This project, which has somewhat outgrown its title, emphasizes a promising and scarcely known aspect of some of the classical problems of mathematical physics.

The project has developed an unusual synthesis of pure and applied mathematics. Perhaps it would be well to begin with a broad description of what an "applied mathematician" usually does, or is supposed to do. An applied mathematician is a physicist himself, or an engineer, or a mathematician who works in close contact with physicists and engineers. In constructing a new machine or planning a new experiment, engineers and physicists may need the numerical value of a certain physical quantity, and it is the task of the applied mathematician to compute that numerical value.

The variety of physical quantities the computation of which may be required is limitless. Take, as an example, a plane figure such as a circle, a square, or a semicircle. We may need the numerical value of the area of such a figure, or the length of its perimeter, or its moment of inertia with respect to some axis. These quantities are relatively easy to compute, but there are many others which are more difficult. The given figure may be the cross section of an elastic shaft, and we may need the torsional rigidity of the shaft. Or the figure may be the contour of a vibrating membrane, and we must know the frequency of vibration when the membrane emits its deepest tone (the so-called "principal frequency"). Or a metallic plate may have the given shape,

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George Polya, professor of mathematics at Stanford University, studied at the universities of Budapest, Vienna, Goettingen, and Paris. His Ph. D. was conferred by Budapest University (1912); he also has an honorary degree, Sc. D. in Mathematics honoris causa, from the Swiss Federal Institute of Technology (École Polytechnique Fédérale) of Zurich (1947). Dr. Polya entered the Zurich Institute of Technology as instructor in 1914 and left it as Dean of the School of Mathematics and Physics in 1940. He has been at Stanford since 1942. He was a Rockefeller Traveling Fellow in 1924-25 in Oxford and Cambridge, England, and a corresponding member of the Académie des Sciences, Paris in 1947. Jointly with Gabor Szegö, Dr. Polya directs the Office of Naval Research project discussed.

and the electrostatic capacity of that plate (against a very large sphere) may be required. An applied mathematician must face all these and many other such demands.

It must be confessed, however, that usually he cannot give an exact answer--usually he can give only an approximation. Yet an approximate value will do in practice, provided that the difference from the exact value is known to be sufficiently small. And so applied mathematicians must spend much of their time in devising methods of approximate computation.

An obvious method is to modify the problem by changing the proposed figure and to compute the desired physical quantity, not for the proposed, but for the changed figure; if an exact solution can be obtained for the latter, the method works. A drawback of this simple scheme is that it is not completely reliable, because it is usually very difficult to predict how much or in which direction such a change in the figure will influence the value of the desired quantity.

Our project tends to blend this kind of "applied" work with "pure" mathematics, which is more concerned with logical generality or with esthetic appeal than with single cases. We have succeeded in deriving some striking results, one of which is presented here.

Consider A, B, and C in figure 12. A is the quadrant of a circle with radius a. B is a semiellipse with minor axis a (along which the full ellipse has been bisected) and with major axis 2a (only the semiaxis a belongs to our semiellipse). Finally, C is a full circle with diameter a.

These figures are derived from each other by a simple geometric operation called "symmetrization." We give no formal definition, but the inspection of the figures may suggest what is meant by symmetrization. A, the quadrant of a circle, has no vertical axis of symmetry, but B has such an axis, and shifting each layer (row of squares) horizontally, we change A into B. Again, B has no horizontal axis of symmetry, but C has such an axis, and shaking down each slice vertically we change B into C. Now C is obtained from B, and B from A by symmetrization.

The remarkable thing about symmetrization is that this geometric change influences the value of several physical quantities in a predictable manner. Here is the full statement: Symmetrization does NOT CHANGE the area at all, DECREASES the perimeter, the polar moment of inertia with respect to the centroid, the principal frequency, and the electrostatic capacity, and INCREASES the torsional rigidity.

What we have just stated is a mathematical theorem of great generality and rare esthetic appeal. (As our work started, only the simplest

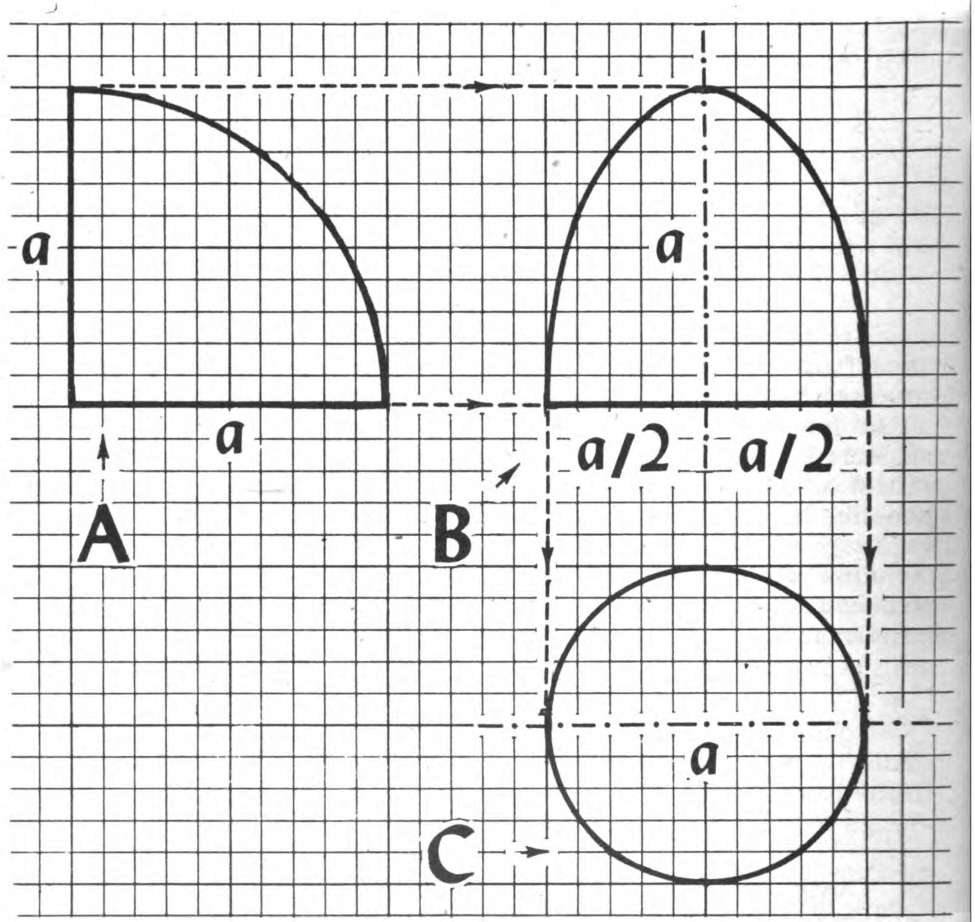

Figure 12. Symmetrization.

part, concerned with area and perimeter, was known, which was discovered by Jakob Steiner about 100 years ago.) Yet this theorem has also some practical use.

High school mathematics is enough to compute the perimeter of a circle (C) or that of the quadrant of a circle (A). Yet the knowledge of an average high school graduate is not enough to compute the perimeter of an ellipse or that of a semiellipse (B). We have been told, however, that symmetrization diminishes the perimeter. Therefore, the perimeter of C is less than that of B, and this is less than that of A. That is, the perimeter of B, the semiellipse, is contained between that of C, the full circle, and that of A, the quadrant of a circle. And so we have obtained with high school knowledge precise and reliable information about the perimeter of the ellipse, the exact computation of which needs much more than high school knowledge.

The following table derives estimates for B from well-known results about A and C.

Quantity computed	Circle (exact)	Quadrant (exact)	Semiellipse (approximate)	Limit of error
Perimeter	3.14	3.57	3.34	6.4%
Moment of inertia	0.10	0.11	0.10	5.6%
Torsional rigidity	0.10	0.08	0.09	8.6%
Principal frequency	4.80	5.14	4.97	3.4%

The approximate value in the fourth column is computed as a mean value (harmonic mean) of the exact values in the second and third columns. The last column gives the extreme limit of the error of approximation in percentages of the (unknown) true value. We take $a = 1$.

The foregoing simple example opens a new perspective. Symmetrization enables us to obtain ready and reliable approximations for physical quantities more interesting and less accessible than the perimeter. There are other examples in which the same method leads to much sharper approximations, and other methods of approximation have been developed in our project, although perhaps none is more intuitive than symmetrization.

Significant "Firsts"

The funds allocated in 1879 for experiments to determine the velocity of light probably constituted the Navy's first appropriation for basic research. With the $2,000 so provided, Master A. A. Michelson, USN, completed development of his phototachometer; by measuring the angle through which the high-speed mirror of this device moved during the time a beam of light was reflected from it, along a base line of known length and back again, Michelson was able to determine the velocity of light to an accuracy of 1 part in 10,000. The measurements were made along base lines of 2,550 meters from Fort Whipple--now Fort Meyer, Virginia--to the Naval Observatory and the foot of the Washington Monument. From this noteworthy beginning, Michelson went on to become the first American Nobel Prize winner in physics.

LOOKING AT THE ATOMIC NUCLEUS THROUGH GAMMA RAYS

G. P. Harnwell and L. Cranberg
University of Pennsylvania

The Navy is keenly aware of the importance of science to national defense, and the current resurgence of research has been greatly aided by Naval interest and support. Investigation of gamma rays is of particular interest to the Navy for two reasons. The first is that they provide a unique tool for many purposes. They are used to detect flaws in heavy structures, in tracer techniques for the monitoring and control of fluid flow, and in naturally occurring cosmic radiation for meteorological work. The second reason is that gamma rays inevitably accompany almost all nuclear processes such as those involved in nuclear power and ordnance. A thorough understanding of them and their properties will be necessary if nuclear energy is to be applied to Naval problems.

With the support of the Office of Naval Research, the Department of Physics at the University of Pennsylvánia is engaged in experimental investigations of atomic nuclei with special regard to the properties of gamma radiation. Gamma radiation is the shortest wavelength electromagnetic radiation known. Its fundamental nature is akin to that of radio and radar waves and ordinary visible light. The wavelength of radar waves is measured in centimeters and that of light in hundred thousandths of a centimeter. Gamma ray wavelengths, of the order of 10^{-10} cm, are as much smaller than light wavelengths as the latter are smaller than those of radar.

The energy carried by radiation is not indefinitely divisible, but occurs in characteristic units or quanta which are determined by the

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L. Cranberg is a Harrison predoctoral Fellow in Physics at the University of Pennsylvania. He received his B. S. from the College of the City of New York and his A. M. from Harvard. During the war he was employed as a physicist by the Signal Corps Engineering Laboratories, in charge of the development of optical-electronic devices. His research interest is in beta- and gamma-ray spectroscopy.

wavelength or frequency of the radiation. The energy associated with a quantum of radiation is proportional to the frequency, and hence the energy units in which gamma rays occur are about 10^{10} times as large as those in which radar energy is radiated. In consequence of this, gamma rays are frequently known as high energy radiation, and the phenomena associated with them are quite different from those familiar in radar. Gamma rays are much more penetrating and their physiological effects differ widely from those of low energy radiation. The techniques by which the radiations are generated and studied are also quite dissimilar. Gamma rays are one of our most important tools for studying the high energy processes within atomic nuclei, whereas radar waves find important applications in studying low energy molecular problems.

The specific employment of gamma rays for the Navy's purposes takes place in the service laboratories and stations; the role of the university laboratory in this scheme is an exploratory one. It is in the university laboratories primarily that the basic phenomena are studied and the nature of high energy radiation and its relation to nuclear processes are unravelled by slow, painstaking experiment.

Gamma rays are produced by naturally or artificially radioactive elements and are emitted by them at certain discrete wavelengths characteristic of the element which is their source. This is quite analogous to the discrete spectrum of X-rays and visible light emitted by atoms at greater wavelengths. The origins of the gamma rays and of the X-ray and optical line spectra are different. The former come from the inner core of the atom, the nucleus; the latter come from the outer, extranuclear structure.

Just as studies of optical and X-ray spectra have been invaluable in leading to an understanding of the extranuclear structure of atoms, so studies of the gamma ray spectra of naturally and artificially radioactive nuclei furnish detailed information about the nuclei themselves, and contribute to our understanding of their structures.

Radiations are now also available from high-energy electron accelerators, such as betatrons and similar nuclear machines. These are comparable to and even exceed in energy and penetrating power the gamma rays from radioactive nuclei. It is characteristic of these machines that the radiations they produce are not of discrete wavelengths but form a continuous spectrum, analogous to the white light spectrum emitted by incandescent bodies. The process of production of these radiations is associated with the deceleration of the accelerated electrons as they strike a target; hence the name bremstrahlung (impact radiation) is applied to radiations of this sort.

Such controllable, energetic radiations have immediately useful applications in radiotherapy and radiography but are of special research interest to the physicist because they provide another tool with which to explore the nucleus. The outer portion of the atomic system interacts easily with incident optical radiation of wavelengths close to its own emitted wavelength, resulting, for example, in emission of an electron from the atomic system's extranuclear structure (photoelectric effect). It follows that the nucleus is responsive to radiations comparable in wavelength to those which it can emit itself, and one gains insight into the processes of nuclear disintegration and the nature of the forces holding nuclei together by studying the ways in which they react to excitation by such radiations. This general technique has been highly developed using radioactive nuclei themselves as sources of radiation, but the new machines make available more intense sources of greater energy and thereby open new possibilities. Nuclear disintegrations have been observed, for example, in which several particles in succession have been split off stable nuclei. Splitting in large segments has also been observed, in the process called photofission. There is, in fact, a rapidly developing field of study here one might call nuclear photochemistry.

For work of the kind outlined above, precise measurement of gamma ray energies is essential. Prism or ruled grating spectrometers useful at optical wavelengths fail at X-ray wavelengths; crystal spectrometers useful for X-rays are of little use in the gamma ray region. Of the various special methods devised for measuring a gamma ray spectrum, much is still left to be desired by way of resolution and precision.

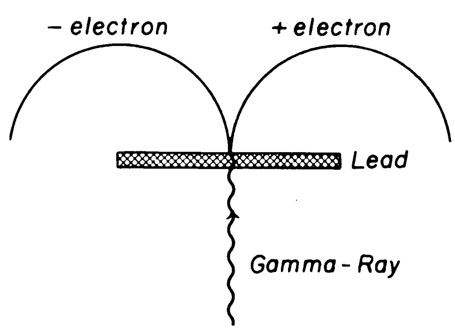

Figure 13. Illustration of electron-positron pair production by a gamma ray in a lead plate and the deflection of the product electrons in a uniform magnetic field perpendicular to the plane of the paper.

A method now under development in several places which holds considerable promise takes advantage of the ability of a high-energy gamma ray photon* to materialize as an electron-positron† pair when it comes close to a nucleus, particularly a highly charged one. This phenomenon is one of the most dramatic evidences of the equivalence of mass and energy. It can occur when the energy of the photon exceeds the energy associated with the rest masses of an electron and a positron. These masses are equal and together are equivalent to about one million electron volts, as calculated from the relation $E=mc^2$.

*A photon is a unit of electromagnetic radiation.
†A positron is a positive electron.

When such materialization of a photon takes, place the difference between the energy of the photon and one million electron volts is imparted to the product electron and positron. Hence the problem of photon energy measurement is reduced to that of measuring the energies of an electron-positron pair. This is relatively easy to do with high precision, as the energy may be inferred directly from the radius of curvature of the paths of these particles in a uniform magnetic field.

Nuclear physics has led to a weapon of unparalleled destructive power and also to techniques of the greatest beneficent promise in the fields of power and medicine. It would be a great mistake, however, to credit this to our understanding of nuclear processes. The applications in this field have been made in spite of our dense ignorance of even the most basic things, such as the fundamental nature of radiation and the simplest elementary particles with which we deal. If we can advance our knowledge of these matters even a little, the promise of future benefit is incomparably great. It is the advancement of this knowledge to which the Office of Naval Research is contributing in sponsoring studies such as the one at the University of Pennsylvania.

A Stitch in Time

The technique of using gamma rays for the nondestructive examination and testing of steel and other metals was introduced in the United States by Dr. Robert F. Mehl,* of the Naval Research Laboratory, in 1929. It had been developed four years earlier by MM. Henri Pilon and M. A. Laborde, in France, to inspect a turbine which, because of its location aboard ship and the thickness of its metal, could not be examined by X-rays. Gamma rays, as employed in the Pilon-Laborde method, can be used to examine metals up to twelve inches in thickness.

The metallurgists of the Naval Research Laboratory were given an opportunity to demonstrate the value of this technique in 1931, when the sternpost of USS Chester cracked during the light cruiser's high-speed tests. They found flaws not only in the Chester's sternpost but also in the sternposts of four other ships of its class. The information thus obtained enabled the Navy and the shipbuilding industry materially to improve the quality of the subsequent castings. It also provided an excellent example of the value of having the findings of completed research available for use when needed.

*Dr. Mehl is now at the Carnegie Institute of Technology, a principal investigator on two ONR contracts in metallurgy. An article in the 15 March 1948 issue of Research Reviews (p. 11) describes work under his direction.

NAVAL RESEARCH RESERVE

Chartered in May 1948 by Naval Reserve Multiple Address Letter No. 24-48, the Naval Research Reserve program was actually organized by a letter promulgated on 30 August 1948 by the Chief of Naval Personnel. This letter, which established the objectives, qualifications, and the general training program for Research Reserve, was discussed in the 15 October issue of Research Reviews.

The information concerning the Research Reserve which has been promulgated officially has resulted in a variety of informal inquiries from the field. In short, the individual Reserve officer of scientific background is asking: "How will I benefit from being affiliated with an organization such as the Volunteer Research Reserve? Where are such units located? Is there one in my area? If not, what can be done to get one activated? What type of training will I get, and in what sort of program will I participate?"

These questions and their answers are necessarily interrelated, but let us take them up one at a time.

"How will I benefit by joining a Volunteer Research Reserve Unit?" The answer to this question lies in the answer to a larger one. How can the Navy best locate its scientific reserve and maintain it in a state of readiness? It has been determined that, since there are no research billets in the Organized Reserve, the best method of keeping Scientific personnel "tagged" and abreast of the current program of the Office of Naval Research is to make available a definite program for Reserve officers whose qualifications would make them of value to the Office of Naval Research or any of its field activities in the event of mobilization. Such a program can be administered through a Volunteer Research Reserve unit whose objectives would be to keep Reservists informed of the activities of the Office of Naval Research and to offer to the Reservists an opportunity to make their own contributions to those activities. Since the program has one objective of locating and tagging the individual Reserve officer so that he will be of most value to the Navy in the event of mobilization, it follows that it will benefit the Reservist by assisting in his optimum mobilization assignment and keeping him from becoming a "square peg in a round hole."

In addition to locating the qualified Scientific Reserve Officer, the Naval Research Reserve offers this type of officer the best method of maintaining his useful affiliation with the Navy. The Inactive Reserve officer who does not belong to an Organized or Volunteer Reserve unit receives only general information concerning the Navy program. By being in a Volunteer Reserve unit, he is kept in constant touch with a specific Naval activity which has indicated its desire for his services if he is mobilized. Through this affiliation and training program the Reserve officer will be kept abreast of current programs, will have a part in them, and will have the benefit of a continuous indoctrination for his mobilization assignment. By being a member of the Research Reserve the inactive Reservist will have first hand access to the latest developments and will have the opportunity to discuss his reactions and ideas with a group with similar background. He will also be in a position to express his opinions on these matters to the Navy in the most direct manner.

The Reservist who asks, "Are there any advantages to me over and above my mobilization readiness and optimum assignment?" might well consider the opportunities he will have in this program for maintaining his commission in force, for preparing for advancement in rank, and for qualifying for retirement under recently enacted legislation.

While at the present time there is no minimum requirement to keep commissions in force, consideration is being given to such a requirement. For promotion purposes, however, comprehensive examinations will be required of <u>all</u> Naval Reserve officers by the Bureau of Naval Personnel on the following basic subjects: Naval Regulations and Customs, Naval Leadership, Naval Administration, and Naval Courts and Boards.

Each officer will also be required to take an additional comprehensive examination in his specialty. Correspondence courses are approved in lieu of certain written examinations for promotion of Reserve officers. New correspondence courses are being prepared which will be published after the first of the year (see September issue of "Reservist"). Publication of new courses is scheduled to be completed by July 1949. A member of the Research Reserve unit would profit from affiliation with a local unit which would have as an important objective the dissemination of information to its members on what courses are available and on other methods which are available for improving military proficiency. For example, the statement of correspondence courses available at Naval Correspondence Centers as of May 1948 includes a course in Nuclear Physics. The establishment of similar courses for other scientific subjects is contemplated. The Research Reserve through its local units can assist in establishing and reviewing such courses. When these courses are published, in addition to having a course in his specialty, each scientific Reservist can take the other courses for broadening his scientific interest and for compiling his credits for satisfactory service.

This brings us to the matter of retirement. By Public Law 810, 80th Congress, approved 29 June 1948, provision was made for extending retirement benefits to members of the Naval Reserve. The Bureau of Naval Personnel in a letter of 28 July 1948 has advised Commandants of Naval Districts that the contemplated effective date of this act is 1 January

1949. Prior to this date a directive will be issued which will provide detailed information as to the latest requirements and administrative procedures for this program. A limited supply of copies of this act is available in Code 103R, Office of Naval Research, and copies will be furnished to Branch Offices and local Research Reserve Units on request. Section 303 of this law is quoted here to give a general idea as to possible extent of participation.

"Section 303. Any person granted retired pay pursuant to the provisions of this title shall receive such pay at an annual rate equal to 2-1/2 per centum of the active duty annual base and longevity pay which he would receive if serving, at the time granted such pay, on active duty in the highest grade, temporary or permanent, satisfactorily held by him during his entire period of service, multiplied by a number equal to the number of years and any fraction thereof (on the basis of three hundred and sixty days per year) which shall consist of the sum of the following:

(i) All periods of active Federal service;

(ii) One day for each point credited pursuant to subparagraphs (2) and (3) of subsection 302 of this Act, but no more than sixty days shall be credited on this basis in any one year for the purposes of this section: PROVIDED, That no person shall be entitled to receive such retired pay at an annual rate in excess of 75 per centum of said active duty pay: PROVIDED further, That for each year of Federal service, other than prior to the date of enactment of this Act and credited in accordance with subsection (c) of section 302 of this title, such member shall be credited with fifty days for each of such years, for the purposes of this section."

A year of satisfactory Government service as it applies to qualifying for retirement benefits will be a year in which a minimum number of 50 points has been accumulated. Everyone will receive 50 points for each year of inactive duty in the Reserve up to effective date of act. Approved procedures for getting these points in the future will be promulgated in the anticipated directive from the Bureau of Naval Personnel. It is known now that an inactive Reserve officer will get 15 points merely for being in the Inactive Reserve. If he should make a two weeks training tour, he would get 14 more points, bringing his total to 29. A member of one of the Research Reserve Units would get a point for each meeting attended, and since the groups now organized meet 26 times a year, he would qualify for the year with 55 points without benefit of correspondence courses or other approved methods of obtaining credit. A member of a Reserve unit taking an active part in its program would be automatically qualifying himself for maximum participation in retirement benefits.

In connection with training duty, the Bureau of Personnel on 13 September established the priorities for training Volunteer reserves. Volunteer reservists attached to Reserve units will be given priority over other inactive reserve officers in any case of curtailment of training duty due to limitation of funds.

Another advantage is that the training and associations made by a Reserve officer in a Volunteer Reserve unit would add to his scope of interest in his civilian life, and in many cases improve his performance in his civilian career.

In short, the fact that a man is approved for a Volunteer Research Reserve unit means that the Office of Naval Research or one of its field activities desires the services of that officer on mobilization. It follows that the requesting activity would want this officer to receive the greatest possible military, professional, and personal benefit from the Naval Reserve during his period of inactive duty.

"How can I get into this program?" The Reserve officer who wishes to get into the Research Reserve will find units already activated and functioning in several areas.

The following three Volunteer Reserve Units have already been established:

Designation	Location	Commanding Officer
12-1 (Composite)	U. S. Naval Shipyard, Hunters Pt. San Francisco, California	CDR J. E. Laurence, USNR %Office of Naval Research U. S. Naval Shipyard, Hunters Point, San Francisco, California
12-2 (Biological Sciences)	University of California Berkeley, California	LCDR Nello Pace, USNR University of California Berkeley, California
W-1 (Composite)	Office of Naval Research Washington, D. C.	CDR F. C. Wiesner, USNR Office of Naval Research Washington, D. C.

Additional units are in process of organization in the areas indicated below. Names and address of persons to be contacted for information are given.

CAPT Chalmers L. Gemmill, USNR
Department of Pharmacology
University of Virginia Medical School
Charlottesville, Va.

LCDR John Burwell Jr., USNR
Department of Mechanical Engineering
Massachusetts Institute of Technology
Cambridge, Massachusetts

CDR L. S. Jacobsen, USNR
Head of Mechanical Engineering Department
Stanford University
Palo Alto, California

LCDR C. J. Vogt, USNR
University of California
Berkeley, California

CDR James E. Boyd, USNR
Georgia School of Technology
Atlanta, Georgia

Information concerning a unit now being organized at Fresno State College, Fresno, California can be obtained by writing Commander J. E. Laurence, ONR Branch Office at San Francisco, who is coordinating the program for San Francisco area. Official addresses for all Branch Offices of the Office of Naval Research were published in the October issue.

Unit W-1 at Washington, D. C., has been growing steadily. At present it has more than 80 members and according to expectations will soon be augmented by the addition of a large group of officers from the Naval Research Laboratory at Washington. It is anticipated that there will be two or three additional units in the Washington area before the first of the year.

Volunteer Research Reserve Unit, 11-1 (Special Devices), has been activated in the Los Angeles area with Lieutenant Commander H. J. Pedersen, USNR as Commanding Officer. Interested Special Devices personnel in the Com 11 area can secure information on this unit by writing to the Commanding Officer of the Office of Naval Research Branch Office at Pasadena or by writing directly to LCDR Pedersen, 510 West 6th Street, Los Angeles, California. Sufficient applications have also been received to indicate the activation of Special Devices units at Washington, D. C., and at Port Washington, N. Y., in the very near future.

The official procedure for establishing a unit, where none exists, has been outlined as follows: Units are activated officially and orders issued to individual officers by District Commandants upon recommendation of Commanding Officers of ONR Branch Offices. Copies of the organizational letter sent out by the Bureau of Naval Personnel on 30 August can be secured by writing either to the Chief of Naval Research, Code 103R, or to the appropriate Branch Office. Experience has indicated that the activation of the new Reserve Units in Naval Districts is expedited when individuals initiate the program by locating qualified personnel, securing applications, and processing these applications through the appropriate Branch Office. For instance, if a Reserve officer finds that a sufficient number of qualified personnel exists in his area, he should contact the nearest Branch Office to get the required official application blanks, which should be executed in quadruplicate. When a large enough group is assembled, application for activation of the unit should be sent to the Commanding Officer of the Branch Office serving the Naval District in which the group has been assembled. This letter of application should contain a recommendation for the Commanding Officer of the unit. The Branch Office will screen the applications, approve the recommendation for Commanding Officer if he is qualified, and request the District Commandant for official activation of the unit. Interested Reserve officers in a number of areas are now studying the availability of qualified personnel and scheduling preliminary organizational meetings. Representatives of Office of Naval Research or its Branch Offices have attended these meetings to explain the program in detail and to assist the groups in securing official activation. The Director of Research Reserve, Office of Naval Research, Code 103R and the Branch Offices will be glad to render any assistance possible in the organization and activation of these units. Where the number of personnel available does not come up to the minimum for activation of a unit, subunits can be organized to affiliate with larger units established in the area.

"What will the training program be?" Officially, training is the responsibility of the Commandants under policies established by the Chief of Naval Personnel, with the Office of Naval Research furnishing technical assistance through its Branch Offices. Actually, as indicated in the organization letter, the individual units are encouraged to formulate their own programs. Because of the very nature of research and the variety of fields represented in the program, the Research Reserve cannot propose to train each officer in his particular field. What it can do is keep him up to date on the research program of the Office of Naval Research and give him the opportunity to participate in it. The general program objectives for accomplishing this dual purpose have been officially established and their implementation has begun. They are broad and comprehensive in scope.

Experience to date has indicated a number of practical approaches to these objectives. A composite unit has made effective use of devoting the first hour of a two-hour period to a program of general interest to the group. The group then divides into discussion subdivisions, in which the program is based on specialized subjects. In providing speakers for the general meetings, the separate units can be of mutual assistance, with individual Reserve officers receiving credit for preparing and delivering addresses to other groups. The Special Devices group at Los Angeles has reported a profitable field trip to an aviation development activity. When finding it impracticable to transport the entire group on subsequent field trips, this group has planned to assign small groups to cover installations in the area and to report their finding to the unit. The Special Devices Center is now preparing recommended program material for specialized units of this type.

A number of procedures for Research Units are now being planned. Seminars such as the one held in June this year have been suggested, both at ONR and in local areas. Another seminar at ONR is planned next year with date to be announced. Activity reports of Branch Offices, research proposals, contract reports, manuals, bulletins, proposed training materials, and other material which must be properly evaluated by the Office of Naval Research will be made available to Research Reserve Units. In evaluating such material a local unit can make a significant contribution to the current Research program in addition to keeping its members informed of the nature of that program. Comments concerning research proposals and contractor reports would be a very valuable contribution. Another contribution would be assistance in selecting from a large mass of technical publications the material particularly pertinent to the research activities of the Navy.

In the future specific projects will be assigned by ONR and its Branch Offices to the separate units. Original recommendations for projects from the units are encouraged. In the case of an activity such as Special Devices, where actual equipment is produced, personnel in the local units can serve as consultants on equipment with which they have had experience and every effort will be made to provide devices for experimental purposes. A suggested project in this connection would be the editing of operational and maintenance manuals for training devices.

As new units develop and new people come into the program valuable ideas are received. For instance, in locating and commenting on the qualifications of scientific personnel, either military or nonmilitary, local units are rendering an invaluable service. The Office of Naval Research will coordinate the training experiences of the separate groups and will pass these experiences from unit to unit. It is contemplated that by the first of the year approximately twenty Research Reserve Units will be activated. At that time a representative of ONR Research Reserve will visit each unit and discuss its program with its officials, with the view of preparing an Office of Naval Research training publication which will be based on group experience. In summary, through this program the Office of Naval Research can let its scientific reservists know what ONR is doing and can at the same time avail itself of their many talents. The scientific reserve officers can insure that they are better prepared to fill a mobilization billet in which their abilities and training will be fully utilized.

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