● DECEMBER 1949

RESEARCH REVIEWS

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

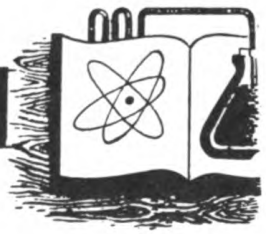
NAVEXOS P-510

COVER PHOTO: Aerial view of the Special Devices Center located at Sands Point, Port Washington, Long Island, N. Y. The 163-acre site was formerly the estate of Daniel Guggenheim. The Stables (upper left corner) is now the SDC Laboratory, which houses the machine shop, demonstration area, television studios, and radar laboratory.

Approved by Bureau of the Budget, 13 April 1948.

RESEARCH REVIEWS

Informs the Fleet of ONR-sponsored Research



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Editorial Notes

An important part of the ONR organization is the Special Devices Center located at Sands Point, Port Washington, Long Island, N. Y. The Special Devices Center designs and develops training equipment for the individuals who man the Navy's ships and planes, and conducts research into the relations between man and the machines he must operate. It is the Center's task to bridge the gap between the Navy's men and today's complex weapons of war.

The Special Devices Center began in 1941 as a special desk in the Engineering Division of the Bureau of Aeronautics, and later became a Division itself. In May, 1945, the Special Devices Center became a division of the Office of Research and Inventions, which in turn became the Office of Naval Research in August 1946, by Act of Congress. In April 1946 the Special Devices Division moved from its wartime location in Washington, D. C., to its present site on Long Island's north shore.

To prepare men for the new tasks that result from scientific progress in weapons and warfare, the Center provides training devices, teaching aids, and training systems, and studies and recommends training techniques.

Development and perfection of mass training techniques is not only economical in peacetime, but saves precious time in emergency when large numbers of men must be trained rapidly and thoroughly. The television education program is foremost in the development of mass training mediums at the Center. A small but complete and modern television studio has been set up from which classes in naval ordnance and gunnery have been programmed to students at King's Point Merchant Marine Academy. The effectiveness of the television program is being evaluated by the Physiology Department of Fordham University.

The largest of all the training devices programs is the one in aviation. The Operational Flight Trainer simulates closely the characteristics of aircraft in operation. This provides for training pilot and crew without the cost and danger of actually operating the aircraft and permits training for situations which because of danger to personnel and material are not feasible as actual training situations.

The Armament Section, the Flight Trainer Section, the Human Engineering Branch, the Navigation and Seamanship Section, the Electronics Section, the Special Projects Branch, the Visual Design Branch—these are all concerned with developing and furnishing new methods and equipment for training personnel to operate and maintain the latest weapons as soon as, or before, they roll from the production line.

Many spectacular new weapons have been developed in recent years as a result of the efforts of research scientists and engineers. But even the most potent of new weapons depends for its successful use upon the skill of a human operator. The Center is the link in the Office of Naval Research organization which joins the products of research with the men who must use them. The Special Devices Center is concerned with preparing men to use properly the armament fashioned by science.

Orientation in Space

by

H. A. Witkin
Brooklyn College

The disorientation experience described below is only one of many that may occur in an airplane. The report appeared in the Aviation Supplement of the BuMed News Letter for September, 1945 under the heading, "Case of Vertigo."

"On 14 July 1945, Captain M., USMCR, a senior flight instructor in the torpedo squadron, took his flight on a night tactics hop in TBF/M type planes. Weather was contact. Takeoff and rendezvous were normal. Captain M. made frequent rapid turning movements of his head from side to side to see that his flight was intact. Vertigo suddenly developed. He had a feeling that his plane was peeling off in a steep left-hand dive, and had a strong desire to use right rudder and right aileron, but saw by his instruments that he was flying straight and level. 'It took all the guts I had to believe those instruments,' he said, 'but I knew they were right and that my sensations were wrong.'

"Captain M. led his students on the one hour flight, which included banks, turns, and dives, entirely on instruments. Throughout the flight he had the sensation that his plane was falling off in a left-hand dive. He approached the landing field and came into the groove still on instruments. Just before landing he shifted to contact flight in spite of the fact that the runway seemed to him to be at a 45-degree angle incline upward to the starboard, and appeared to oscillate. He landed port wing and port wheel down, started to ground loop, but corrected it. Vertigo continued for about fifteen minutes after he was on the ground.

"Captain M. stated that no combat experience had frightened him as had this attack of vertigo. He felt helpless and had a cold fear of impending doom. He had a strong tendency to tighten up and freeze at the controls."

This report shows dramatically how distressing and dangerous a loss of bearings during flight can be. In some instances the person is in error about his position in space, but yet believes himself properly oriented; in other cases, the person may lose his bearings completely, so that he is not sure which way "up" and "down" are; finally, there are times when these experiences are accompanied by illness of varying degrees of severity. Although there are undoubtedly many different causes of disorientation, in every case something has gone wrong with the person's ability to integrate the information he receives from his different senses into a correct estimate of his position in space. He can, of course, as Captain M. did, establish his true position from his instruments, but it is often difficult to accept instrument readings when they are in conflict with one's own sensations. It is much more natural to act according to what your body tells you than according to a number on an instrument panel. To make headway in dealing with

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disorientation during flight, therefore, it is not enough to develop more and better instruments; we must find out what accounts for the difficulty in integration of sensory experiences that is responsible for disorientation.

For a number of years our laboratory at Brooklyn College has been investigating the process of space orientation in man. Since relatively little is known about this process, basic studies must be carried out before some of the practical problems encountered in flying can be solved. These experiments should ultimately help provide answers to questions, which are important to aviation: Under what conditions does disorientation occur in the plane? Do some people become disoriented more readily than others, and if so, is it possible to pick them out in advance of flight training? Can a person's space orientation be improved, either by training or by altering the structure of the plane's cockpit or instruments?[1]

To answer the first question, a variety of devices has been developed in our laboratory, each of them duplicating in a relatively simple way one of the situations found in everyday life in which people must maintain their bearings. These devices have been constructed in such a way that changes may readily be made in them, and the influence of these changes upon orientation determined. Two of them will be described here, but before considering them a word should be said about the means by which people generally determine the vertical and horizontal directions in space. Fundamentally, our ability to establish these directions as quickly, easily, and accurately as we ordinarily do is based upon the stable representation of the upright in our surroundings and upon our possession of adequate sense organs to detect these representations. First, the direction of gravity, which corresponds to the true upright, is readily established through the continuous adjustments our bodies must make to this force. Second, our visual environment includes a large number of proper verticals and horizontals, and they also serve us as ready indexes of the upright. These two sets of factors ordinarily work in very close cooperation, resulting in a unified impression of the upright. Furthermore, since the visual and gravitational uprights coincide in direction, the outcome is the same whichever determinant is used as the main basis of judgment. As will be seen, our experimental devices permit a separation of these two sets of factors, making possible a study of the importance of each in orientation.

The first experimental device to be considered is shown in Figure 1. It consists of a small room containing a chair. Both room and chair can be tilted to left or right, by any amount, either by the operator standing on the outside or by the subject seated in the chair. The room and chair may be tilted alone or together, to the same side or to opposite sides, at the same speed or at different speeds. The test procedure consists of tilting the room and chair to set positions while the subject's eyes are closed and then requiring him, after opening his eyes,

[1] This article presents findings relating to the first two questions only. A detailed account of a study concerned with the last question may be found in the following report by the author: "The Effect of Training and of Structural Aids on Performance in Three Tests of Space Orientation," Civil Aeronautics Administration, Division of Research, Report No. 80.

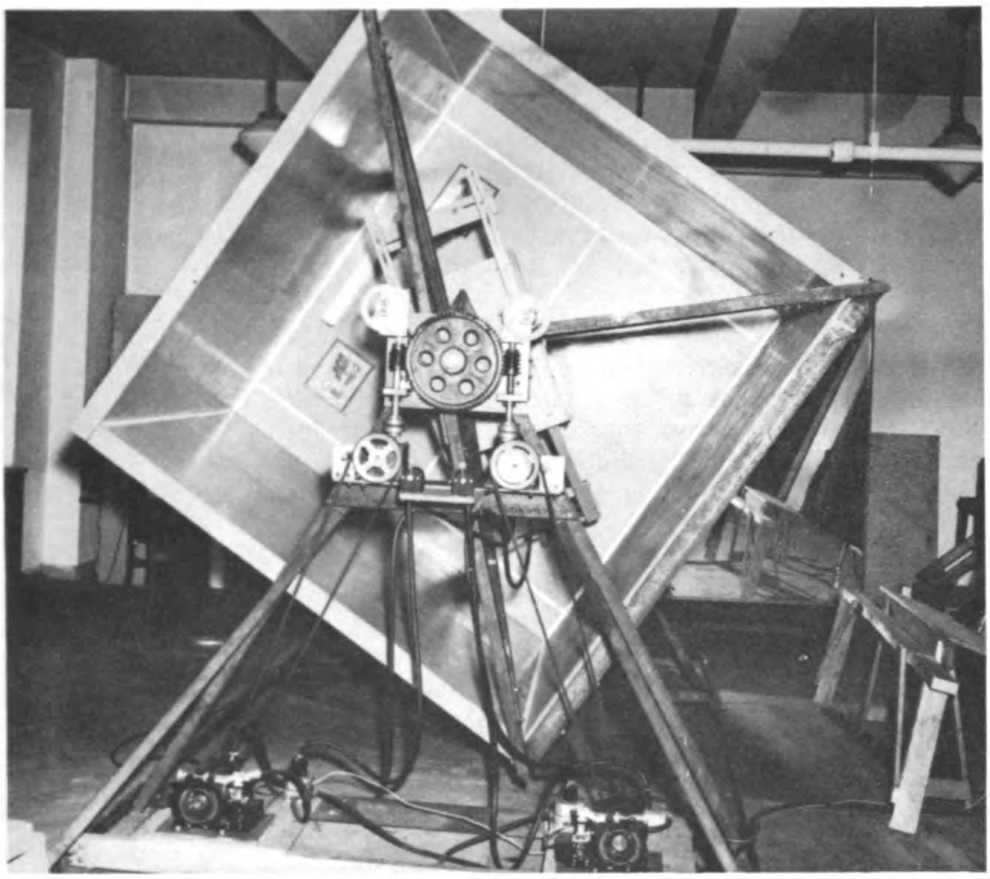

Figure 1. Experimental room and chair, both of which can be tilted either to the left or right for orientation experiments.

to adjust one or the other to the upright—the room on some trials, his chair on other trials. The position to which room and chair are brought may be measured to the nearest degree, so that the results are expressed in quantitative terms.

One of the most striking results obtained with this experimental situation relates to the manner in which people establish the position of their own bodies in space. When required to place their bodies (i.e., the chair) in upright position when the room was tilted, most subjects tilted themselves, in the direction in which the room was tilted. This is easily explained. When the subject's body was actually upright, it was very much out of line with the axes of the tilted room and thus the subject felt tilted in relation to the room. To compensate for this visual effect, he tilted his chair towards the room's tilted axes, even though this meant that his body was actually leaning to one side. Such reactions indicate that we judge our bodies to be straight not only when they <u>feel</u> straight but also when they <u>look</u> straight in relation to our surroundings. The tendency to judge their position on the basis of visual environment was so strong in some subjects that they actually tilted themselves as far as the room was tilted. Although this sometimes meant that the subjects were leaning over at a 35° angle, many of them failed to experience any pressure against the side of the body, and reported that they were sitting perfectly upright. It was also found that when room and chair were tilted to the <u>same</u> side, but by different amounts,

these subjects reported that their bodies were tilted to the opposite side from that of the room. With the room at 35° left and the chair at 22° left, for example, such individuals judged themselves to be tilted right and requested that they be moved to the left to become straight. Obviously, this was a visual illusion, caused by the fact that the subject's body was not tilted as far to the left as the room, and therefore appeared to be tilted to the right in relation to it. When the chair was brought to a position of near-alignment with the tilted room such people judged themselves to be upright.

It was also observed in this situation that when the subject was tilted even momentarily and then returned to the true upright, he felt himself leaning over to the side opposite the initial direction of the tilt. Consequently, in order to make him feel straight, it was necessary actually to tilt him to the side to which he had originally been displaced, in some cases by a considerable amount. It is easy to see how this after-effect of being tilted, and the tendency to judge body position on a visual basis, as described above, may lead to serious errors of orientation during flight.

A second important result obtained with this apparatus relates to the manner in which subjects judged the position of the room—that is to say, their visual environment. Almost invariably, they underestimated the extent of the room's tilt and consequently did not move it far enough toward the true upright when they attempted to make it straight. In some extreme cases, the subjects actually perceived the room as upright in its initial position, even when it was tilted as much as 56°. This is indeed a striking effect. In a plane, this tendency to underestimate the extent of tilt of the immediate environment (the cockpit) if it is tipped to one side is apt to be strongest when the earth below is obscured.

A second experimental device developed in the laboratory permits the study of the effect of rotation on people's space orientation. The device is similar to the one already described, in that the subject's chair and the room about him may be tilted; but in addition the entire unit may be rotated. The outward-acting centrifugal force exerted during rotation is added to the downward pull of gravity, so that the effective force acting on the subject's body is intermediate between these two in direction. The experimental device, which is shown in Figure 2, consists of a small, fully enclosed room mounted on a carriage that is driven about a circular track. The room may be tilted from side to side, and contains a chair that may also be tilted from side to side. The rotation of the whole unit, and the tilting of room and chair, are controlled by the experimenter from the outer laboratory. The rate of rotation may be varied, permitting changes in the magnitude of the centrifugal force and therefore in the direction of the effective force acting on the subject's body. The effects of rotation both with and without visual surroundings may also be studied by turning off the lights in the fully light-proofed experimental room.

The test procedure consists of rotating the unit while room and chair remain upright. If the room appears tilted to the subject, he must make it straight. On other trials, if he perceives his own body as tilted, he is required to make the chair straight. He does this by directing the

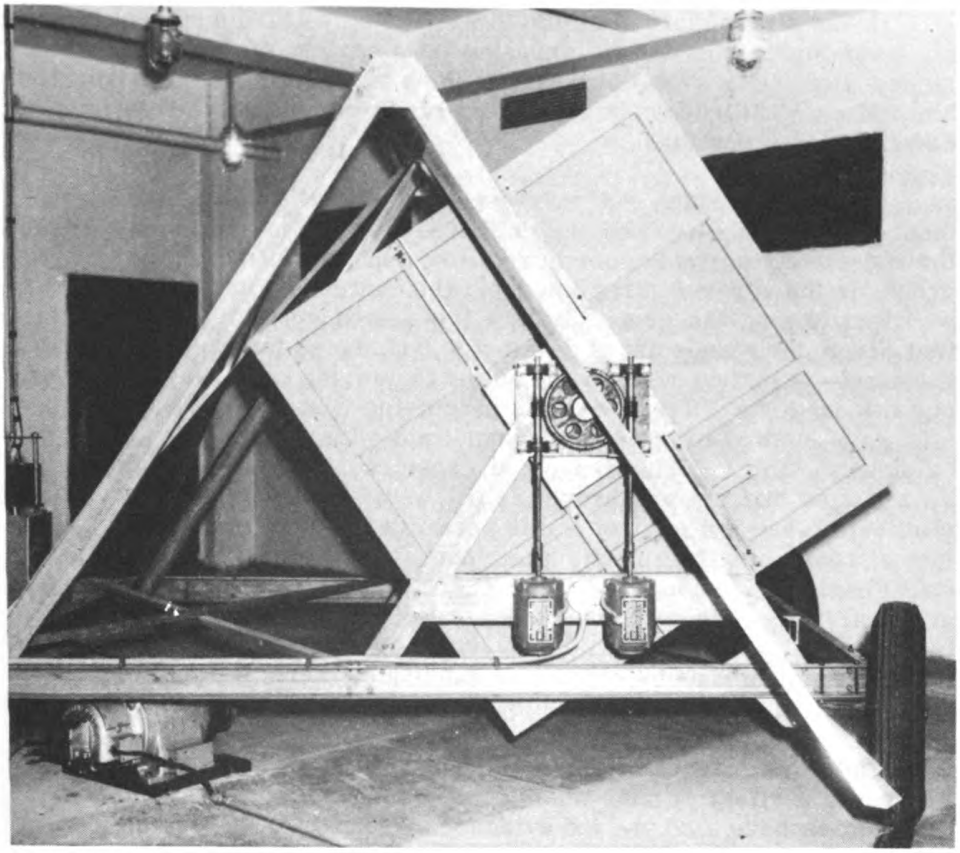

Figure 2. A second experimental room and chair which not only can be tilted but also can be rotated.

experimenter to move the room, or chair, to left or right until he is satisfied that it is upright.

In almost all cases, the subjects felt themselves to be tilted away from the center of rotation to various degrees while seated in the upright chair during rotation. Furthermore, as the rate of rotation was increased, so that the direction of the force acting on their bodies became farther removed from the normal gravitational force, they felt themselves to be progressively more tilted. At all rates of rotation tested, however, the subjects' estimates of the position of their bodies were greatly affected by whether or not they were permitted to see the experimental room in which they were enclosed. When the room, which remained objectively upright during rotation, was lighted, they actually felt much less tilted than when the room was darkened, even though the force acting on their bodies was the same under both conditions. This result was not at all surprising, in view of the tendency noted earlier to judge one's position on a visual basis as well as on the basis of bodily sensations. When the subject could see that his body was in alignment with the room, this visual impression tended to counteract the pull on his body that caused him to feel tilted. In the darkened room, when his estimate of position was based on this pull alone, he judged the tilt to be greater. Here again there is striking evidence of the importance of vision in orientation.

It was also observed in this situation that when the subject moved his head during rotation he experienced a variety of compelling illusions. Depending on the direction of the head movement, he might feel himself catapulting downward, falling off to one side, or experiencing other motion sensations.

The way in which subjects perceived the position of the experimental room was also strikingly affected by rotation. To most of them, the objectively upright room in rotation appeared tilted to various degrees, in the opposite direction from the center of rotation, and had to be tilted toward the center before it seemed upright. A significant fact—from the standpoint of developing techniques for overcoming such illusions—is that even when the subject knew the room was really upright, it made no difference to his perceiving it as tilted. Nor was this effect diminished by repeated experience with the situation. On the other hand, although knowledge and experience were of no avail, it can be assumed that the appearance of tilt would have been reduced, if not eliminated, had the subjects been permitted to look out of the experimental room into the upright outer laboratory, thus providing an additional basis for judging position. Therefore, in applying these facts to aviation, it is safe to conclude that although the disorienting effects produced under some conditions by turns are not remedied by evidence from instruments, or by repeated experience, there is likely to be less disorientation when the earth below is visible.

The results described up to this point help answer the first question posed earlier: "Under what conditions does disorientation occur?" Our studies have also yielded evidence that helps to answer the second question, concerning differences among people in their susceptibility to disorientation. In tests conducted with each of our experimental devices, subjects were found to differ markedly from each other in their manner of determining the upright, as reflected in how successfully they established the position of their bodies and the position of their surroundings. In particular, people differed from one another in the extent to which they tended to judge body position on a visual basis (that is, according to whether or not they were aligned with the axes of the surrounding room), and in the extent to which they tended to accept their surroundings as straight when actually tilted. Some people were quite accurate in bringing their bodies to the upright position by judging on the basis of how they felt, regardless of whether or not they were aligned with their surroundings; these people were also usually able to estimate the tilt of the room accurately, and to adjust it to the true upright. Others, in sharp contrast, proceeded on a strongly visual basis, perceiving their bodies as upright only when they were aligned with their surroundings, and accepting their surroundings as properly upright in almost any position. Finally, there were people whose mode of orientation was intermediate between these two extremes. It was found, that the particular manner of orientation shown by any one person tended to be consistently characteristic of that person under a variety of conditions.

People who tended to depend on their visual impressions often became disoriented in the sense that their estimates of their own position in space or of the position of their surroundings were very much in error, and sometimes in the sense that they were completely unable to get their bearings. In the latter case, the subject might report that he was no longer able to tell which way was up or down; or, seated in the

tilted room, he might move his chair back and forth for long periods of time (as much as 50 minutes) without being able to find a position in which his body both looked and felt straight. At times, this disorientation led to marked illness, including dizziness, sweating, and nausea.

Studies now in progress indicate that a person's mode of orientation represents a deep-seated characteristic, and is related to his general personality make-up. This finding is important in relation to our third question: "May orientation be improved with training?"

Using the knowledge gained about differences in the orientation ability of people, we have developed a standardized test that evaluates the individual's ability to keep his bearings under various circumstances. This test, which employs the apparatus shown in Figure 1, and is known as the "Stability of Orientation Test," has been carefully standardized so that it may be administered by different examiners. To determine whether performance in this test is related to efficiency of orientation in flying, it has been given to a large group of aviation cadets, before they began flight training. When the training, which is now in progress, has been completed, a study will be made to determine whether or not the people who did well in the test also proved to be better in the orientation aspects of flying. If a positive relationship is found, the "Stability of Orientation Test" may be used to "screen out" candidates for flight training who are inferior as far as the orientation aspects of flying are concerned.

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Ceramic Oxides

by

Zane Schofield
Battelle Memorial Institute

This is the third in a series of articles prepared by members of the staff of Battelle Memorial Institute who are conducting research for ONR on heat-resisting materials.

If we observe the uses to which we put ceramic materials, it will be clear that we value them because of two outstanding qualities, their resistance to heat and to chemical attack. The fires and the baths of our metal industry are confined in ceramic chambers. The corrosive solutions of chemistry are reacted and transported safely in contact with ceramic surfaces. It is natural then to think of ceramics when developments in engineering, such as the gas-turbine engine and rocket motor, demand structures to withstand higher and higher temperatures, in some cases in the presence of highly corrosive agents. Among the materials commanding attention are the ceramic oxides.

Many of the ceramic oxides have very high melting points. Thoria has been recorded as melting at 5500°F., magnesia at 5100°F., zirconia at 4900°F., beryllia at 4500°F., and alumina at 3700°F. At temperatures below the melting point, crystals of these oxides have resistance to applied stress. Utility at high temperatures, therefore, appears promising.

But certain disadvantages of these materials must be kept in mind. When we use high temperatures, we can expect differences in temperature, both from time to time and from one location to another. Most of the oxides have high thermal expansion and low thermal conductivity, a combination which tends to build high stresses within the material. The modulus of elasticity is high and the ductility is low, so that the oxides tend to resist relaxation of such thermal stresses without damage. In addition to stresses caused by thermal expansion, mechanical stresses also build up under concentrated or eccentric loading. The ceramic oxides have ample compressive strength to resist these stresses. Their tensile strength may be low or high, but in either case it is hard to use because of the difficulty in safely gripping or fastening a tension member of such a material and in loading it uniformly.

Investigations sponsored by the Office of Naval Research have thrown much light on the problems involved in fabricating ceramic oxides into useful parts for high-temperature service. Let us consider briefly the conventional way of making an oxide body. First, the grains or particles of a powder are formed or "assembled" into a shape. Following removal of any volatiles or combustibles, the shape is heated to a temperature a little below the melting point. This sintering process joins the particles into a continuous phase. We need not consider here

Zane Schofield, supervisor of the ceramic division at Battelle Memorial Institute, received his B.Cer.E. from Ohio State University in 1929. After six years in the floor and wall tile industry, Mr Schofield returned to Ohio State University as a member of the ceramic research staff of the Engineering Experiment Station. While there he was awarded the degree of Cer.E. Mr. Schofield joined Battelle's staff early in 1943 where much of his work has been concerned with ceramic construction materials for jet-propulsion devices and nuclear reactors.

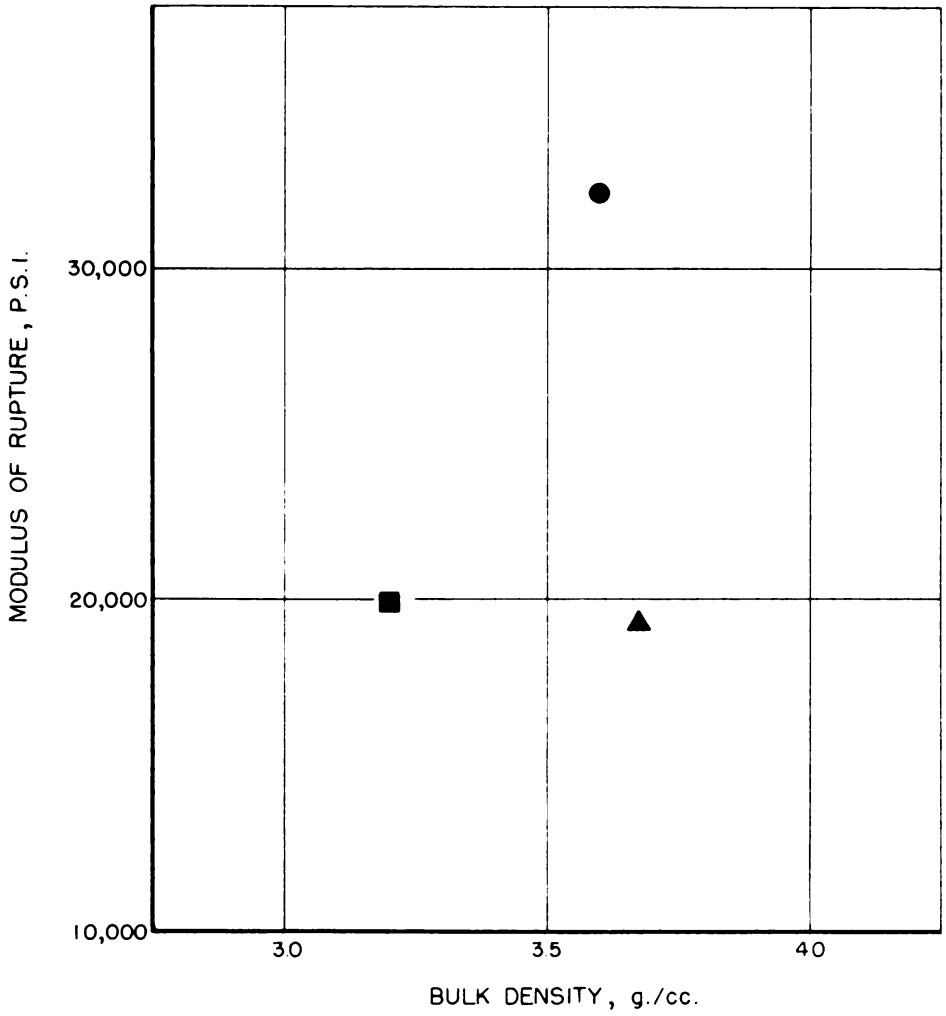


FIGURE 1. PROPERTIES OF SOLID, FINE-GRAINED ALUMINA STRUCTURES AFTER SINTERING FOR 27 HOURS AT 3100 °F.

■ POWDER HAVING AVERAGE GRAIN SIZE OF ABOUT 20 MICRONS. SPECIMEN FORMED BY PLASTIC EXTRUSION.

● POWDER HAVING AVERAGE GRAIN SIZE OF ABOUT 5 MICRONS. SPECIMEN FORMED BY PLASTIC EXTRUSION.

▲ POWDER HAVING AVERAGE GRAIN SIZE OF ABOUT 5 MICRONS. SPECIMEN FORMED BY DUST PRESSING.

what forces, such as "surface tension" and "viscosity" or volatilization and condensation, are influential in accomplishing this joining, although research should establish the answer. Under present procedures of fabricating pure oxide bodies, the properties of the final product, ready for use, are influenced by many factors, each requiring tedious control. Among these are the chemical and physical nature, including the grain size, of the oxide particles in the starting material. Also of great

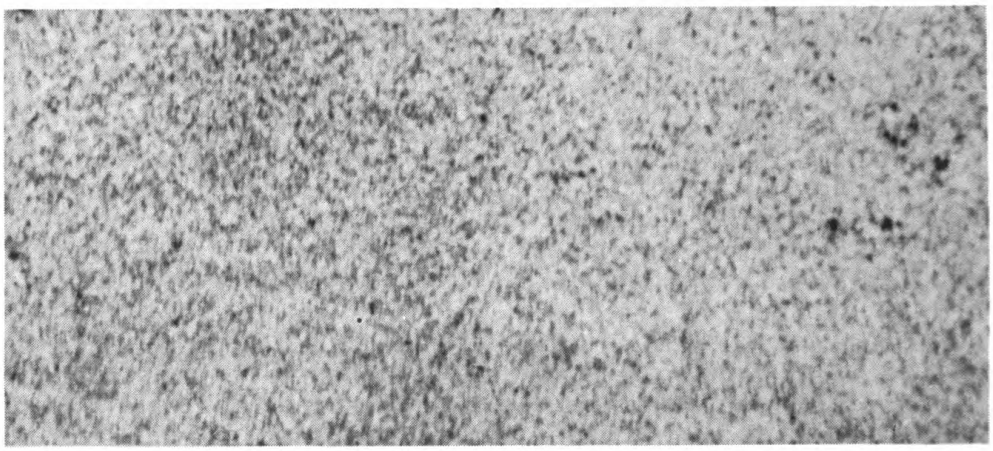


Figure 2. Specimen formed in plaster mold by casting aqueous suspension of alumina powder (average grain size five microns); then sintering three hours at 3100°F. Modulus of rupture, 35,000 psi. (Mag: X15)

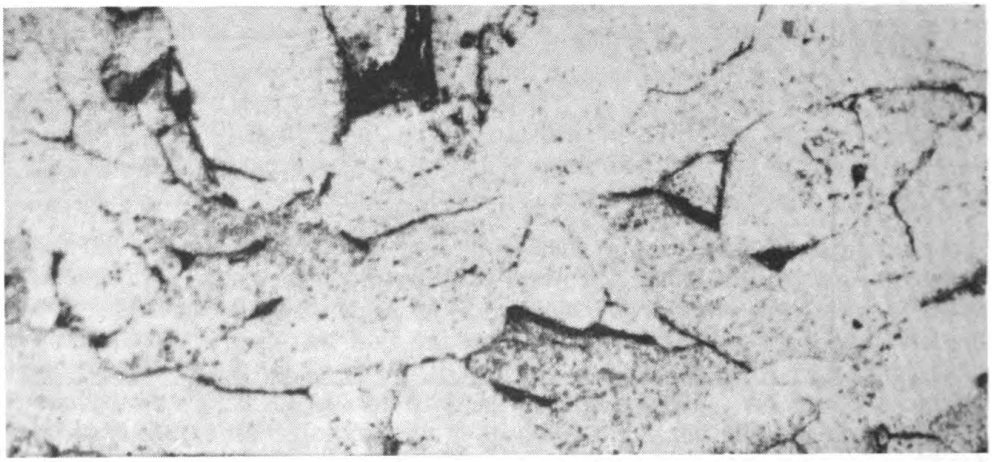


Figure 3. Specimen formed as described for Figure 2, but sintered for nine hours at 3300°F. Modulus of rupture was 3800 psi. (Mag: X15)

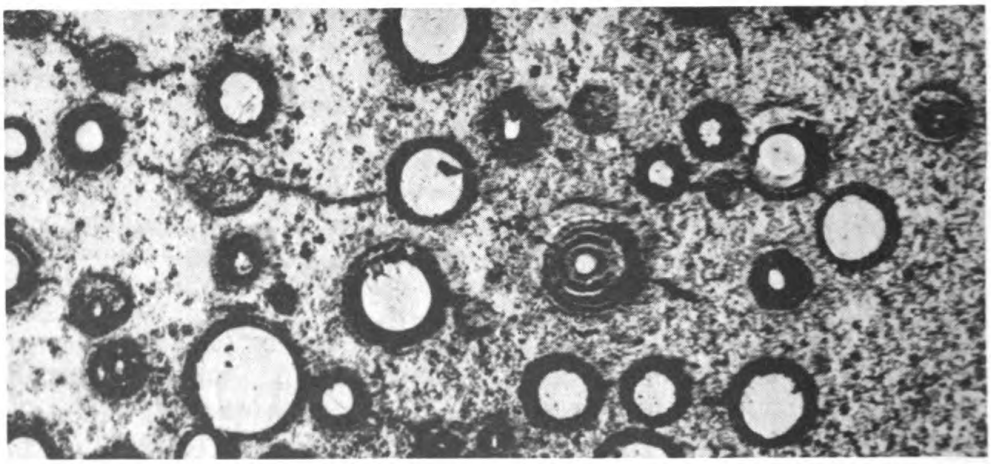


Figure 4. A dense, finely knit ceramic body into which spherical pores were "engineered" by incorporating tiny organic spheres before forming and sintering specimen. (Mag: X15)

influence are the method of assembly of the particles into a shape (including relative distribution of the various particle sizes, orientations, and concentration) and both the time-temperature schedule and the atmosphere of sintering. The influence of some of these variables is shown in Figure 1. It is also notable that as the severity of the sintering treatment is increased, a degree is reached at which the coalescence of the powder grains to form a finely knit structure is supplemented by coarse crystal growth. This development in the internal structure, illustrated in Figures 2 and 3, influences the properties of the product greatly.

Thus far, we have been considering the formation of homogeneous ceramic bodies. Our apparent aim in such research is to form, at once, a solid mass of the oxide into the shape of the desired engineering element and then heat-treat it so as to yield the useful part. Such a homogeneous body, however, has one serious drawback. The solid mass of crystals would have mechanical properties seriously limited by the disadvantages which were listed previously for the oxides. An extension might be had beyond these apparent limitations, however, by engineering designs and execution of structures, dimensioned in thousandths of an inch, within the oxide crystal mass. A very crude example which illustrates what might be done is shown in Figure 4. A cursory test was made of such small-scale or "minute" engineering in the studies for the Office of Naval Research. Progressively increased amounts of slender cylindrical pores were "engineered" in a dense alumina structure by incorporating fine organic monofilaments before forming and sintering. The susceptibility of the structure to thermal shock, as observed by percentage loss in strength and by tendency to crack, seemed to be reduced by such "engineering," at least at some temperatures of shocking. Unfortunately, time has not permitted pursuance of this research to establish the effect of the shape, placement, or "content" of the pores. As a narrow example, the "pores" could consist of a refractory metal prestressed in tension. The combination might take advantage of the metal's high tensile strength and also of the high compressive strength of the oxide.

A field of endeavor, employing fundamental engineering design and intentional construction dimensioned in thousandths of an inch or in microns, appears worthy of attention somewhere between the field of controlling the arrangement of molecules and the field of assembling fabricated elements dimensioned in feet and inches.

Sound engineering design, dimensioned in feet and inches, is executed today with eminent success. Attention is given to tension, compression, torsion, and shear stresses in selecting and combining the material or materials. Contour, slenderness, thermal expansion, elasticity, Poisson's ratio, creep, fatigue, prestressing, joinings, and others, "to infinity," are appraised before the elements are fabricated separately and then assembled into a Lockheed Constitution, an Empire State Building, a George Washington Bridge, a Lincoln Tunnel, or a Mt. Palomar telescope. Certainly, we do not and could not form, at once, a solid mass of the proper chemical composition into the shape of one of these imposing structures and then heat treat it so as to cause a migration, precipitation, volatilization, condensation, recrystallization, or orientation to yield, lo, the useful contrivance. When we design and form the internal structure of a ceramic body, we cannot apply completely all of the engineering deliberation which goes into a large-scale structure. But much intentional arrangement is possible.

* * * * * *

High Polymer Research

by

Paul J. Flory
Cornell University

So-called polymeric ("many-membered") substances play an important role in man and in his environment. All organic structural materials are polymeric, that is to say, their molecular structures are enormously large as molecules go. Outstanding examples of natural polymers are the starches, proteins, cellulose, and rubber. Their molecules are 1000 to 100,000 or more times larger than the simple molecules from which they are built up. They are called macromolecules (from Greek macro, large).

Proteins are essential to all forms of living matter; furthermore, they provide the structural material for animals. Cellulose performs a similar function in plants. Nonpolymeric natural products, such as sugars, vitamins, hormones, and antibiotics, are but fragments from, or accessories to, the fundamental macromolecular principle in nature and in natural processes. This explains the obvious importance of high polymer science to the understanding of living processes. Many inorganic substances such as silicate glasses and the complex phosphates may properly be regarded as polymers also.

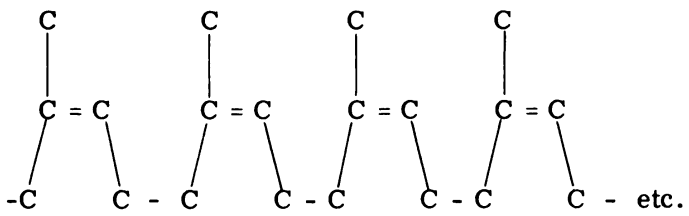
Practical utilization of natural high polymers, chiefly cellulose (wood, cotton, flax) and proteins (silk, wool, animal hides), is as old as the history of the human race. To these substances of natural origin should be added natural rubber, widespread use of which has come about only within the past century. In recent years numerous synthetic materials have replaced the natural polymers and have found many new uses as well. Experience shows without exception that the synthetic material, like the natural product which it replaces, must be polymeric. Thus, our synthetic rubbers are high polymers and synthetic fibers are composed of long chain macromolecules characterized by a simple, regularly repeating structural unit. To these examples could be added plastics, surface coatings (paints), thermosetting resins, and films. America's annual production of synthetic polymers for a wide variety

Paul J. Flory, professor of chemistry at Cornell University, received his B.S. degree from Manchester College in 1931 and his Ph.D. degree from Ohio State University in 1934. He became interested in the polymer field while a research chemist at Dupont Experimental Station. Dr. Flory was later a research associate at the Basic Science Laboratory, University of Cincinnati and a research chemist with the Standard Oil Development Co. Before joining the faculty of Cornell University in 1948, Dr. Flory was for five years in charge of fundamental research for the Goodyear Research Laboratory. He received the Joseph Sullivant Medal of Ohio State University in 1945 and the Baekeland Award in 1947.

of uses runs into several billion pounds, and is steadily on the increase. This is small compared to the use of natural polymers such as wood, textiles, paper, leather, and rubber. It does not include chemically processed natural polymers such as rayon (from cellulose) or wool substitute (from proteins).

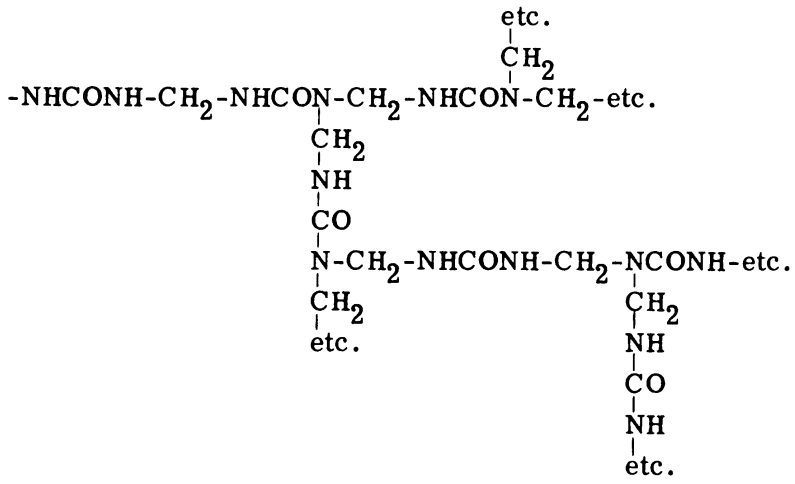
Some of the newer high polymers exhibit properties unknown in natural macromolecules. Certain synthetic fibers surpass natural fibers in strength and durability, and some synthetic rubbers withstand heat, sunlight, and solvents far better than does Hevea brasiliensis rubber. (Hevea brasiliensis, a type of small South American tree, is the world's principal supply of crude rubber.) Other synthetic polymers perform excellently as electrical insulation even at quite high temperatures. The possibilities for future development and practical application of these synthetics have no visible limit.

Despite the diversity of macromolecular substances, they all possess a common similarity in their chemical structure. Polymer molecules are composed of hundreds, thousands, or even hundreds of thousands, of structural units connected by chemical bonds to form very long chains, meshes, or other structural patterns. The chemical structure of natural rubber is a chain of successive five-carbon units, as indicated in the following skeletal chemical formula for the molecules occurring in natural rubber; hydrogen atoms omitted:



The native rubber molecules average some 10,000 C_5 units in length. The actual molecules are not ordinarily straightened out rods as the above formula might imply; they coil irregularly, so interwined that at proper magnification a piece of rubber might resemble a mass of animated spaghetti, wriggling ceaselessly under the influence of thermal agitation. Cellulose, polystyrene, nylon, and many other macromolecules are composed of other types of structural units similarly connected in very long chains. The polymer chain may be made up of several different kinds of repeating units as in GR-S synthetic rubber or in nitrocellulose. All of these substances, whether serving as rubbers, plastics, fibers, or protective films, share in common the characteristic polymer chain structure. The links of the chain are always of ordinary molecular size (molecular weight well below 1000, often below 100). Thus, an ordinary molecule is to a chain polymer as one car is to a freight train up to several hundred miles in length!

There are other nonlinear polymers in which the structural units are connected in branched arrays. A typical example is represented in the following portion of the chemical structure within a urea-formaldehyde thermoset resin:



The units are connected in chains as in linear polymers, but some are connected to more than one chain sequence. It is difficult to represent such a structure literally, as the possible variations are innumerable. If a branched chain structure such as the one shown continues to interconnect one chain with another, the result is a giant network of structural units — something like an imaginary hopelessly tangled fishnet in three dimensions. Such a network may continue throughout the sample and hence may be macroscopic in size, that is large enough to be seen by the naked eye. Obviously the term "molecule" is out of place in the description of such substances. All thermosetting resins, paint films, and vulcanized rubber are of this type. In the last, the long chains are cross-linked at points some distance apart, so that the mobility of intervening chain portions is relatively unrestrained. Hence, in vulcanized rubber high flexibility is combined with strength and dimensional stability. A portion of the network structure in vulcanized rubber is represented schematically in Figure 1.

Research and developmental investigations on high polymers were until quite recently, almost always empirical. Polymers and polymerization were considered too complex to justify research into basic principles, if indeed such principles could ever be established. In short, the field was considered to be off limits for theoretical scientific inquiry. To some extent this belief may yet prevail, but advances of the past few years show unmistakably that the complexities of polymers are largely within range of known techniques. Average molecular sizes of linear polymers may now be determined by measuring osmotic pressures, or scattering of light, or other procedures which have become little more than routine. The dimensions of an irregularly coiled polymer molecule may be estimated from the viscosity of its dilute solution or from the angular dissymmetry of the light scattered by the solution.

The mechanisms of polymerization reactions have received a great deal of attention by research workers during the past decade. As a result, new polymeric types may now be developed by following well established principles instead of relying on prohibitively laborious cut-and-try exploratory experiments. Greatest interest has centered on the polymerization of unsaturated compounds such as styrene, butadiene, and methyl methacrylate. The synthesis of polymers from such compounds proceeds by a chain radical mechanism whereby an active center

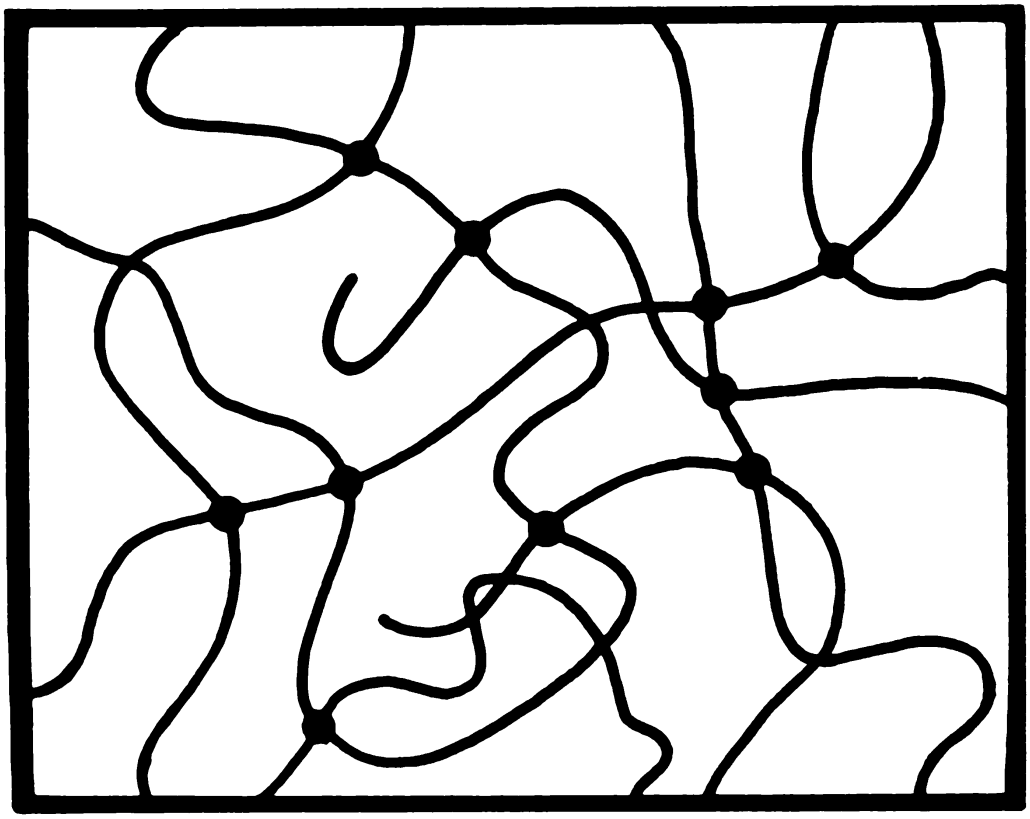


Figure 1. Schematic representation of the structure of vulcanized rubber. Dots represent cross-linkages.

(or radical) released from a catalyst sets off the rapid combination of thousands of monomer molecules to form the long polymer chain. If M represents the monomer molecule (e.g., styrene), and M* the monomer activated by the catalyst, the process may be represented as follows:

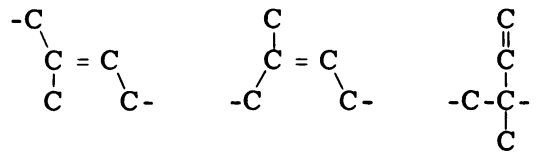
$$M^* \xrightarrow{+M} M\text{-}M^* \xrightarrow{+M} M\text{-}M\text{-}M^* \xrightarrow{+M} \text{etc.}$$

The center of activity indicated by the asterisk combines chemically with a monomer molecule, and shifts to this added unit M, whereupon the process is repeated. The addition of monomers is exceedingly rapid; in some cases the entire molecule composed of thousands of units being formed within a fraction of a second.

The above remarks do not mean that all major problems pertaining to polymers and polymerization have been solved. Rather, it may be said that some phases of the subject have been sufficiently investigated to establish a few basic principles and techniques. Doubtless these will prove most fruitful in further fundamental research, and in applied research as well. Although a great deal remains to be done, rapid advances should be possible with the theories and experimental methods now in hand.

Most polymerization studies, both pure and applied, have been concentrated up to now on polymerization of unsaturated monomers. But there are other types of chemical reactions which form macromolecules, and these deserve their proportionate share of attention in

the future. The potentialities of condensation reactions, such as are employed in the synthesis of nylon or of silicone polymers, have by no means been fully explored. Furthermore, natural polymers are formed by unknown chemical reactions which probably are unlike any of the processes used in laboratory or commercial polymer synthesis. The mysterious regularity which characterizes the chain structures of natural macromolecules is seldom reproduced in laboratory polymerizations. For example, in synthesizing nature's rubber from isoprene (C_5H_8), the C_5 units arrange themselves irregularly as follows:



rather than with the perfect regularity of natural rubber as shown in a preceding formula. A somewhat more uniform polymerization of the related monomer, butadiene, was recently accomplished at lower temperatures. Polymerization in nature, however, remains a mystery which if understood might open up incalculable possibilities for synthesis.

Another field yet to be explored concerns the connections between polymer structure and various physical properties such as strength, elasticity, viscosity, and solubility. Problems in this vast field are of importance both practically and as fundamental scientific questions. That such properties as strength, rubber-like elasticity, and toughness are observed almost exclusively in polymeric substances, is not particularly surprising. It might well be supposed that giant molecular chain structures would favor high strength, durability, and even elasticity under proper conditions. Theoretically the elastic modulus, or stiffness, of vulcanized rubber should be proportional to the density of cross-linkages (Figure 1) which it contains. Recent experiments confirm this prediction. Connections also can be traced between the strength of the sample and its network structure. Ends of chains dangling freely in the network represent flaws or weak spots which lower the strength, and may also retard elastic recovery from deformation.

High polymers excel where pliability (or high elasticity in the case of a rubber) is required together with high strength. For many uses this combination of properties is needed over the widest possible temperature range. These considerations immediately lead to questions concerning the factors responsible for high strength on the one hand and for flexibility (or its disappearance at low temperatures) on the other. High strength is generally dependent upon the occurrence of crystallinity in the polymer. If the polymer chains are sufficiently regular in structure and if the intermolecular forces are great enough, the chains will arrange themselves in parallel bundles, or crystallites. The polymer is then tough, strong, or even fiber-forming (e.g., nylon or polyethylene). Natural rubber and certain synthetics are normally noncrystalline, but become crystalline when stretched. Hence they combine soft rufferiness at low extensions with very high ultimate strength (up to 50,000 psi based on the cross-section of the fully stretched specimen). Crystallization on standing at low temperatures cannot be tolerated in a rubber, for it then loses its rubbery character, becoming hard and boardy instead. In other words, crystallization on stretching

is desirable, but appreciable crystallization without deformation at the lowest use temperature must be avoided. Detailed investigations of the factors affecting crystallization in polymers are very much needed.

Even if the polymer does not crystallize on cooling, it will eventually harden to a glassy (vitreous) state. Below its "glass temperature" (alias "second order transition temperature" and "brittle point") the polymer is hard and brittle; it cannot be used as a rubber. On the other hand, above its glass temperature it is soft, rubbery, or even molten; it cannot be used where strength and dimensional stability are required unless crystallization intervenes, or without suitable reinforcement with fillers such as carbon black. Polystyrene, for example, is a transparent, highly useful "glass" at ordinary temperatures. Above about 200° F., however, it softens to a very viscous semi-elastic material, useless (at such a temperature) for the normal applications of polystyrene. The glass temperature for GR-S rubber occurs at about -80° F., below which it may be compared to polystyrene at room temperature. The glass temperature imposes a lower limit to its usefulness as a rubber. Films, protective coatings, and polymers in other applications often become too brittle, and hence too susceptible to fracture, to permit use below their vitreous state transitions.

The nature of the vitreous state in polymers represents another field where research is much needed. Little is known concerning the relation between the glass transition and polymer structure. It seems to depend in some way on the intensity of the intermolecular forces between chains and perhaps also on the stiffness of the polymer chain.

The above brief discussion indicates the approximate status of scientific endeavor in the polymer field, and points out some of the problems which now seem to be of major importance. The successful establishment thus far of a few guiding principles encourages further investigation, and abundant opportunities for fruitful research seem to be at hand.

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Man and Thermal Radiation

by

Lawrence R. Prouty, M. D.
Cornell University Medical College

How does the color of human skin affect thermal radiation exchange in various climates and at different altitudes? What is the best deck color for naval vessels in the tropics in time of peace? Why are crews inside ships sometimes unbearably hot or cold even though thermometers indicate that room air is at a comfortable temperature? Why are human radiant heat losses so much greater on a clear night or at a high altitude?

Studies of the exchange of heat radiation between the human body and environment, until recently one of the more neglected subjects in physiology, can furnish definitive experimental answers to such currently puzzling questions as these. A research group under Drs. E. F. Du Bois and J. D. Hardy at Cornell University Medical College, which is attempting to solve some of these enigmas, is actively engaged in developing new instruments and techniques for measuring infrared radiation emitted from and received by the human body. Their starting point is the commonly accepted fact that the living subject is constantly producing internal heat which must be dissipated to the surroundings to prevent rise in body temperature. There is a constant loss of heat by infrared radiation in the 5μ to 50μ portion of the infrared range (1μ = 1 micron = one millionth of a meter). Heat is lost from the surface of a warmer body to cooler surroundings. Conversely, warm bodies receive infrared radiation from all objects in the environment warmer than themselves. The net exchange is an important factor in human thermodynamics.

The infrared radiation from the sun is largely absorbed by the earth's atmosphere before reaching sea level. Atmospheric moisture so greatly reduces solar infrared radiation striking the earth that at sea level this radiation may be greater on a clear winter day than on a cloudy summer day. Infrared radiation is electromagnetic energy and travels at the speed of light (186,000 miles per second). It passes through a vacuum and is independent of air temperature. The human subject may feel quite chilly in a room filled with warm air but with cold walls because of radiation losses to the walls.

Radiation exchange between human skin and environment obeys the same physical laws applicable to inanimate objects. This exchange will depend upon temperature difference, surface area exposed, and emissivity as expressed by the principles of Newton, Planck, Wein, Stefan-Boltzman and Lambert. Only living subjects, however, possess the ability to shunt blood from deep to superficial areas for better utilization of these principles through altered surface temperature.

Lawrence R. Prouty is an instructor in physiology and a research associate under an ONR contract at Cornell University Medical College in New York City. He received his B.S. degree from Colorado University in 1940, and his M.D. from Cornell in 1943. Dr. Prouty interned at Bellevue Hospital in 1944. He has been engaged in his present ONR project on human and animal temperature regulation since 1946.

Figure 1. Hardy Dermal Radiometer.

The emissivity factor largely depends upon skin texture and color. All human skin acts as a black body for the invisible infrared radiation. Visible light also contains heat energy. The skin color will largely determine radiation absorption and emission in this portion of the electromagnetic spectrum. In visible light, if radiation were the only factor to be considered, the skin of a very dark man would feel twice as hot in direct sunlight as that of a white man. The dark skin is usually thicker and penetration of the sun's rays is therefore less.

Accurate measurements of skin temperature are important in determining heat exchange with the environment. They are also useful in evaluating thermal insulation properties of clothing and the range of environmental temperatures producing a sensation of comfort. These measurements can also indicate the blood flow through the skin and can be correlated with such physiological factors as pulse rate and blood pressure. For example, the effectiveness of a drug which dilates the blood vessels in patients with vascular disease can be estimated by administering the drug and estimating the skin blood flow by means of accurate skin temperature determinations.

No really accurate method of measuring human surface temperature existed until 1934 when a radiometer was developed by Hardy for this purpose. The radiometer (Figure 1) contains a sensitive thermopile which detects infrared radiation from the skin and radiation from the environment to the skin. The older instruments such as liquid-in-glass thermometers, thermocouples, resistance thermometers, and various surface pyrometers require direct contact between the instrument

and the surface. A contact instrument thus involves boundary layer temperature. It also tends to change surface temperature, since the instrument tends to measure primarily its own temperature as modified by contact with the skin. Contact instruments also tend to deform a surface by pressure and thus alter contact area, causing local vascular changes and sweating. All these factors are serious sources of error. Some contact instruments are subject to errors of $\pm 3^{\circ}C$.

The radiometer, however, "sees" the infrared (heat) radiation from the skin without surface contact. Accuracy of the dermal radiometer is now established at $\pm 0.001^{\circ}C$. and its full response time is less than eight seconds.

At present extensive evaluations of all surface temperature measuring devices are being made by Stoll and Hardy. Although the importance of skin temperature measurements is well recognized, the use of widely different techniques makes it difficult to correlate work of various investigators. In comparing surface temperature measuring devices Stoll and Hardy test the instruments against a standard surface consisting of several concentric layers of leather surrounding a constant temperature bath (Figure 2). Although these studies leave little doubt of the dermal radiometer's superiority in accuracy, other methods such as thermocouples and thermistors can be reliable if methods of application are standardized.

Ebaugh and Thauer are using the dermal radiometer to determine local temperature sensation in the skin at different environmental temperatures. The rate of change of skin temperature at which a sensation of warmth or cold is first perceived is known as the "threshold"

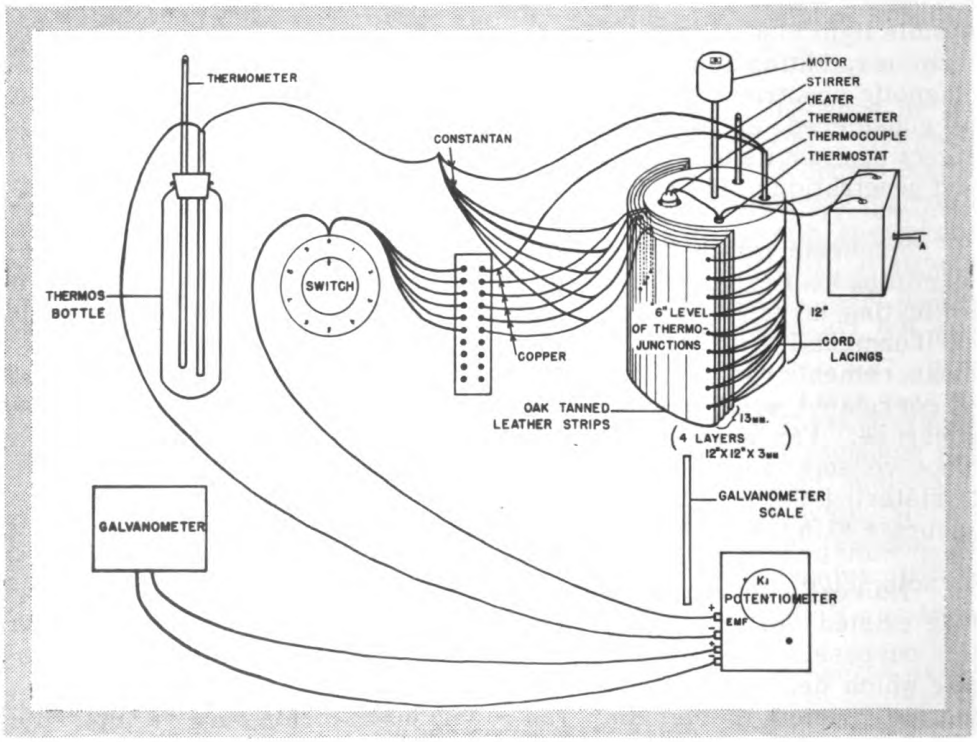

Figure 2. Standard surface used by Stoll and Hardy for testing surface temperature measuring devices.

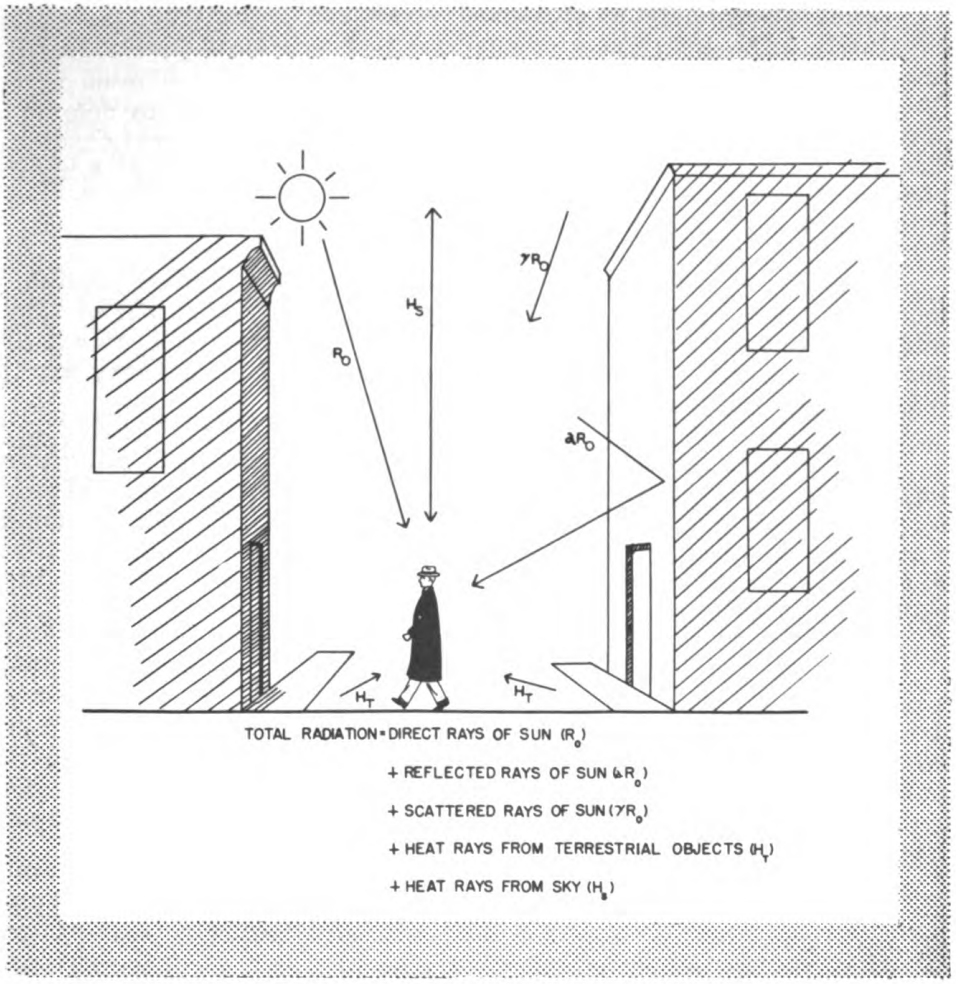

Figure 3. Radiation exchange of man with outdoor environment. (After Hardy and Richards.)

temperature for that sensation. Heat is supplied to a local skin area by infrared radiation from a small laboratory hot-plate. The skin is cooled by having it radiate to a block of dry ice. Surprisingly enough, the cold threshold increases almost two-fold in environments from 34-40°C. although the threshold to warmth is unaffected by the surrounding temperature. This means that if a mint julep were held in the hand on the warm veranda of a Southern plantation, it would invoke less sensation of cold than it would in cooler surroundings. The explanation of this phenomenon is not yet clear.

Useful as it is, the dermal radiometer is inadequate for measuring mean radiation exchange between man and his out-of-door surroundings. A radiometer can "see" only one small area of skin surface or environment at a time. An instrument called the pan-radiometer has been developed by Hardy and Richards to "see" the entire environment approximately as the human skin "sees" it. Figure 3 indicates various sources of radiation falling on a man in an out-door environment. Such an instrument is made possible by the fact that the solar radiation spectrum does not overlap appreciably the low temperature radiation spectrum from terrestrial objects.

The pan-radiometer measures solar and terrestrial radiation separately. The instrument consists of four pea-sized hollow silver spheres, each of which encloses a thermocouple and a heating coil. The surface of one sphere is painted matte white, another is painted dull black, and two have polished silver surfaces. The white sphere reflects visible radiation and absorbs infrared. The black sphere acts as a black body to absorb practically all radiation falling upon its surface. The polished spheres reflect 93 percent of the incident radiation.

When the pan-radiometer is placed out-of-doors in the sunlight, the black sphere becomes warm, the polished spheres less warm. The white sphere becomes least warm because it reflects visible radiation and loses infrared radiation into space, so that on a clear sunny day it will be several degrees cooler than the air.

In a similar manner, man and other warm objects continually lose infrared energy to interstellar space and gain it from other warmer terrestrial objects. The net radiation exchange for a white-skinned man in the out-of-doors is usually negative, i.e., more radiation is lost to the environment than is gained. This is because more of the visible radiation is lost to the low radiant temperature of the sky than is gained.

The mean radiant temperature of a dark-skinned man is usually much higher than that of a white-skinned man out-of-doors because the dark skin acts much like the black ball of the pan-radiometer. This does not mean that a dark-skinned individual will have a higher skin temperature when exposed to out-of-door radiation because man can acclimatize by increasing vaporization, convection, and conduction heat losses.

To determine the thermal stress on man in given surroundings, the pan-radiometer is used to obtain the operative temperature as follows: The white and one of the polished spheres are supplied with internal heat to bring them to the temperature of the black sphere. This heat and the temperature of the black sphere are measured. The direct radiant heat of the sun, the albedo or reflecting power of the surfaces of the spheres, and the equivalent radiant temperature of the environment are then combined with the air temperature and velocity to give the operative temperature.

Direct solar radiation measurements are also correlated with the above data. To obtain them a separate radiometer is kept pointed directly at the sun by a servo-mechanism utilizing photocells to follow the sun's position.

Since man loses about 55 to 60 percent of his body heat by radiation in an ordinary environment, the following conclusions may be made from preliminary experiments with the pan-radiometer for out-of-door environments.

Except in cloudy weather the white sphere is usually below air temperature. The mean radiant temperature for a white surface out-of-doors is usually negative even though the sun is shining.

In general, protection against the sun in a warm climate is best accomplished by utilizing white surfaces. In tropical climates, human

clothing, hospital roofs, tents, and ship decks should be white if thermal comfort is more important than camouflage protection.

On cloudy or overcast days, the negative radiation from human skin to the sky is effectively cut off. Clouds act as positive radiators to earth and the mean environmental radiation becomes positive.

As atmospheric moisture decreases, as for example on clear days or in mountainous regions, the mean radiation exchange of the environment becomes greatly negative. To protect crops against this cooling effect, citrus fruit farmers burn smudge pots to form a blanket to shut off the radiation to the sky.

With regard to ships, aircraft, and projectiles, the radiant temperatures of the surroundings are probably more important than ambient air temperatures. This important fact should be considered in air conditioning and painting surfaces to suit probable radiation factors in the climates and altitudes encountered.

Although a black skin and a white skin act as almost perfect black bodies for infrared radiation, the darker skinned man will have a higher mean radiant temperature in most out-of-door surroundings. This is due to the fact that the lighter skin will reflect much of the visible radiation, the darker skin will absorb it. Both skins will have a negative exchange in the infrared region. The net result is a lower mean radiant temperature for the lighter surface.

Man has now shrunk the earth by his speed of travel and communication. In a short space of time the human body can go from a sweltering tropical climate to the arctic cold of the stratosphere. If he is to retain maximum operating efficiency a knowledge of human radiation exchange is of tremendous importance. Man can lose heat by radiation to a cool surface or gain it from a warm surface, in extreme environments, to remain comfortable even though air temperature and humidity are not controlled. The results of these studies in human radiation exchange when given practical application should greatly increase the comfort of working and living spaces. Many older concepts of heating and air conditioning by control of room air and humidity alone are certain to be replaced.

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On the Naval Research Reserve

Of interest to all Research Reservists is the invitation which the Director of the U. S. Naval Experiment Station, Annapolis, Md., has extended to scientific personnel of Volunteer Naval Research Reserve Unit 4-1 to visit the station in order to become acquainted with the various laboratory facilities and the station personnel. In extending a cordial invitation to LCDR Paul Busse, USNR, Commanding Officer of Unit 4-1, Princeton, N. J., Mr. W. D. Leggett, Jr., Director of the Experiment Station stated that "the Engineering Experiment Station is interested in contacts with Reserve scientific personnel in order to keep close contact with the work of universities and industry on research problems and to become acquainted with individuals who might logically fit into the station organization in time of emergency." The work of the Engineering Experiment Station is primarily of a test and development nature and its diversified workshop contains many interesting facilities. The programs of the Experiment Stations' six major laboratories were briefly summarized in the invitation to the Princeton Unit.

The Chemical Engineering Laboratory's present fields of investigation cover fuels, natural and synthetic, and their by-products, water treatments, paints, cements, anti-freezes, metals, packings, gaskets, insulations, and other chemical engineering materials. The Internal Combustion Engine Laboratory tests and develops large and small Diesel engines as well as component parts and accessories, and lubricating and fuel oils. This laboratory is one of the largest Diesel engine testing laboratories in the world. One of its most recent additions is a low temperature test facility where temperatures as low as 85° F below zero can be maintained. The Mechanical Laboratory includes an experimental Allis Chalmers gas turbine plant, hydrogen peroxide experimental gear, a large machinery section which conducts tests on all types of shipboard machinery, and a special bearings test section. In the Metallurgical Laboratory extensive equipment for fatigue testing is available and equipment for studying wear in bearings and cylinder liners, and flash sintering of powdered metal compounds. An automatic X-ray diffraction spectrophotometer is a much used instrument in this Laboratory. The Wave Mechanics Laboratory, the newest laboratory on the Station, is concerned with tests, research and development work in the fields of applied acoustics, vibration, and mechanical shock. Three large anehoic chambers for sound tests on full size shipboard machinery would interest physicists and engineers. A large underwater sound effects test tank is another interesting feature. The Welding and Electrical Laboratory is equipped to conduct investigations and tests of all types of welding methods, procedures, equipment, and materials. Underwater cutting and welding tests and procedures also are conducted by this laboratory.

A visit to the Experiment Station offers an opportunity for an interesting and instructive field trip for units where transportation facilities can be made available. Commanding Officers who would like to arrange such a field trip for their units or for groups within units should write to the Director, U. S. Naval Experiment Station, Annapolis, Md., via Chief of Naval Research (Code-104).

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Officially Activated

Volunteer Research Reserve Units

Designation	Time and Place of Meeting	Commanding Officer and Mail Address
1-1	2000, 1st & 3rd Mon. Auditorium, Navy Bldg. 60 495 Summer St. Boston, Mass.	CAPT J. W. Hammond, USNR ONR Branch Office 495 Summer St. Boston, Mass.
1-2	1930, 2nd & 4th Tues. USNROTC Bldg. Brown University Providence, R. I.	CDR C. J. Fish, USNR Oceanographic Institute Woods Hole, Mass.
1-3	1900, 1st & 3rd Tues. University of Massachusetts Amherst, Mass.	LCDR E. D. Emerson, USNR Mechanical Eng. Department University of Massachusetts Amherst, Mass.
1-4	2000, 1st & 3rd Tues. Coburn Hall University of Maine Orono, Maine	LT Francis J. Sullivan, USNR 25 Myrtle St. Orono, Maine
1-5	2000, 1st & 3rd Mon. Stratton Hall Worcester Polytechnic Inst. Worcester, Mass.	CDR Emerson A. Wiggin, USNR 25 Bay State Rd. Worcester, Mass.
3-1	1930, Alt. Thurs., from 8 Sept. Auditorium Cornell University Medical College 1300 York Ave. New York, N.Y.	CDR J. D. Hardy, USNR Cornell University Medical College 1300 York Ave. New York 21, N.Y.
3-2	1930, 2nd & 4th Mon. Special Devices Center Engineering Bldg. Sands Point, Port Washington, Long Island, N.Y.	CDR L. E. Yoder, USNR Special Devices Center Sands Point, Port Washington, Long Island, N.Y.
3-3	2000, 1st & 3rd Mon. USNR & MCRTC 3 Porter Ave. Buffalo, N.Y.	LCDR Ralph Bloom, Jr., USNR USNRTC & MCRTC 3 Porter Ave. Buffalo, N.Y.
3-4	1930, 1st & 3rd Tues. USNR & MCRTC 900 East Main St. Rochester, N.Y.	CDR Henry C. Sheve, USNR USNR & MCRTC 900 East Main St. Rochester 7, N.Y.
3-5	1930, 2nd & 4th Thurs. USNRTC Fort Nathan Hale Park New Haven, Conn.	CDR D. S. Rowell, USNR USNRTC Fort Nathan Hale Park New Haven 13, Conn.
3-6	2000, 2nd & 4th Mon. USNRTC Syracuse (Liverpool) N.Y.	LT A. O. Quinn, USNR USNRTC Syracuse (Liverpool) N.Y.
3-7	2000, 2nd & 4th Thurs. USNRTC Scotia, N.Y.	LCDR. Earl E. Vezey, USNR USNRTC Scotia, N.Y.

Designation	Time and Place of Meeting	Commanding Officer and Mail Address
4-1	2000, 1st & 3rd Wed. Nassau Tavern Princeton, N.J.	LCDR Paul Busse, USNR Aeronautical Eng. Bldg. Princeton University Princeton, N.J.
4-2	1930, Alt. Thurs. Franklin Institute 20th St. & Parkway Philadelphia, Pa.	LCDR Wm. G. Amey, USNR Electronics Section Franklin Institute 20th St. & Parkway Philadelphia 3, Pa.
4-3	2000, 2nd & 4th Thurs. 303 Thaw Hall University of Pittsburgh Pittsburgh, Pa.	CDR Neil D. Cole, USNR Office of Naval Research University of Pittsburgh 303 Thaw Hall Pittsburgh, Pa.
4-4	1930, 1st & 3rd Wed. Elec. Eng. Bldg., Rm 110 Pennsylvania State College College Station, Pa.	CDR E. R. Queer, USNR c/o Eng. Experiment Station Pennsylvania State College College Station, Pa.
4-5	2000, Alt. Thurs., from 21 Nov. USNRTC Foot of Madison St. Wilmington, Del.	LCDR Donald MacCreary, USNR USNRTC Foot of Madison St. Wilmington, Del.
W-1	2000, 1st Thurs. Navy Dept. Bldg. T-3, Rm 1515 2000, 3rd Thurs. Auditorium, Interior Dept. Washington, D.C.	CDR W. M. Richardson, USNR ONR, Bldg. T-3, Rm 2602 Washington, D.C.
W-2	1900, 1st Thurs. NRL Auditorium, Bldg. 8 2000, 3rd Thurs. Auditorium, Interior Dept. Washington, D.C.	LCDR H. A. Tanner, USNR Naval Research Laboratory Bldg. 8, Rm 152 Washington 20, D.C.
W-4	2000, 2nd & 4th Wed. Navy Dept. Bldg. T-3, Rm 1803 2000, 3rd Thurs. Auditorium, Interior Dept. Washington, D.C.	LCDR Lawrence Gardiner, USNR Atomic Energy Commission Public Health Bldg., Rm 102 Washington, D.C.
5-1	1930, 1st and 3rd Wed. Rouss Physics Lab. University of Virginia Charlottesville, Va.	LTJG Gilmer T. Fitchett, USNR Cobb Chem. Laboratory University of Virginia Charlottesville, Va.
5-2	1915, 1st & 3rd Fri. Virginia Polytechnic Institute Bldg. 364 Blacksburg, Va.	LCDR E. D. Harrison, USNR P. O. Box 575 Blacksburg, Va.
5-3	2000, each Tues. Camp Detrick Frederick, Md.	CAPT LeRoy D. Fothergill, USNR Camp Detrick Frederick, Md.
6-1	2000, Alt. Thurs. 103 Physics Bldg. Georgia Institute of Technology Atlanta, Ga.	CDR J. E. Boyd, USNR Physics Bldg. Georgia Institute of Technology Atlanta, Ga.
6-2	1915, 1st & 3rd Mon. 204 Ross Lab. Alabama Polytechnic Institute Auburn, Ala.	LTJG J. E. Land, USNR Chemistry Department Alabama Polytechnic Institute Auburn, Ala.

Designation	Time and Place of Meeting	Commanding Officer and Mail Address
6-3	2nd & 4th Tues. A.E.C. Townsite Oak Ridge National Lab. Oak Ridge, Tenn.	LCDR D. J. Mallon, USNR P. O. Box P Oak Ridge, Tenn.
6-4	1930, 1st & 3rd Tues. Engineering Bldg. University of Florida Gainesville, Fla.	LCDR E. G. Rietz, USNR Chemistry Department University of Florida Gainesville, Fla.
6-5	2000, 1st & 3rd Thurs. USNRTC Gulfport, Miss.	LT W. O. Smallwood, USNR 2412 East Ave. Gulfport, Miss.
6-6	1945, 2nd & 4th Thurs. USNROTC Armory University of North Carolina Chapel Hill, N.C.	LCDR R. F. Stainback, USNR 317 W. University Drive Chapel Hill, N.C.
6-7	2000, 2nd & 4th Thurs. (Irregular) Biology Bldg. Duke University Durham, N.C.	LCDR John H. Roberts, USNR 2813 Legion Ave. Durham, N.C.
8-1	1930, 1st & 3rd Tues. USNROTC Bldg. Tulane University New Orleans, La.	LCDR John M. Scott, USNR Chemistry Department Tulane University New Orleans, La.
8-2	1930, 1st & 3rd Wed. Rm. 221 Coates Lab. Louisiana State University Baton Rouge, La.	LCDR W. R. Edwards, Jr., USNR Chemistry Department Louisiana State University Baton Rouge, La.
8-3	1930, 2nd & 4th Mon. PMA Bldg. or Bolton Hall Texas A & M College College Station, Tex.	LCDR Norman F. Rode, USNR Electrical Eng. Dept. Texas A & M College College Station, Tex.
8-4	1930, Alt. Wed. (21 Dec.) USNROTC Bldg. The Rice Institute Houston, Tex.	LTJG John J. Banewicz, USNR 4811 Mt. Vernon St. Houston, Tex.
8-5	2000, Alt. Tues. & Wed. (13 Dec.) Physics Bldg., Rm 201 or Chemistry Bldg., Rm 15, University of Texas Austin, Tex.	LCDR G. H. Ayres, USNR Chemistry Department University of Texas Austin, Tex.
8-6	1930, Last Mon. USNRTC Galveston, Tex.	LTJG C. N. Sechrist, USNR 1235 3rd Ave. North Texas City, Tex.
8-7	2000, 1st & 3rd Wed. USNRTC 1805 Yale Ave. Albuquerque, N. Mex.	LCDR Sherman A. Wengard, USNR P.O. Box 346 Albuquerque, N. Mex.
8-8	(Time & Date Not Established) Central High School Bartlesville, Okla.	LCDR E.O. Box, USNR 1642 Hickory St. Bartlesville, Okla.

Designation	Time and Place of Meeting	Commanding Officer and Mail Address
8-8 Sub-Unit	Louisiana, Mo.	LT Herbert B. Sachs, USNR Synthetic Fuels Plant P.O. Box 316, Louisiana, Mo.
8-8 Sub-Unit	Stillwater, Okla.	LT O. H. Hamilton, USNR 503 Pine St. Stillwater, Okla.
9-1	1900, 2nd & 4th Tues. Navy Pier Campus University of Illinois Chicago, Ill.	CAPT George C. Lamb, USNR Technological Institute Northwestern University Evanston, Ill.
9-2	1930, 1st & 3rd Mon. 319 Gregory Hall University of Illinois Urbana, Ill.	CAPT Chauncey M. Louttit, USNR 303 Administration (E) University of Illinois Urbana, Ill.
9-3	(Time & Date Not Established) Angell Hall, Rm 18 University of Michigan Ann Arbor, Mich.	CDR Freeman D. Miller, USNR 1012 W. Washington St. Ann Arbor, Mich.
9-4	1930, 2nd & 4th Tues. Old Armory, Rm 107 Ohio State University Columbus, Ohio	LCDR Karl E. Krill, USNR Engineering Exp. Station Ohio State University Columbus, Ohio
9-5	1930, Weds. NROTC Bldg. Iowa State College Ames, Iowa	LCDR O. C. Kreider, USNR Mathematics Department Iowa State College Ames, Iowa
9-6	1930, 1st Mon. & 3rd Tues. Murphy Hall Auditorium University of Minnesota Minneapolis, Minn.	LCDR J. A. Wise, USNR 220 Experimental Eng. Bldg. University of Minnesota Minneapolis, Minn.
9-7	1930, 2nd & 4th Thurs. 111 Stanley Coulter Hall Purdue University Lafayette, Ind.	LT L. M. Baker, USNR Psychology Department Purdue University Lafayette, Ind.
9-8	2000, Odd Thurs. 101 Crew Hall Washington University St. Louis, Mo.	CDR R. M. Varney, USNR Physics Department Washington University St. Louis, Mo.
9-9	1930, 1st & 3rd Thurs. (22 Dec.) 204 Mechanics Hall Missouri School of Mines & Metallurgy Rolla, Mo.	CDR R. A. Cooley, USNR Missouri School of Mines & Metallurgy Rolla, Mo.
9-10	1930, 1st & 3rd Wed. USNRTC Peoria, Ill.	LTJG Thomas G. Pridham 1004 N. Underhill Peoria, Ill.
9-11	2000, 1st & 3rd Mon. (Irregular) USNRTC 1089 E. Ninth St. Cleveland, Ohio	LCDR Viktor Schreckengost, USNR 2366 Noble Road Cleveland 21, Ohio
9-12	1930, 2nd & 4th Thurs. Botany Bldg. Annex, Rm 2 Colorado A & M College Ft. Collins, Colo.	LTJG W. D. Thomas, USNR Botany & Plant Pathology Dept. Colorado A & M College Ft. Collins, Colo.

Designation	Time and Place of Meeting	Commanding Officer and Mail Address
9-12 Sub-Unit	Boulder, Colo.	LTJG George J. Maler, USNR Electrical Engineering Dept. University of Colorado Boulder, Colo.
9-12 Sub-Unit	Laramie, Wyo.	LTJG Fred K. Elder Jr., USNR Physics Department University of Wyoming Laramie, Wyo.
9-13	(Time and Date Not Established) USNRTC 9th & Pleasant Sts. Des Moines, Iowa	LCDR John R. Maloney, USNR 2920 48th St. Des Moines 10, Iowa
9-14	1930, Wed. or Thurs. (2/mo.) USNRTC University of Wisconsin Madison, Wis.	CDR W. B. Sarles, USNR 310 Agricultural Hall University of Wisconsin Madison 6, Wis.
9-15	1900, 1st & 3rd Thurs. Conference Room, Pers. Bldg. Dowe Chemical Co. Midland, Mich.	LTJG D. D. McCollister, USNR 1220 Michigan St. Midland, Mich.
9-16	1900, 2nd & 4th Mon. 206 EE Bldg. Michigan State College East Lansing, Mich.	LT Elbert S. Churchill, USNR Bacteriology Department Michigan State College East Lansing, Mich.
11-1	2000, 1st & 3rd Tues. 1030 E. Green St. Pasadena, Calif.	LCDR Frederick P. Dillon, USNR 1030 E. Green St. Pasadena, Calif.
11-2	2000, Alt. Thurs. USNRTC Pasadena, Calif.	LCDR J. H. Biggar, USNR 680 E. Colorado St. Pasadena, Calif.
11-3	2000, Alt. Mon. USNR & MCRTC 851 Chavez Ravine Rd. Los Angeles, Calif.	CDR L. P. Delsasso, USNR Physics Department University of California Los Angeles, Calif.
11-4	2000, 1st & 3rd Wed. USNRTC San Pedro, Calif.	LCDR Myron S. Allen, USNR 3130 East Second St. Long Beach, Calif.
11-5	1930, 2nd, 3rd, 4th, Last Tues. USNRTC San Diego, Calif.	CDR Gifford C. Ewing, USNR 1205 Muirlands Drive La Jolla, Calif.
12-1	2000, 2nd & 4th Mon. 801 Donahue St. San Francisco, Calif.	CDR J. E. Laurance, USNR ONR Branch Office 801 Donahue St. San Francisco, Calif.
12-2	1945, 2nd & 4th Mon. Donner Lab., Rm 201 University of California Berkeley, Calif.	LCDR Nello Pace, USNR Life Science Bldg., Rm 2519 University of California Berkeley, Calif.
12-3	2000, 2nd & 4th Wed. Engineering Corner, Rm 208 Stanford University Stanford, Calif.	CDR L. S. Jacobsen, USNR Mechanical Engineering Dept. Stanford University Stanford, Calif.

Designation	Time and Place of Meeting	Commanding Officer and Mail Address
12-4	2000, 2nd & 4th Thurs. McLane Hall, Rm M-103 Fresno State College Fresno, Calif.	CDR Ralph A. Jack, USNR Physics Department Fresno State College Fresno 2, Calif.
12-5	1930, 2nd & 4th Wed. LeConte Hall, Rm 208 University of California Berkeley, Calif.	CDR C. F. Garland, USNR Engineering Design Division University of California Berkeley, Calif.
12-6	1945, 2nd Mon. Animal Science Bldg., Tower Room University of California Davis, Calif.	LT Arthur H. Smith, USNR Animal Husbandry Division University of California Davis, Calif.
13-1	1930, 2nd & 4th Mon. Anatomy Bldg., Rm 108 University of Washington Seattle, Wash.	CDR H. S. Bennett, USNR Anatomy Department School of Medicine University of Washington Seattle, Wash.
13-2	1900, 2nd & 4th Tues. American Legion Hall Richland, Wash.	LT W. W. Gonder, USNR General Electric Co. Richland, Wash.
13-3	1930, 2nd & 4th Mon. YMCA Pullman, Wash.	LCDR W. G. Gnaediger, USNR Community College Serv. State College of Washington Pullman, Wash.
13-4	1930, 1st & 3rd Mon. Swan Island Portland, Oreg.	LCDR Richard F. Stevens, USNR 811 N. E. Oregon St. Portland, Oreg.
13-5	(Time & Date Not Established) Oregon State College Corvallis, Oreg.	LCDR Albert V. Logan, USNR Chemistry Department Oregon State College Corvallis, Oreg.

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