OFFICE OF NAVAL RESEARCH JANUARY 1953

RESEARCH REVIEWS

"Congratulations"

NAVEXOS P-510

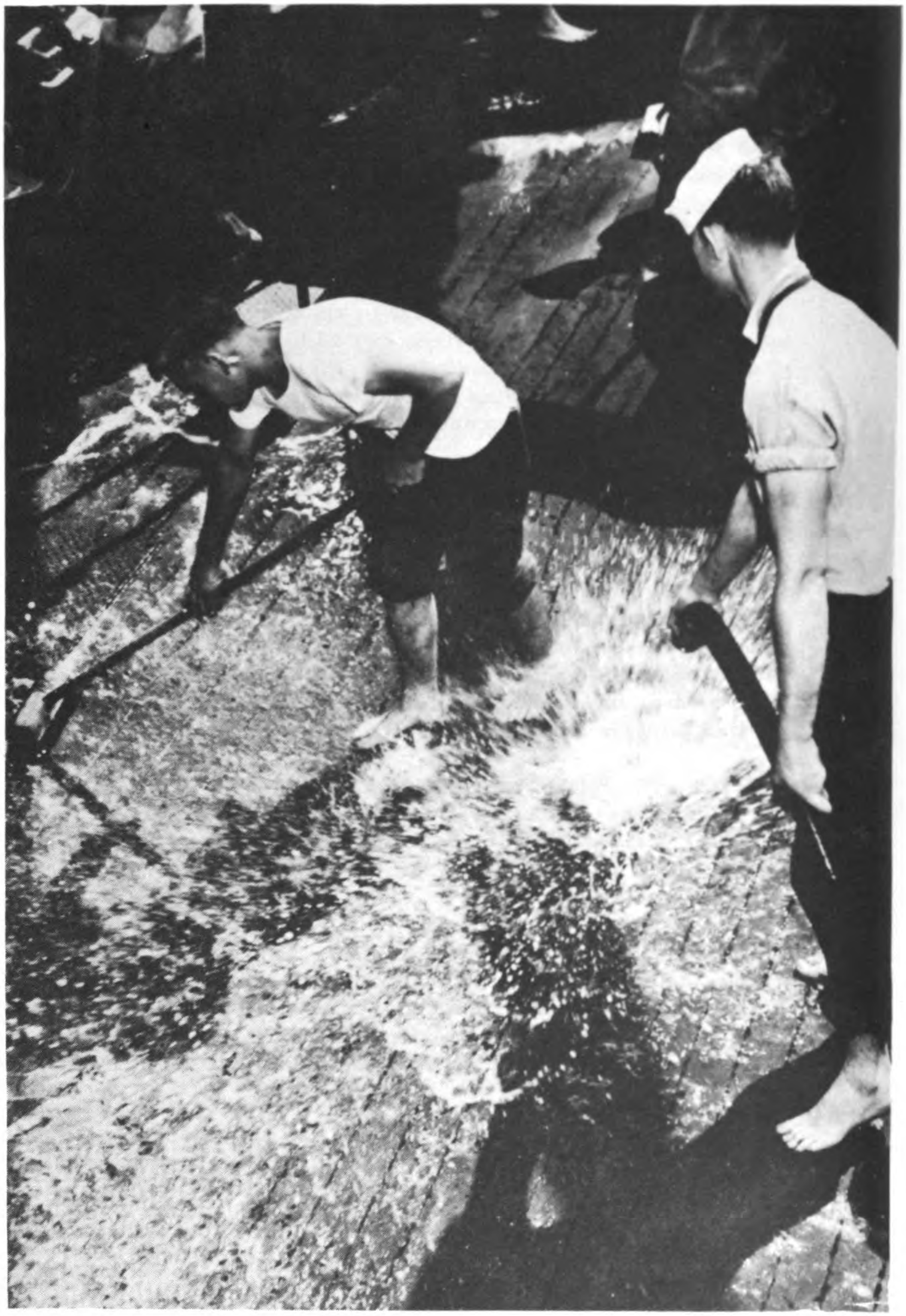
DEPARTMENT OF THE NAVY
WASHINGTON, D. C.

COVER PHOTO: Captain Shilling, Director of the Research Division of the Bureau of Medicine and Surgery and Special Assistant for Bio Sciences at ONR, is being congratulated by President Harry S. Truman. CAPT Shilling has just been awarded the Association of Military Surgeons' Founders' Medal given each year for outstanding contributions to military medicine. The presentation was made at the Association's annual meeting, held November 17-19 in Washington. Dr. Shilling first made a name for himself back in 1939 when he personally supervised the medical treatment of 33 men rescued from the sunken SQUALUS off Portsmouth, N. H. Since then he has continued research on submarine medicine and deep-sea diving; he has recently been called, by Lamont Pugh, Surgeon General of the U.S. Navy, a "specialist without peer."

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

Approved by Bureau of the Budget, 14 February 1952

In This Issue



The Navy has many uses for cleansing agents, including the one pictured above. From swabbing the deck, these uses range all the way to polishing the most delicate optical lenses. Where true soaps were once used for most of these varied operations, custom-made detergents, because of their highly specialized properties, are now replacing them in some cases.

How Detergents Work

Eric Hutchinson

... assistant professor in chemistry at Stanford University, has conducted research in the U. S. and in England on various phases of surface chemistry.

The rapid increase in the number of synthetic competitors to the true soaps in recent years has added the word detergent to the pseudo-scientific argot of the general public, and much has been made of the great advantages possessed by, and claimed for, synthetic detergents. Along with the growth of the detergent industry there has been a corresponding, apparently inevitable, multiplication of terms so that we now have "syndets" (synthetic detergents), "surfactants" (surface-active agents), etc., and a considerable literature relating to the properties of these materials is now on library shelves. Some 2000 or more different detergents are now commercially available, although not all are obtainable in large-scale quantities.

Many of these detergents possess highly specialized properties, and it is this custom-built feature of synthetic detergents which is responsible for their great popularity. All materials of this class of compounds possess certain features in common, and only these general properties, in particular those relating to cleansing, will be discussed.

To inquire what cleansing is, at first sight, might appear to be asking a question with a perfectly obvious answer: the act of removing dirt. But this raises the further question of what dirt is. A safe definition of dirt would be simply "chemical matter in the wrong place"; but, for most ordinary purposes, we refer to the kind of dirt that won't wash off readily and this may be less carefully defined as being greasy (or oily) matter.

The greasy materials, which are organic in nature, may be fatty substances or hydrocarbons—oils such as lubricating oils. Obviously the most efficient method of removing greasy materials would be to use a solvent such as a dry-cleaning fluid. However, this method has the disadvantages of being expensive and, as far as personal cleansing is concerned, somewhat hazardous (since most dry-cleaning fluids are poisonous). In addition, such a solvent would be rather too efficient since it would dissolve not merely the foreign greasy matter on our skin, but also many of the oils which cover the epidermis, the removal of which causes discomfort.

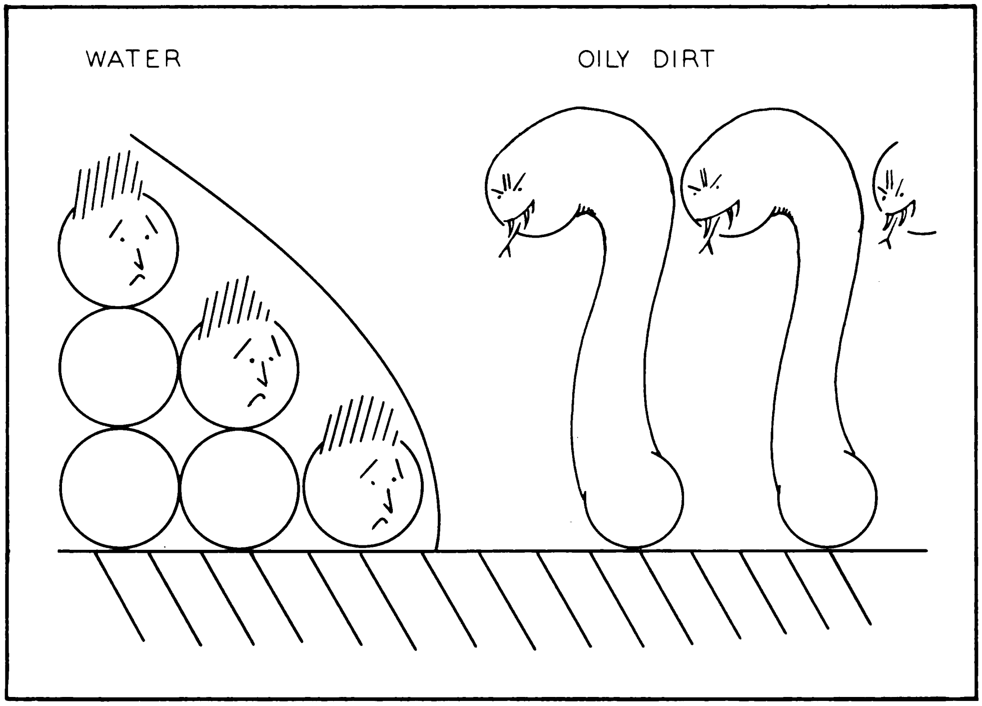
A compromise is evidently called for, and a little consideration indicates that the kind of chemical compound needed is one that will combine the cheapness and safety of water with the solvent power of gasoline. If we are to prepare a compound to be used in water, however, we clearly need to bring about considerable modification toward a gasoline type of molecule, for—as is common knowledge—oils and water do not mix. A compound which combines the ready water-solubility of soda with the solvent properties of gasoline is the desired end. This in fact is actually what a soap is. If we choose some other type of compound for the parent water-soluble material, say sodium sulfate (Glauber's salt), and attach a gasoline chain to this, we have a different type of detergent. Or we could start with ammonia and attach hydrocarbon chains to get yet another type. The different water-soluble starting materials confer different individual properties on the final detergent, such as resistance to precipitation by hard water or greater chemical stability. It is particularly in this respect that so many of the newer detergents are superior to the true soaps (the older detergents derived basically from soda).

Attaching a hydrocarbon chain to a water-soluble molecule results in some extremely interesting phenomena, which have been the subject of serious study for some 30 years.

To start with, let us look at the action that takes place in the removal of greasy matter from a surface. No success will be achieved unless the cleansing agent can first wet the grease. Wetting is a phenomenon which is essentially associated with the chemical similarity of materials, and which in its most extreme form is exhibited by the phenomenon of solubility. For example, alcohol and water are quite closely similar in chemical form and readily dissolve in each other; paraffin wax and benzene are closely related and are mutually soluble.

In the last analysis, the question of whether one kind of chemical material "likes" another well enough to dissolve in it is resolved in terms of the electrical forces which operate between molecules as a result of the essentially electrical nature of all matter. The magnitude of these forces, we can predict, at least approximately, from a knowledge of the nature of the molecules, although the detailed calculations are still well beyond our powers. It is clear enough, however, that the attractive forces operating between water molecules and hydrocarbon (or grease-spot) molecules are so small compared to those between water molecules themselves that, for all practical purposes, they are negligible. So, if we attempt to bring water molecules and hydrocarbon molecules together, they appear to recoil from each other and curl up, each in its own more favorable environment (as facetiously illustrated in the drawing at the top of the next page).

This lack of attraction between oil and water, which I will loosely term a repulsion, has a profound effect on the properties of a soda-and-hydrocarbon-chain detergent dissolved in water. The figure on p. 4 illustrates in an exaggerated fashion what happens to a dissolved detergent molecule. In the drawing, the round end of the molecule represents the water-soluble "head" of the detergent, that is, the soda or Glauber's salt part of the molecule, while the "tail" represents the hydrocarbon part of the molecule. Because the water surrounding the molecule is repulsive, the hydrocarbon tail curls up in an effort to reduce to the very minimum the contact between water and hydrocarbon, so that the detergent molecules act as if they were curled-up hedgehogs. But at the <u>surface</u> of the solution, where the water meets the air, an entirely different situation is encountered. Here the molecule, instead of curling up, has the alternative of removing its hydrocarbon chain entirely from the water so that it sticks up into the air, where—because it is now surrounded by other hydrocarbon chains—it no longer tends to curl up. The tendency for the molecule to adopt this position in the surface of the solution is very strong even in very dilute solutions. So the surface



As everybody knows, oil and water don't mix. This drawing shows, in exaggerated form, what happens when water is put on a grease spot.

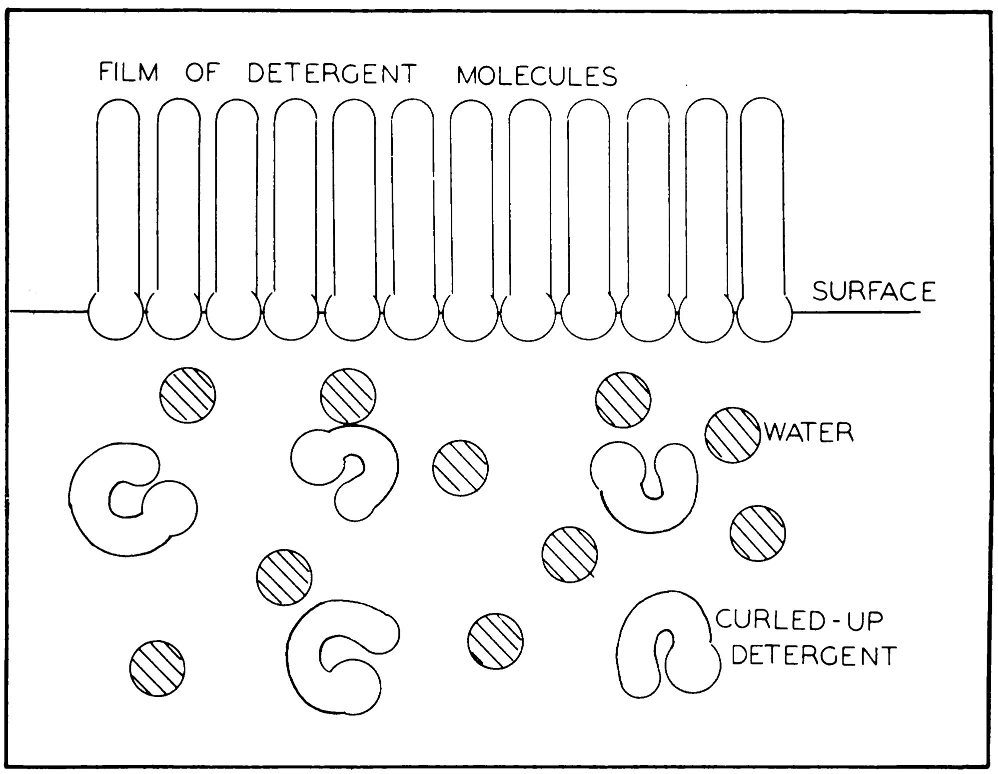
appearance of a detergent solution, seen from above, is quite similar to that of a hydrocarbon oil itself.

Now observe what happens if we bring, not water, but a solution of a detergent up to a piece of greasy matter. Whereas the water and the oil repel one another, now, since the surface of the detergent solution is to all intents oily itself, there is considerable attraction between the surface film and the molecules of oil or grease. This attraction is sufficient for the solution to wet the oil, and the first requirement for cleansing—that the cleansing fluid shall be able to get close to the dirt—is readily satisfied.

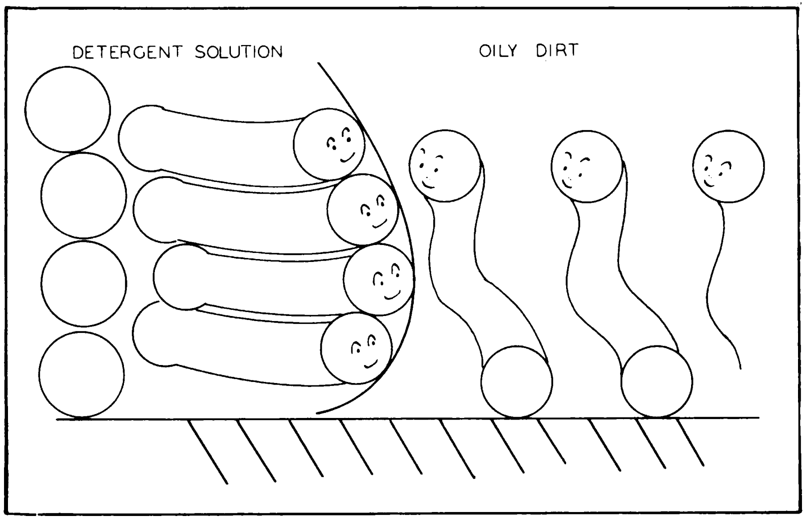
This is only part of the problem, however, for now the wetted oil must be removed bodily from the surface to be cleaned. This implies that we must be able to present to the oil molecules something which attracts them more strongly than the surface to which they are attached. This poses a real problem for, the interior of a water solution, as we have seen, is an unfavorable environment for the oil. It would be a very unpromising situation if the only part of a detergent solution which represented a favorable environment were the surface itself; this would mean that we could only cleanse dirty surfaces by having very extensive surfaces of detergent solutions. A little reflection shows that this could be achieved if the detergent solution were beaten up so as to produce a foam, or shampoo, for each surface of the foam would then have the same properties as the film pictured in the figure on p. 5. Yet this foaming aspect is in many ways quite misleading and at best represents a rather inefficient way of attracting oil away from a surface.

The congregation of detergent molecules at the surface of the solution is, to be sure, a striking phenomenon, but an even more remarkable effect can be observed—an effect which is, again, a manifestation of the repulsion between oil and water. We have seen that the detergent molecules in solution tend to curl up so that their hydrocarbon chains are as little exposed to water as is possible. A much more effective way in which this separation of oil and water can be brought about is illustrated by the drawing on p. 6. By associating together, the detergent molecules can arrange themselves in such a fashion that their hydrocarbon tails are all more or less in contact and almost completely removed from contact with the water, and at the same time put up a "front" which is water-attractive, so that the whole aggregate of molecules assumes a very stable arrangement. These "local unions" of detergent molecules, which are called micelles, are formed rather dramatically in detergent solutions.

In dilute solutions where the detergent molecules are somewhat thinly spread out in the water, and therefore have no particularly close detergent neighbors, the molecules are present as the single species, in their rather uncomfortable curled-up state. As the solution becomes more and more concentrated into micelles the average distance between detergent molecules becomes less and less. At a certain stage, which occurs relatively sharply, the detergent molecules find themselves sufficiently close together that the association is no longer merely a desirable aspiration but a real possibility. The solution then undergoes a striking change. Below this concentration the individual molecules of detergent exist, and above this concentration the relatively large



The hydrocarbon "tails" of detergent molecules in dilute solution try to escape surrounding water molecules. They have two ways of doing this.



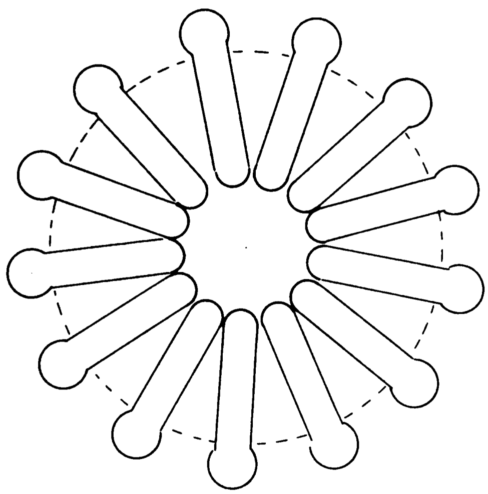
The oily surface film of the detergent solution is enough like the oily dirt to attract and wet it. Thus the first requirement of cleansing is satisfied.

aggregates are formed. The concentration at which this occurs is called the "critical micelle concentration." As might well be imagined, not merely the arrangement of the molecules, but all the other associated properties of the solution such as viscosity, vapor pressure, density, refractive index, etc., also show a sharp change when the micelles are formed.

Now observe what a profound change occurs in the essential character of the detergent solution as soon as the micelles are formed. We have, in the water solution, a large blob of matter which, on its outer surface, is to all appearances rather like soda, but which, in its interior, is very similar to a hydrocarbon. In other words the micelle represents a very successful method of incorporating inside water, in a very stable manner, a droplet of dry-cleaning fluid. Obviously the hydrocarbon interior of this cleaning fluid will offer a very favorable environment for any stray oil molecule, and in this way we can, with the water solution, offer a tempting resting place to oily material. This, then, represents the second aspect of cleansing. The surface of the solution of the detergent is sufficiently attractive that we can wet the oily matter, while the bulk of the solution offers a very convenient place to which the oily matter can go when it leaves the surface to which it is attached.

It now becomes clear why the foaming action of a detergent solution is relatively unimportant. Unless the solution is almost entirely broken up into a very extensive foam, only a small fraction of the detergent molecules will be in a position either to wet the oily matter or to attract it away from the surface to which it is attached. On the other hand, all of the detergent molecules in the solution can cooperate in forming the micelles, and therefore all of the detergent molecules may take part in the cleansing action. Indeed the foaming action may almost be regarded as incidental; many very efficient detergents at present available possess little foaming action, the formation of a stable foam depending on a number of factors, in addition to the existence of a surface film.

The opportunities for making detergents for highly specialized purposes now become clear. The readiness with which an oily molecule is incorporated inside the micelle clearly depends on a number of factors such as the size and shape of the hydrocarbons of the detergent and the oil, the detailed nature of the attractive forces between them, and so on. Prior to 1920 the only materials which were known to have these detergent properties were the soaps themselves. But a change has come with the realization that detergent properties are a general feature of any molecule which contains a hydrocarbon chain attached to some group which is sufficiently water-attractive to drag the "tail" along with it into solution. The possibilities have now become unlimited.



Detergent molecules in concentrated solution form groups like this.

Here is a larger group having solubilized oil molecules inside.

As might well be guessed, the longer the hydrocarbon chain attached to the water-soluble head, the greater is the tendency for the chains to remove themselves from the water environment and form micelles. This is exactly what we find: The longer the chain the more readily do micelles form at low concentrations in solution. This of course means that the longer the chain the more economically can we form the dry-cleaning droplets in water.

The situation depicted in the figure above, right, might be changed to one in which the amount of oil is so large that it comprises by far the major portion of the system (in which case it is called an emulsion). However, such a change is not a very large one in kind, but only of degree. We find in practice that detergents are capable of stabilizing such oil-in-water systems with considerable success. However, there is no real difference in principle between the action of a detergent in stabilizing an emulsion and its action in dissolving oil.

Our present state of knowledge is such that the general behavior of these systems, as outlined here, is understood, but the detailed mechanisms whereby the phenomena are brought about are still a matter for prolonged study.

Blood Clotting and Thrombosis

Alfred L. Copley

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Blood is an organ of highly developed animals which differs from other organs in that it is in a fluid state circulating through the body. It is in a closed vascular system and comes in contact with the walls of blood vessels (arteries, veins and capillaries) of various sizes and functions. The blood of mammals consists of three different deformable cellular elements: red cells, white cells, and platelets (believed to be small fragments of certain bone-marrow cells). These are of various sizes, shapes, and numbers and are suspended in plasma, a fluid containing various solutes including several proteins.

Bleeding, or hemorrhage , is the escape of blood from this closed circulating system and its sustained arrest is called hemostasis. One of the hemostatic mechanisms is the formation of a clot at the site of vessel wounds to prevent blood from being lost. While hemostatic blood clotting is essential to healing, clotting in the blood vessel can cause death; this kind of blood clotting during life is called thrombosis and the clot itself, a thrombus. The pathologic condition of thrombosis occurs in many diseases of the heart, lung, brain, and other vital organs. It is a most dangerous condition, for a thrombus may form in a major blood vessel, or in the heart, and cause a partial or complete obstruction. The thrombus may travel along the blood stream (in which case it is called an embolus) threatening to become lodged somewhere in the circulating system, with disastrous results.

Many theories have been advanced to explain intravascular clotting. With the development of the biological and medical sciencies, the concepts have changed considerably and therefore a great deal of confusion exists in the literature. However, some of the older ideas continue to be useful when they can be confirmed by modern methods.

There are three conditions of blood clotting: agglutination (or collecting in clumps) of the cellular elements, coagulation of the plasma, or a combination of these. These different facets of blood clotting, which must all be taken into account in a study of thrombosis, are schematically shown on the next page.

Among the many theories proposed to explain the mechanisms of coagulation, the classical or thrombin theory is generally accepted. This concept maintains that fibrinogen, present in healthy blood as a soluble protein, is converted to fibrin, an insoluble fibrous protein, by the action of a substance called thrombin. Thromboplastin acts as a "trigger" setting off the first phase of the reaction, the activation of thrombin (in the presence of calcium and other agents) from its presursor, prothrombin. Working against these substances are others, including antithrombin, antithromboplastin, and heparin, which exert their influence to maintain the fluidity of the blood.

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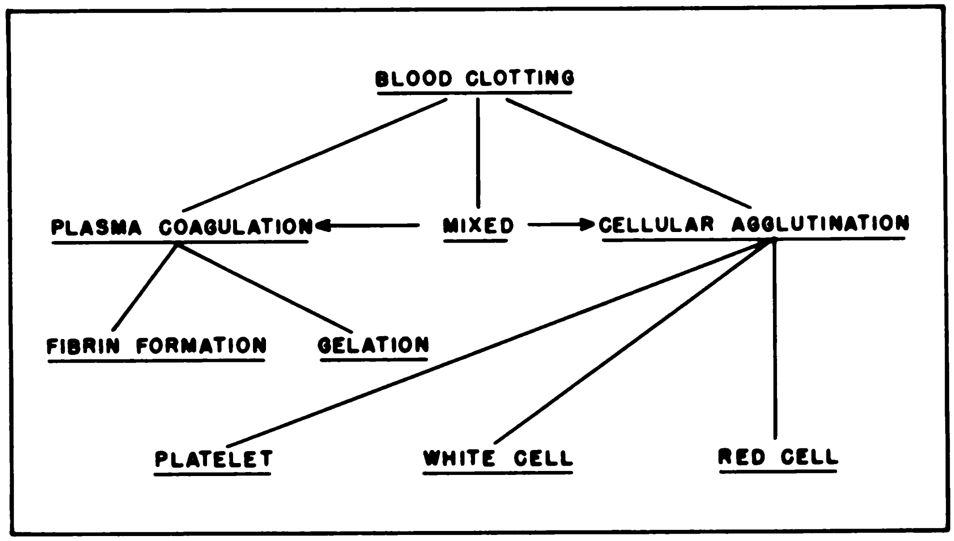


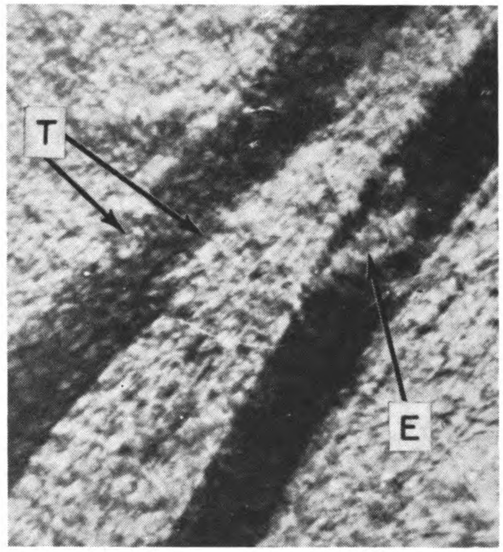
These different states which may be present in blood clotting must all be taken into account in a study of the pathologic condition of thrombosis.

It has been proposed that normally the coagulative properties of blood are kept in equilibrium by the production in the right proportions of all of these substances and that their release into the circulation is regulated by an unknown mechanism. In conditions of coagulation thrombosis, such an equilibrium might be disturbed so that there would be a relative increase of coagulant substances.

Many controversial theories have been offered as to what causes the first phase of the reaction, the activation of thrombin from prothrombin. Important advances were made by Howell, the great American physiologist who devoted more than 60 years of his life to the study of blood clotting. In his theory (1918-1935) he included heparin as an inhibitor of this change. Howell's theory was extended by Copley (1942) who considered (1) that antithrombin is heparin plus a complementary factor and (2) that antithromboplastin is also heparin. Thus, one physiologic anticoagulant, heparin, maintains the fluidity of blood instead of three. Another feature of Copley's theory is the identity of the complementary factor in antithrombin with that in the inactive thrombin-containing prothrombin complex.

The coagulation process may ultimately terminate in a third phase—gelation of the plasma. This process converts the plasma into a different fluid called serum, in which fibrin, in the form of needles or network of fibers, is suspended. The gelation phase is affected by geloplastic agents which promote it and antigeloplastic agents which inhibit it. Heparin was found to be antigeloplastic and calcium in small amounts to be geloplastic.

The process of the dissolution of fibrin clots, called fibrinolysis, has long been known. In recent years this phenomenon has been emphasized by many investigators, and new advances in the biochemistry of fibrinolysis have been made by the Danish scientist Astrup. Nevertheless, its physiologic significance is shrouded in mystery. Recently we have established that the strength of the capillary wall is appreciably lowered by the action of a protein responsible for fibrinolysis, called fibrinolysin. This striking finding suggests that the inner lining of blood vessel walls may contain fibrin which is destroyed by fibrinolysin, thus damaging the wall. Such injury may then permit tissue juice to seep into the damaged vessel wall and, because of its content of coagulants and agglutinants, induce thrombosis.

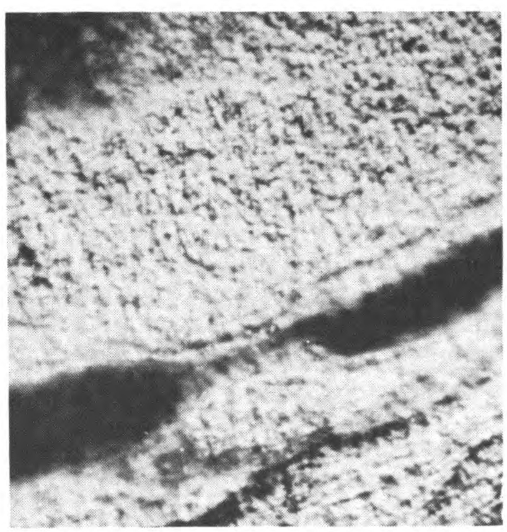


Platelet agglutination embolus (E) and thrombus (T) in hamster's pouch.

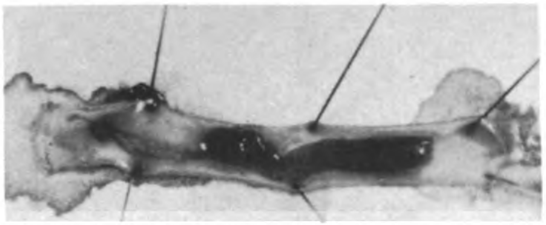
When one or more of the cellular elements present in the blood of mammals, the red or white cells or platelets, collect into clumps, the process is known as agglutination. During the evolution of the animal species, the two clotting processes, coagulation and agglutination, have been developed independently. In many primitive organisms, only agglutination, the earlier of the two, takes place, but in higher forms of animal life both processes persist. Various theories advanced to explain the mechanism of agglutination have been based on stickiness of the cellular elements, adsorbed colloidal substances, or electric charge.

It has not been definitely established that intravascular white cell clots occur independently in mammals, although pure white cell thrombi have been claimed to be present in leukemia. However, white cells may be agglutinated with platelets to form the so-called white thrombi, which have not yet been extensively studied.

Bleeding from a vessel wound is primarily terminated by an agglutination thrombus of platelets (see microphotographs of blood vessels in hamster's pouch), one of the formed elements of mammalian blood. Although the origin and development of platelets is poorly understood, it is generally believed that they are small fragments of the largest cells of the body, the megakaryocytes (giant cells) of the bone marrow. Such a thrombus may or may not be mixed with a coagulation thrombus. In any case, the two processes are governed by different mechanisms and this clumping of platelets is independent of any fibrin formation which might occur.


Platelet agglutination thrombus, nearly occluding the blood vessel.

Since the discovery of human blood groups by Landsteiner in 1901, immunologists have studied red cell agglutination in samples of blood. It occurs independently of platelet agglutination: the experimental conditions underlying



Coagulation thrombus in artery of dog. Note marked retraction (syneresis) of blood coagulum. (Full-size photo)

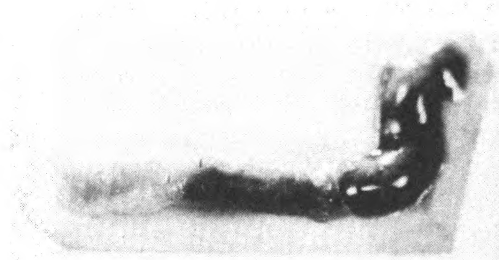
the two types of agglutination follow different mechanisms. It is believed that the severe reactions following transfusions of incompatible blood are caused by immunologic agglutination; that is, the plasma of one blood is incompatible with the red bells of the other.

Red cell clotting may occur in association with fibrin formation, but the two are independent of each other. This can be shown by a simple experiment based upon the fact that certain substances when injected affect the surface of red blood cells and induce their agglutination. One of these substances was injected intravenously into a rabbit together with an anticoagulant to prevent fibrin formation. The blood did not coagulate, but death was nevertheless caused as a result of the agglutination of the red cells.

Death from malaria has been ascribed to the multiple occurrence of red cell thrombosis in blood capillaries, and this type of agglutination has recently been observed in the capillary blood vessels of malaria-infected monkeys and humans. However, it is not yet established whether or not the red cell masses observed in many diseases of humans always constitute agglutinated red cells, that is, cells which adhere irreversibly to each other. Another condition was first observed in 1699 by van Leeuwenhoek, who noted that aggregated red cells in the circulation of tadpoles broke up into single cells again. There is considerable controversy about the nature of these blood masses, their complete composition, how they are formed, and what changes they undergo.

One of the chief causes of thrombosis has been ascribed to the slowing of blood flow, a contention which gained support from physical studies carried out in a river laboratory at the beginning of the century. It was demonstrated that the countless small particles of different specific gravity suspended in the water separated out at dams and at other sites where the flow was slowed down. By comparison, it was concluded that there must be some critical velocity of the blood which will bring about a local aggregation of particles, such as can be observed under the microscope in the formation of thrombi. It is for this reason that, in recent years, following certain major operations the patient is directed to move his legs or to get up in order to counteract slowing of the flow of blood. An analysis of such problems may be expected from an application of rheology, the new science (founded by the American chemist and engineer, Bingham) of the deformation and flow properties of matter.

Other research was carried out more than one hundred years ago by Jean Poiseuille, a French physiologist and physician, who studied the flow in living blood capillaries. He used as a simple model the flow of distilled water through glass tubes of very small diameter. However, upon applying his findings to the study of blood, he discovered that, because of the difference in viscosity, blood does not behave according to the law (based on Newton's equation for flow) established by him for the flow of distilled water. In 1942 we successfully applied a concept of rheology, concerning non-Newtonian flow, and established that the behavior of blood cells contributes to the anomalous flow properties.



Coagulation thrombus in vein of dog. This blood coagulum was not adherent to the vein wall. (Full-size photo)

A second well recognized cause of intravascular clotting is an injury (or trauma) of the inner (endothelial) lining of blood vessels. Alterations of other parts of vessel walls, produced in certain diseases (for example, arteriosclerosis or hardening of the arteries), are also claimed to lead to thrombosis. A simple comparison helps to show the importance of the physical character of the inner lining of the vessel in maintaining the fluidity of the blood. When a vein segment is tied in two places under antiseptic conditions and the wound heals without infection, the included blood column remains liquid. In contrast, after blood is shed, it coagulates when placed in contact with various foreign substances, for example, glass, silicone, or paraffin. Thus, alterations in the physical character of the vessel lining might play a role in intravascular clotting.

A possible additional source of clotting in cases of injury is the introduction of agents contained in the surrounding tissues. When vein segments of dogs were crushed and the stagnant blood left in contact with the injured vessel wall up to two days in the living animal, we obtained clotting only in some cases. It was always due to coagulation, which was apparently induced by coagulant agents contained in tissue juice seeping through the injured portions of the vascular walls. In those cases where clotting did not occur, it was assumed that there were insufficient coagulant substances present. On the other hand, when the blood is still circulating at the site of an injury, clotting is brought about by platelet thrombi which may be initiated by the platelet agglutinant substance present in tissue juice entering the injured vessel.

When a thrombus retracts (a process called syneresis) and at the same time is not adherent to the vessel wall, it is likely to be dislodged and circulate in the blood. In this case it is called an embolus, which may also be a piece broken off from a larger clot or it may be brought about by the disintegration of thrombi. Recent observations have been made of an unanchored, retracted coagulation thrombus produced, without infection, in the arteries and veins of a living dog. Surgeons have stressed the clinical differentiation between thrombosis associated with inflammation and thrombosis without inflammation. In the former, the clot was said to be firmly adherent to the inflamed vessel wall, while, in the latter, a non-adhering clot existed which is of potential danger of becoming an embolus.

So far, the prevention and therapy of thrombosis has emphasized the use of the anticoagulant heparin and hemorrhagic agents like dicumarol. Dicumarol (a complex organic chemical originally derived from spoiled sweet clover) was found not only to produce severe hemorrhage, when administered in large doses, but it also reduced the amount of prothrombin in the circulation. From this it was concluded, but quite erroneously, that it was not merely a hemorrhagic agent but also an anticoagulant. Our recent findings of normal and, occasionally, even increased blood coagulability in rabbits following the administration of large doses of dicumarol, which produced a very low prothrombin level, appear of utmost significance. Dicumarol administration in some cases even produced coagulation thrombi in the rabbit's heart.

This startling discovery led to an investigation of the role of the amount of prothrombin necessary for the gelation phase of blood coagulation. It was shown that marked prothrombin reduction, produced by several means, does not affect the gelation phase. Thus, the contention that a prothrombin-reducing hemorrhagic agent, like dicumarol, is necessarily a blood anticoagulant can no longer be maintained. Moreover, it is erroneous to believe that a hemorrhagic agent is identical to an anticoagulant. The use of dicumarol in the treatment of thrombosis therefore is not based on sound theoretical grounds. If dicumarol administration is actually beneficial in the treatment of thrombosis, as claimed by many physicians, then the effect can hardly be attributed to its anticoagulant action, but must be based on some other antithrombotic action which needs experimental support. The effect of dicumarol on platelet agglutination has not been well investigated.

In recent experiments, isolated platelet suspensions were strongly agglutinated by plasma containing extremely high amounts of heparin. Platelet agglutination in the capillary bed of hamsters treated with heparin gave further evidence that heparin actually promotes, rather than inhibits, the agglutination of platelets. Heparin is therefore not an ideal anticlotting substance. Since it is considered the physiologic anticoagulant and also has a platelet agglutinant effect, it has been proposed that some platelet agglutination inhibitor or antiagglutinant substance may be present in the circulating blood and that some mechanism may exist to prevent this action of heparin on platelets.

Platelet agglutination thrombi or emboli produced by the use of heparin, because of their small size, may be clinically of less importance than the coagulation thrombi that heparin counteracts. Thus it may still be practical to use heparin. In thrombotic conditions for which platelet thrombi are mainly responsible, anticoagulants may not be of therapeutic value.

Another approach in the treatment of thrombosis is the use of substances (for example, fibrinolysin, trypsin) to dissolve clots. However, coagulation and agglutination thrombi may not be equally affected by the same dissolving substance. The hazards of such treatment are many. Partial dissolution of a thrombus may result in dangerous circulating clots. Damage may also result to the inner lining of vessels and cause new clots or lead to hemorrhage.

Further experimentation in the intricate fields of blood clotting and thrombosis is needed for a better understanding of numerous thrombotic conditions. An adequate analysis of intravascular clotting should provide better treatment for a large number of diseases in man affecting the blood vessels and the heart.

Shoulder Harness Lessens Air-Crash Fatalities

The development of several new types of shoulder harness has raised discussion concerning how many pilots understand the value of the shoulder harness, and whether civilian pilots will use the harness if it is provided as standard equipment. A number of military studies have been made on the effectiveness of the shoulder harness in military aircraft. However, there are too few non-transport type aircraft built expressly for civilian purchase and use, and equipped with the shoulder harness, to permit a study of the harness under conditions of normal civilian flying. Therefore, it was necessary to analyze cases in which civilian pilots retained, and used, standard World War II military shoulder harnesses in surplus, civilian-owned, military aircraft. A Crash Injury Research Project, carried out by Cornell University Medical College under ONR contract, performed this study.

A sample of 82 accidents (occurring over several years) was used, representing approximately 1-1/2 percent of the total number of these aircraft in active use at the time of the study. Other data have indicated this percentage to be numerically equivalent to the severe accidents in which such surplus military trainers were involved each year. To determine the effectiveness of the shoulder harness, data from each of the accidents were divided into three categories: (1) severity of accidents, (2) seriousness of head injury, and (3) conditions of harness use.

The analysis of the 82 accidents revealed that: (1) There was no shoulder harness in 68 percent of the planes when the accidents occurred, (2) In 77 percent of the cases, the harness either had been removed prior to the accident or was not used, (3) Of the pilots who retained the harness in their aircraft, 73 percent were wearing the harness at the time of the accidents, and (4) When the shoulder harness was not used, non-dangerous head injuries occurred twice as frequently as when the harness was used. Dangerous and non-dangerous injuries, combined, occurred six times as frequently when the harness was not used. Thus it can be concluded that if the harness were used more pilots would emerge from accidents without injuries, or injuries sustained would be less serious, and more pilots would survive "fatal type" accidents.

There were four main objections to the harness: (1) the inconvenience of putting the harness on and taking it off; (2) the discomfort encountered when wearing the harness; (3) the binding of the shoulders which, in turn, made it difficult for the pilot to reach certain cockpit controls unless he unlocked the harness; and (4) the necessity of adjusting the harness webbing to fit the person.

As a result of the study, it was recommended that: pilots should be indoctrinated in the increase of safety provided by the shoulder harness; a type of shoulder harness should be devised which will be acceptable to civilian pilots from the combined points of view of safe restraint and convenience, comfort, and utility; and shoulder harnesses and their anchorages should be strong enough to remain fully effective in crashes which do not destroy basic cockpit and cabin structures.

Dr. E. O. Hulburt

Who's Who in Naval Research

Four years ago Congress decided that the Naval Research Laboratory, which had expanded ten fold over the war years, should have a No. 1 scientific position, or Director for Research. The choice fell quite naturally on Dr. Edward O. Hulburt of the Optics Division. He was not only universally liked and respected but he was unquestionably one of the most distinguished scientists aboard.

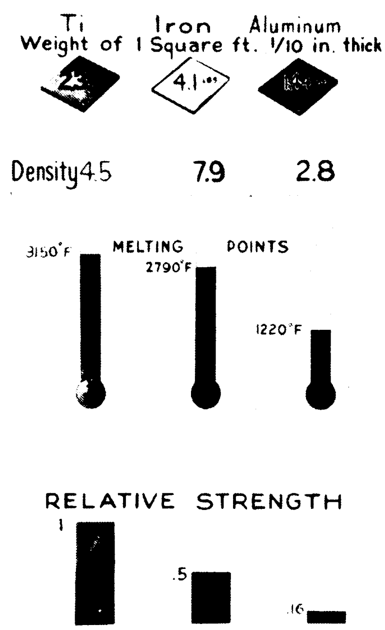
Dr. Hulburt is almost a charter member of NRL, though not quite. He joined the civilian staff in 1924—a year after the Lab opened—as head of the "Heat and Light Division" (the title was later changed to Physical Optics, and finally just Optics). At that time he was 34, and was already gaining distinction as a physicist. The son of a Johns Hopkins professor, he graduated from that institution in 1911, obtained his doctorate four years later, and then taught at Western Reserve until World War I interrupted his career. He came out of the Army as a captain in the Signal Corps. Once more a civilian, he was invited to instruct at Johns Hopkins. He remained there until 1921 and then went to the University of Iowa as an assistant professor of physics.

Although Dr. Hulburt has held a supervisory position at NRL from the start, he has never been one to sit at a desk and let subordinates do the research. Four fat volumes of published papers are ample testimony to that. He took a leading part in the radio-wave propagation experiments that did so much to establish NRL's reputation, he pioneered in naval applications of infrared and ultraviolet light, he led the research that improved submarine periscopes, during World War II he was an expert on ship camouflage and a member of the Army-Navy-NRC Vision Committee, he has taken part in three eclipse expeditions (heading the last one), and he was an observer for the Navy at the Bikini tests—all in addition to his duties as a division superintendent and, more recently, Director of Research. His basic studies—usually dealing with light propagation—have earned him prominence in numerous learned and honorary societies; he is Chairman of the Physics Section of The American Association for the Advancement of Science and an editor of the Journal of the Optical Society of America.

Probably Dr. Hulburt's outstanding personal characteristic is his obvious love of the out-of-doors. He nearly always has a deep tan, he apparently doesn't even own a hat, and when he writes about the night sky, or of zodiacal light, or the aurora, the specific language of science becomes almost poetic. He has a 30-ft ketch which, with his wife, son, and daughter, he has sailed into every harbor and mudhole from the Bay of Fundy to Cape Hatteras. He is never happier than when he is off to some sky-roofed laboratory like the eclipse site at Khartoum and he always returns with a packet of charming water-color landscapes which he paints as an expeditionary hobby. (He belittles his art, and claims his more important pastime is playing the violin.) The Hulburts live in Alexandria, we suspect so that he can be one with that hardy, weather-conditioned group who commute to the Lab by motor-sailer.

Concerted Attack on Titanium

Urgent demands for more efficient metals to meet expanding military needs have accelerated the program of research and development on titanium. This ultramodern metal has possibilities over a wide range of engineering end-uses and, in some types of construction, is superior to aluminum and magnesium alloys, to steel, and to other rigid structural material. The characteristics that appeal to the designer are high strength, light weight, and corrosion resistance that exceeds either aluminum or stainless steel. However, the price is a limiting factor Titanium in sponge-metal form is quoted at about $5 per pound but when fabricated the cost is closer to $20. If the cost can be brought down, military consumption alone might run to thousands of tons annually.



Although titanium-bearing ore is abundant, the metal itself is hard to obtain because of its preference for remaining a compound--usually a complex oxide or halide. The commercial process today requires the reduction of titanium tetrachloride by molten magnesium, an awkward and expensive procedure. Hence the Metals and Minerals Advisory Board, a function of the National Research Council, has advised an exhaustive basic research program. The Research and Development Board asked ONR to undertake the task.

Already several contracts have been negotiated; a total of twelve to fifteen are contemplated. The contractors include government agencies such as the Bureau of Standards and the Bureau of Mines, industrial laboratories such as Battelle Institute and the Brush Development Corp., and several universities.

Problem Solving Behavior

Howard H. Kendler

...Professor of Psychology at New York University and Chairman of the Department of Psychology at University College (NYU), served on the OSRD staff during the war.

How many of us have taken our cars out of a garage and driven hopefully away only to discover that the car was in no better shape than when we drove it in. Some good mechanic no doubt repaired something, but the defect in question was still obvious. The reason for this? Simply that the mechanic was not able to select from, admittedly, a practically infinite number of possibilities, what was wrong with the car. If he had known he could have fixed it, but this is small help.

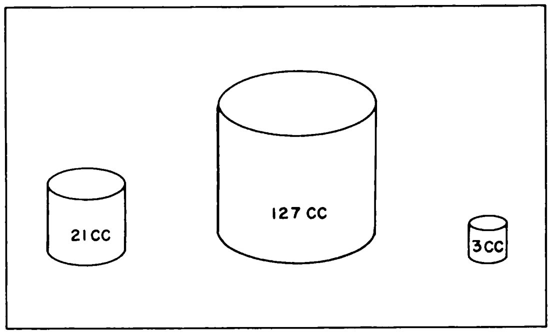
Situations like this occur countless times every day, and not only among mechanics. The efficiency with which an individual responds to such problems—his problem solving behavior—obviously governs to a large extent his ability to adjust to his complex environment. It is not surprising, therefore, that psychologists have begun to show an intense interest in this aspect of human behavior.

On the contrary, what does seem surprising is that this interest has remained dormant for so many years. One obvious reason for this is that problem solving behavior represents the most complex activity of human beings. It is not difficult, therefore, to understand why, in a science as young as psychology, the research worker would gravitate toward other problems which hold more immediate promise. But there is another important reason which goes back to a philosophy prevailing among many educators. An assembly-line outlook has been adopted which assumes that any individual possessing the necessary aptitudes can be trained to do any job well if he is taught the various routine tasks involved in that job. This theory assumes that practically all jobs can be reduced to a group of tasks, all of which can be more-or-less automatically performed.

In the case of the mechanic, this means that he would receive intensive training in all kinds of mechanical repairs. But fixing a defective engine actually depends upon much more than this. He must be able to collect the necessary information, to recognize what is wrong, and finally to make the indicated repairs. Training him to carry out the last step—to replace spark plugs, adjust carburetors, etc. —without consideration for the first two steps is only a waste of time, since in most instances the successful use of this training is of no value until the first two steps have been successfully completed.

He must be taught to think, efficiently and effectively. This conclusion was reached during the last war when we saw many novel situations arise that required effective reasoning behavior in jobs formerly considered strictly routine. Thus, we have begun to realize that the old notion of education is inadequate and misleading for many jobs, and that we cannot eliminate reasoning tasks from all jobs except the top-level ones.

It would be nice, now, if we could formulate a method for teaching the processes of reasoning. Unfortunately, this cannot be done. But we can present some of the problems and techniques which are involved in a research program aimed at understanding reasoning behavior. The first problem confronting the psychologist is to decide upon the nature of his research program. There appear to be two possible approaches. One involves an attempt to analyze each job requiring problem solving and then to find techniques by which the trainee can be taught to think effectively in his particular job. The second approach is to investigate problems with a view toward generating principles of problem solving behavior that will be applicable to all specific job situations.



How would you get 100cc?

The relative merits of these two approaches, representing the difference between applied and pure research, have always been a source of controversy. A realistic appraisal of the lessons we can learn from the history of science would indicate that there is no recipe to follow in the selection of one approach over another. Sometimes one has proven more fruitful, and at other times the reverse has been true. It appears then that the most practical program to follow in studying the psychology of thinking is a combination of the two.

The research being conducted at New York University is seeking to formulate some general principles of problem solving behavior. Psychologists have designed many experimental techniques to investigate reasoning behavior, several of which have appeared promising. In our own research program, we have utilized two different techniques: one involving arithmetical problems which resemble those used frequently in intelligence tests, and the second requiring subjects to form abstract concepts of cards having geometric patterns varying in terms of size, form and color.

One of our major concerns has been how to find variables related to flexible and rigid reasoning behavior. These terms may appear vague or mystical to the reader who is not acquainted with experimental techniques used in psychology. Let us attempt to define them by describing one of our techniques. A single method of problem solving was fixated by insuring its successful utilization and then presenting a problem which could be more efficiently solved by another method. The subject was asked how to obtain a certain amount of water by using three jars having various capacities. The first problem, for example, consisted of jars with capacities of 21, 127, and 3 cubic centimeters. The problem was to measure out exactly 100 cc of liquid. This could be accomplished by filling the 127-cc container and then removing 21 cc and 3 cc twice. Other similar problems were given, all of which required the subject to fill the second jar first and then remove from it the amount necessary to fill the first container once and the third container twice. Following a series of such training problems, the subject was presented with the following critical problem: Given a 23-cc container, a 49-cc container and a 3-cc container, how would you measure out exactly 20 cc? If the subject persists in his set way, he will solve the problem by the "49-23-3-3" method. If, however, the subject is flexible in his approach, he will solve it in the simple, direct, "23-3" manner.

Research has indicated that a large majority of subjects, regardless of educational background, after receiving about six training problems, will solve the test problem in the indirect set manner (49-23-3-3). In fact, the author has found that people are so susceptible to this set that about half of them, following six training trials, will solve a "10-25-5, get 5" problem in an indirect manner; by either a "25-10-5-5" or "10-5" method. Of course, the simplest procedure would involve merely filling the 5-cc container.

In an attempt to get our subjects to solve these problems in the direct manner—in other words, to become less rigid in their thinking—we arranged a series of experiments. Although the results did not provide a technique for making subjects more flexible, they did contribute some understanding of problem solving behavior. It was found that the set manner of responding was not solely a function of the fact that the problems were presented as a "paper-and-pencil" test. Containers of various capacities were constructed, and the subjects were required to obtain certain amounts of liquid by actually manipulating the containers. The results indicated that in the concrete problem situation, 61 percent of college students solved the critical problem in an indirect fashion. Although this represents an improvement over the "paper-and-pencil" test, it still indicates that the rigid, set way of responding to the critical problem also predominates in a concrete situation.

But more basic than this result are some other implications of our research with this experimental technique. It has been the general tendency to believe that, in most problem situations, the main task of the subject is to acquire the correct efficient response. An analysis of our experimental situation indicates, however, that the task confronting the subject is not the acquisition of a new form of behavior, since the response necessary for efficient behavior (subtracting 3 from 23, for example) is already within the repertoire of the subject. The major problem is to weaken or eliminate response tendencies (such as initially filling the center container in the training problems described) which inhibit more efficient problem solving behavior. In the psychology of learning, it has been discovered that different principles operate in the acquisition or strengthening of response tendencies as compared with the weakening or elimination of response tendencies. It has been our aim to apply the principles of extinction (weakening and eliminating response tendencies) to problem solving behavior, in an attempt to overcome set ways of responding. Some of our findings seem to justify our attempt, although the picture is not clear cut, and more research is necessary.

In one of our experiments, designed specifically to encourage flexibility, subjects were given a series of problems, all different in form. It was assumed that these varied problem solving experiences would give the subjects a flexible mode of responding to problem solving situations. In this way, they were "drilled" in being flexible. The subjects, however, failed to demonstrate any greater flexibility on the critical problem (23-49-3, get 20) following training problems than did subjects who received a group of similar problems. It was then postulated that people cannot be made to think flexibly by passively experiencing a series of different problems, but rather they must have active experience in overcoming rigid forms of behavior. An attempt was made to test this latter hypothesis.

Subjects were given several groups of problems designed to be solved by one set method. They were then given a problem which forced them to break this set method. Much to our surprise, these subjects did not respond any differently to the critical problem than did those subjects who had no set breaking experience. Such results, at first glance, would seem to have rather pessimistic implications for a psychologist who is interested in devising methods to make people think more flexibly. But it should be noted that these training sessions, aimed at making the subject more flexible, lasted, at the most, only 30 minutes. This is one of the great difficulties in doing research in human problem solving behavior: the experimenter has so little time in which to overcome the life-long habits of reasoning (or lack of reasoning). If we consider that these subjects, during their lifetime, have developed very definite personality patterns and modes of thought, as well as definite attitudes toward arithmetical problems, it is not difficult to see how 30-minute training sessions might be ineffective.

The difficulties inherent in our first experimental technique led us to design a procedure which we hoped would not be so dependent upon the past experience of the subjects. We used a card sorting test, which requires subjects to sort cards, having various designs, into different categories. The problem for the subject to learn is the basis of the correct sorting procedure. As a simple example, the designs might vary in terms of color, form, and number. In one part of the test the subject has to learn to sort the cards in terms of form, then in terms of color, and then in terms of number. This technique permits us to observe how concepts develop and how individuals shift from responding on the basis of one concept to another.

The card sorting test used in our research was more complex than the one described. The subjects were required to learn concepts based upon more than one stimulus attribute. For example, four colors were used (orange, yellow, black, and gray), and the subject had to learn the concepts of "chromatic" and "achromatic." This abstract concept was frequently combined with another abstract concept to make the reasoning problem rather difficult.

The card sorting technique, it is hoped, will fulfill some of our most pressing research needs. It seems likely that this technique will provide problems which will be less dependent, for solution, upon the past experience of the subjects. This technique also is well suited to investigate problems involved in the abstraction process which is so basic to the formation of general principles.

We have obtained some evidence indicating that overtraining in specific tasks will interfere with the formation of general concepts. In the card sorting situation, subjects required to sort the cards in terms of form (square, triangle, circle, and crescent) have some difficulty in perceiving that these forms fall into two separate classifications based upon certain abstract features; i.e. those made up of curved lines and those made up of straight lines. These findings, assuming they are supported by future research, imply that training for positions involving both specific and general tasks should proceed from the general to the specific rather than the reverse.

Our research with the card sorting techniques has been expanded to include several problems related to the ability of individuals to shift from one concept to another. This, of course, is also a problem in flexibility of reasoning behavior. Another investigation already started concerns the problem solving ability of small groups. For example: Will a group of three individuals with a specified leader solve problems more quickly than one without a specified leader? It is hoped that our experimental investigations will throw light upon these problems.

The important consideration is that, unless serious attempts are made to understand reasoning, this important area of human behavior, which forms the basis of our contemporary civilization, will always remain beyond our comprehension.

Naval Research on TV

The subject of Johns Hopkins University's 187th "Science Review"—telecast in the Baltimore-Washington area on December 8—was "Behind the Scenes of Naval Research". The half-hour program introduced Chief of Naval Research RADM C. M. Bolster, Dr. E. O. Hulburt of NRL (see page 14), Dr. Alphonse Chapanis of Johns Hopkins, and Dr. Leonard Mead of Tufts College.

The theme of the show was the teamwork between university scientists and the Navy's own laboratory researchers and how it operates in creating better, and more usable weapons for the Navy. The latter part of the review brought out one of the most perplexing and vital practical problems of modern warfare: Making weapons that men can operate handily enough and fast enough to keep up with jet planes. Combat Information Centers, for instance, are growing so complex and so mechanized that the "CIC" spaces aboard ship are no longer big enough to hold the arrays of electronic gear. A postwar attack on this problem has been the creation of the Systems Coordination facility at NRL. Described by Dr. Mead of Tufts College, it offers an excellent example of a working partnership of naval officers, naval scientists and civilian contractors.

The men shown on the inside back cover are entering data on a simulated CIC plotting board, where all objects on the sea, over the sea, or under the sea are kept tract of. Information gathered by sight, radar, and sound, all finds its way to this plotting board. Since the basic unit of Navy strength is still the man, experiments like these, utilizing simulated problems and conducted under controlled conditions, have proven to be the source of much valuable information as to the capabilities and, even more important, the limitations of the human operator.

Tube With A Future

J. R. Pierce

. . .Ph.D., California Institute of Technology, is Director of Electronics Research at Bell Telephone Laboratories, where he has been engaged in vacuum tube research since 1936.

Some technical devices have past glories, some display present wonders and some hold a promise of things to come. The shining rods and huge flywheels of steam engines fascinated boys of an earlier generation; the internal combustion engine appears to have just passed the peak of its glory, and jets and rockets give us a foretaste of the future. I think we can observe the same thing in connection with electron tubes. Certainly we can put completely in the past such dodos as the magnetically controlled gas tube of the Vreeland oscillator (how many have even heard of it?). Wonderfully simple as they are, and wonderfully adaptable over a range extending from audio frequencies to the longer microwaves, I think that triodes and other negative-grid tubes may have passed the peak of their glory. In the microwave range, magnetrons and klystrons have outperformed the triode in many respects, and are at the heart of the present astonishing microwave art. No doubt there will be better microwave triodes, magnetrons and klystrons in the future, but many believe that a newer microwave tube is on the ascendant: the traveling-wave tube, the subject of this article.

The traveling-wave tube is not precisely new; its public disclosure goes back to 1946, and its first realization beyond that. Nor is it completely unexploited, for traveling-wave tubes are used as output amplifiers in a British Post Office microwave link between Manchester and Edinburgh. But certainly the full potentialities of the traveling-wavetube have not yet been exploited in actual microwave systems.

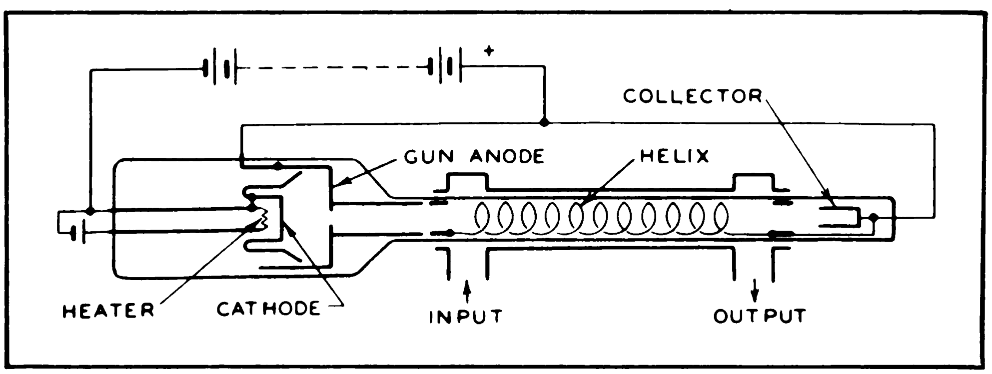
In the laboratory the traveling-wave tube has achieved a good deal. It has amplified at a higher frequency than any other tube (100 times power gain at a frequency of 48,000 megacycles). It has a considerably better noise figure than other microwave tubes though it is somewhat inferior to double-detection receivers using crystal mixers. Several workers have reported noise figures in the neighborhood of 10 decibels. Traveling-wave tubes have provided broader bands than tubes of any other sort—bandwidths of several octaves and bandwidths of thousands of megacycles. So far the efficiency of traveling-wave tubes has been neither very bad nor very good; efficiencies of around 20 per cent have been reported, but there is reason to believe that higher efficiencies may be attained in the future. The magnetron amplifier, a related device (or perhaps we should call it a special type of traveling-wave tube), is reported to have done considerably better. As far as power goes, reported performance is perhaps not impressive compared with that of magnetrons and klystrons, but this is in all likelihood because workers have not tried very hard to get large powers from traveling-wave tubes. Finally, I might mention a new sort of traveling-wave tube, the backward-wave oscillator, which can be tuned over frequency ranges comparable to those covered by traveling-wave amplifiers, simply by varying the applied voltage.

For the tube to come into its own, progress must be made in two directions. Perhaps most important, our present understanding must be drawn on in designing and making reliable and easy-to-use tubes that will enable systems engineers to do new things or to do old things better. But traveling-wave tubes are not yet fully understood or evaluated, and much work also remains to be done both in extending our knowledge, and in seeking the best designs for electron streams, circuits, matching devices and other ingredients.

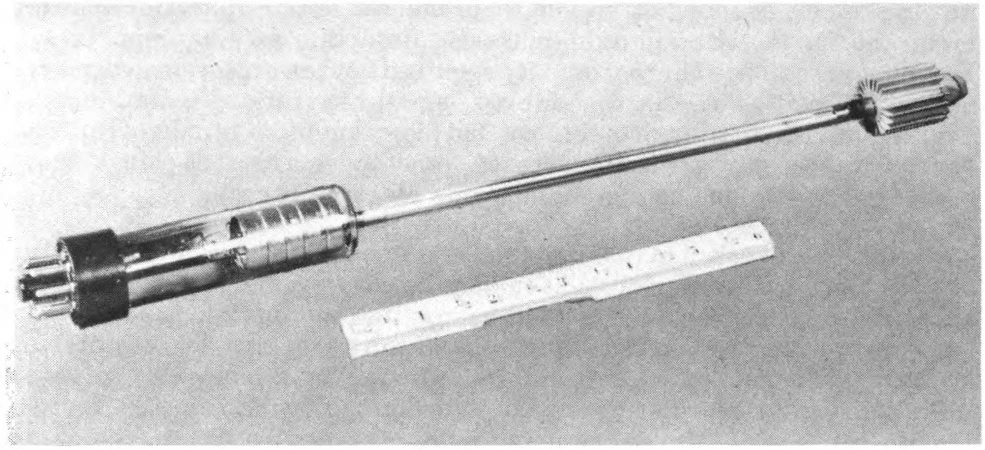
In order to appreciate the problems which arise in traveling-wave tubes, some explanation of their nature and operation is necessary. A traveling-wave tube has two essential elements: A flow of electrons and a circuit which can guide an electromagnetic wave along the flow. The electron flow may be a narrow beam of electrons drawn from a small button cathode and accelerated by a voltage of, say, 1500 volts, so that the electrons travel with 1/13 the speed of light. The circuit may be a long thin coil of wire surrounding the electron beam. If the wire forming the coil is 13 times as long as the coil itself, the wave, which travels with nearly the speed of light along the wire, will just about keep up with the electrons in moving along the coil. When the wave and the electrons have about the same speed, they interact strongly. A wave traveling in the same direction as the electrons acts to "bunch" the electrons, and the bunches tend to transfer energy to the circuit and so to increase the amplitude of the wave. Thus, in a distance of 40 wavelengths the wave energy may increase 1,000 to 10,000 times.

A wave traveling backward, against the electron flow, does not affect the electron flow much. Thus, the combination of a low-loss wave circuit and an electron stream provides a high gain in the forward direction and a low loss in the reverse direction. If a little of the wave is reflected at each end of such a device, the device will oscillate.

An amplifier with a high gain from input to output and a low loss from output to input isn't very useful. Stable, reliable amplification can be obtained, however, by making a circuit that is "lossy" all along its length, or even more effectively, by introducing a large amount of loss



A traveling-wave tube consists of two essential parts: an electron stream and a circuit on which an electromagnetic wave can travel with about the same speed as the electrons. Here the electrons, accelerated away from the hot cathode by the positive anode of the electron gun, are kept in a beam by a magnetic field (not shown). The electromagnetic wave which interacts with the electrons travels on a helix around the beam.



The electron gun is located in the large end of this 4,000-megacycle traveling wave tube; the helix extends through the long narrow section.

midway between output and input. In the forward direction the electron stream carries the signal past the loss, while in the reverse direction the loss virtually eliminates any signal reflected back toward the input from the output end of the tube.

A coil of wire or helix is only one sort of circuit which will carry a slow electromagnetic wave. Ordinarily it is a good circuit, because for a given power flow it provides a strong electric field to act on the electrons and hence gives a high gain. However, the helix has some disadvantages. As we go to higher and higher frequencies, it is necessary to make the helix smaller and smaller. Finally, the helix becomes unduly fragile, incapable of dissipating much power, and rather lossy. If the helix is not made sufficiently small it will not carry an electric wave properly. Antenna men know that helices of certain sizes can be used as radiators.

A number of alternative circuits have been suggested for traveling-wave tubes. One is a stack of pill-box resonators, coupled to one another so as to form a band-pass filter and pierced end-to-end with a hole to pass the electron beam. Another is a waveguide folded repeatedly on itself in a serpentine fashion. A somewhat similar circuit is the "inter-digital" circuit formed by interleaving two comb-like arrays of teeth or fingers. It is not yet clear just which circuits will be most advantageous in particular cases, but in general the helix serves admirably to give high gains, low noise figures and moderate power outputs at frequencies below 10,000 megacycles, while other more rugged circuits may be advantageous for much higher frequencies or for very high powers.

A traveling-wave tube needs not only a circuit, but a long beam of electrons. Perhaps the simplest way to get such an electron beam is to immerse the whole tube, cathode, accelerating electrode system, circuit and all in a strong uniform magnetic field parallel to the desired direction of motion.

It has been found, however, that less magnetic field is required if the electron beam is formed outside of the magnetic field and then suddenly—and properly—injected into it. When this is done it is possible to use a large cathode in an electron gun to produce a small, parallel beam of electrons for injection into the magnetic field; this may be important in reducing the cathode current density required. When sophisticated means of beam formation are used, however, small aberrations in the electron gun, thermal velocities of electrons and the exact form of magnetic field become matters of great importance, and there are still things to be learned about producing and maintaining electron beams.

In some cases it may be desirable to use hollow, cylindrical beams of electrons. Less work has been done toward producing and studying such beams than in the case of solid beams, but one intriguing possibility has been pointed out. If the electrons of the beam are set to whirling around a cylindrical inner conductor surrounded by a less-positive outer conductor, no magnetic field should be needed in overcoming the mutual repulsion of the electrons and so maintaining a well-defined beam.

Other means for "electrostatic focusing" of electron beams have been suggested, and this matter may become very important in cases in which the weight of magnetic focusing fields would be a serious drawback. But much research must be done on electrostatic focusing of beams before it will solve anyone's problems.

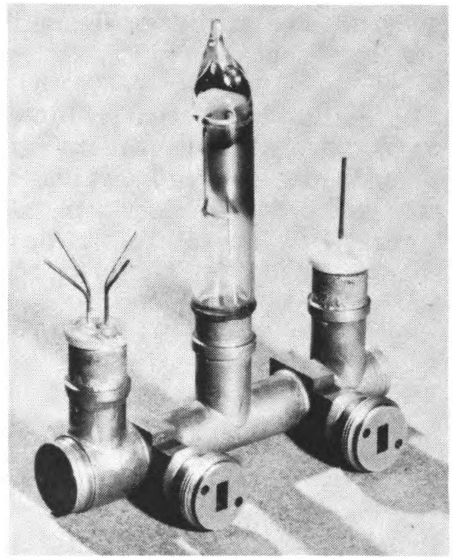
We are able to calculate quite accurately the low-level gain of traveling-wave tubes by applying a linear or small-signal theory. Other things are not so easily worked out. One is the limiting power output or efficiency when the tube is driven very hard.

We have available some laborious step-by-step computations, but while these have given us valuable guidance they are not very trustworthy, for they involve drastic simplifications. Currently, work is going on toward making better calculations and toward making more careful measurements of traveling-wave tube behavior at high levels. In the meantime we do have some guidance from theory and experiment. High circuit impedance, low circuit loss, high current and low voltage seem to favor high efficiency. One must have a good deal of gain beyond the lossy section of a circuit in order to get good efficiency.

Everyone who thinks a little about traveling-wave tubes comes to the conclusion that the circuit should be tapered near the output end so as to slow the wave down as the electrons lose energy and themselves slow down. Experimentally, tapering the circuit has helped only a little. I think that to realize a large gain through tapering we must find out much more about the motion of electrons clear through the tube.

Another field in which our understanding is far from complete is that of noise. Theorists cannot agree positively among themselves on the validity of any calculations we can make concerning small fluctuations in electron flow. Some progress has been made, however, by a combination of drastic approximation, hunch and experiment. Thus, it has been found that irregularities of electron flow at the cathode—the discrete nature of the electrons combined with their thermal distribution of velocities—produce standing waves of noise along an electron beam flowing through a conducting tube. The same simple theory which predicts fairly well the length and intensity of these waves can be used to calculate the noise figure of traveling-wave tubes, and in some cases the calculation seems to fit experiment quite well.

By pursuing a similar theory, noise has been reduced or "de-amplified" by passing the electron beam through regions of appropriate length which have alternately low and high potentials. (Signals can be amplified by a similar process, and this may be of importance in making amplifiers for extremely high frequencies.) Often the noise isn't as low as calculations predict, however, as is especially apparent in the case of complicated schemes which should theoretically reduce the noise a great deal. How much of this is due to complicating factors which can be avoided and how much represents an inherent inadequacy in our admittedly approximate theory we do not yet know, and only further experimenting and theorizing can tell us.



This helix-type tube for 48,000 Mc (total length: 2-3/4 inches) gives only two times power gain.

Besides facing some of the problems I have mentioned, the man who wishes to make a traveling-wave tube for some practical purpose is beset by problems of structure, alignment, heat dissipation, activity and life which are hard to describe to one who has never built tubes but are all too familar to those skilled in the vacuum tube art.

But the casual reader should not conclude that the outlook is dark. On the basis of our present knowledge we can make tubes with quite good noise figures, amplifiers and electronically tuned oscillators with very broad bands, tubes for very high frequencies, and tubes with fairly good efficiencies and probably with considerable output powers. Such tubes could be used in a number of intriguing ways.

The chief civilian application of traveling-wave tubes will probably lie in the field of microwave communication, and especially in relaying broad-band signals such as television and multi-channel telephony. Already traveling-wave tubes are used in a microwave link which I mentioned. There they serve only as output amplifiers, while most of the amplification is carried out at an intermediate frequency. Some present microwave repeaters use video amplification as well. Because traveling-wave tubes can have both a good noise figure and a very high gain per tube, they should make possible more economical microwave repeaters in which all of the amplification is carried out at radio frequencies.

The fact that traveling-wave tubes are very broad band would give an all-traveling-wave-tube repeater several advantages. It should be possible, for instance, to replace tubes in circuits without critical tuning adjustments. More important, broad-band traveling-wave tubes will not cause phase distortion of broad-band signals such as television. Finally, in looking toward the future, traveling-wave-tube repeaters could handle signals with bandwidths of hundreds or even thousands of megacycles. If crosstalk can be overcome, perhaps by the use of some sort of time division multiplex with very short pulses, it should be possible to send several television signals and thousands of telephone channels through the same repeater.

In this connection it is interesting to note that, by using traveling-wave tubes as transmitters and receivers, pulses only 7 millimicroseconds long—about 7 feet long as they travel through space—have been sent and received over a path of 20 miles, between the Holmdel and Murray Hill laboratories of the Bell Telephone Laboratories. Shorter pulses, about 3 millimicroseconds or 3 feet long, have been produced and handled in the laboratory, and even shorter pulses could certainly be produced.

Short pulses should of course have military as well as civilian applications, particularly if they can be combined with the extremely high frequencies of millimeter waves. The millimicrosecond pulses which can be produced and amplified with traveling-wave tubes could give radar range accuracies of the order of a few feet, and millimeter waves can give comparable angular resolution. Of course, such performance is limited in effectiveness both by propagation difficulties and, in the millimeter range at least, by limitations in the power available at present.

The broad-bandedness of traveling-wave tubes, which makes it possible to produce and amplify extremely short pulses, should be advantageous in other ways as well. Together with the backward wave oscillator, traveling-wave tubes make possible transmitters and receivers which can be tuned through octaves or through thousands of megacycles almost instantaneously, either between operations or during operation, in any manner or pattern desired. Surely this should have military advantages in radar, communication and other fields.

We now have the knowledge necessary to develop operable tubes to do the things I have described, although solving practical problems of production, reliability, uniformity and economy would in some cases require a considerable development effort. In many cases, notably in the fields of noise figure, very high powers and extremely high frequencies, we should expect considerably better performance in the future than we can attain right now. Here a great deal more research is called for.

Through ONR and other Service contracts, the various aspects of traveling-wave tubes are being investigated both in industrial and in university laboratories. The Services are also advancing traveling-wave tube work through development contracts. Together with civilian industrial work on traveling-wave tubes, a great deal of effort is going on in the field, and we may expect a continual advance toward the new things I have described.

Correction

In the Research Reserves section of the September issue, there was an interesting article on muscle soreness by LT Wesley Staton, USNR. The editors erroneously used the term "charley horse" as a synonym. The stumble was ours, not LT Staton's.

On the Naval Research Reserve

Nuclear Science Seminar at Oak Ridge

Pictured above are fifty research reservists who spent a profitable two weeks, December 1 to 13, attending the Fourth Annual Nuclear science Seminar at Oak Ridge, Tennessee. In the center are RADM C. M. Bolster, Chief of Naval Research, RADM K. M. McManes, the new Assistant Chief of Naval Operations for the Naval Reserve, and CDR F. L. Edmondson, VNRR Director. The seminar got officially underway with welcoming addresses by RADM Bolster and RADM McManes. Other talks at the opening session were given by CDR G. B. King, the commanding officer of the host naval reserve unit VNRRU 6-3; CAPT F. E. Shoup, Chief of Staff of the sixth naval district; and LCDR E. S. Churchill, Washington training officer.

The high concentration of scientists and scientific facilities at Oak Ridge afforded an excellent opportunity for the reservists to learn all about nuclear reactors, the subject of the seminar. The first instructional address was given by Dr. J. A. Swartout of Oak Ridge National Laboratory on "Problems in the Development of Nuclear Reactors". Other highlights of the program included a film, "Unlocking the Atom"; a talk by Dr. Ralph T. Overman, head of the Oak Ridge Institute of Nuclear Studies training division; and a tour of the American Museum of Atomic Energy.

VNRRU 3-1 Indoctrination Manual

VNRRU 3-1 has completed a rather comprehensive indoctrination manual covering virtually all the information that may be needed by a member of the Unit. The benefits of this project are now available for the use of all other units of the Naval Reserve.

From the early days of the first New York Naval Research Reserve Unit, a need was felt for a medium to promulgate the aims of the Research Reserve and to bring old and new members closer together. This need was felt more keenly as time went on, since the Unit was expanding rapidly and newcomers had little knowledge of what had taken place previously. New members often showed a low morale. In spite of official communications, they seemed not only to lack a sufficient grasp of the principal mission of the Naval Research Reserve, but also to have unnecessary difficulties with the basic routine essentials. The manual was, therefore, primarily directed at new members, to help them become acquainted with the Naval Research Reserve, and in particular with Unit 3-1, its history and policies, and their fellow members.

The idea originated with the Administrative Sciences Division, and they have been responsible for preparing the publication. Under the direction of CAPT William Exton, Jr., the manual took form principally in the hands of LT Elsie U. White. Before it was completed, all divisions of the Unit had contributed freely of their time and energies in the hope of creating a publication useful to all members.

The manual was prepared in loose-leaf form in order to facilitate revision, addition, and keeping it up-to-date. It consists of a foreword, brief biographies of the previous and present Commanding Officers, and four main sections. Two of these sections are equally applicable to the members of any other Unit of the Naval Reserve, active or inactive. The remainder of the manual, while dealing specifically with VNRRU 3-1, can serve as a useful prototype for any unit of the Naval Reserve desiring to produce a similar manual of its own.

Section I is devoted to the interpretation of official communications as they relate to the purpose of the Naval Research Reserve and to the organization of this particular Unit. Membership qualifications are outlined and the advantages of participation are described. Section II is devoted to the history of the first New York Unit, VNRRU 3-1, its development, growth, and administrative organization. Information is included regarding the bimonthly "Newsletter VNRRU 3-1," which is published at the expense of the Unit. Section III is concerned principally with official communications and directives such as fitness reports, correspondence courses, etc. Section IV is intended to facilitate proper correspondence between the reserve officer and the Department of the Navy. Sample letters are given as well as an up-to-date Roster of the Unit, addresses and telephone numbers of the Steering Committee, and an index.

Although issued only in 1952, the manual has already established itself as an invaluable aid to both new and old members. It is planned to revise the manual periodically, and to incorporate necessary additions and changes. Should other units of the Naval Research Reserve be interested in publishing such a manual on a local and volunteer basis, copies from the file of VNRRU 3-1 will be loaned upon request to Commanding Officer, CAPT Robert H. Griffin, VNRRU 3-1, 1300 York Avenue, New York 21, New York.

Brookhaven Seminar a Success

Members of VNRRU 3-9, Upton, New York, and their commanding officer, CDR J.S. Medd, decided last May that Brookhaven National Laboratory would be an ideal site for a reserve seminar. Since there are at this atomic energy installation some of the world's leading scientists as well as excellent research facilities, it offered a wealth of educational opportunities. CDR J.S. Medd approached Brookhaven's administrative staff and the proper Navy authorities on this question and received an overwhelming "Go ahead!"

These plans materialized in a highly successful seminar, ending in November, for the officers shown above. Through the efforts of CDR H.L. Foote and LT J. Weiss, both of VNRRU 3-9, a series of lectures and tours of Brookhaven's hot laboratory and reactor were arranged. The group saw the now famous cosmotron which has produced the highest energy ever created by man, 2.5 billion electron volts. CDR Medd arranged all the administrative aspects of the seminar and the program on accelerators.

LT F.B. Oleson, also of 3-9, arranged the health physics and instrumentation portion of the seminar. Here the reservists learned how to detect, monitor, and measure radioactivity from the personnel protection point of view. LCDR R.A. Love, LT J.S. Robertson, LT L.V. Hankes, and ENS Josephine O'Connell, all of 3-9, and BNL's medical staff prepared the medical program. ENS A.I. Weinstein, USNR program officer of 3-9, acted as program director for the seminar.

Judging from the comments and suggestions submitted by the visiting reservists, the program was not only interesting but well rounded and educational. Pending official Navy approval, VNRRU 3-9 hopes to present another seminar of this kind in 1953.

LCDR J. L. Maxton Talks on Food Procurement

It is a first essential for maintenance of high morale among military personnel that they be properly fed. This was the keynote of a speech given by LCDR J.L. Maxton, Extension Agricultural Economist and member of VNRRU 5-2 (Blacksburg, Va.) at the regular meeting of that unit on October 20. LCDR Maxton stressed the importance of watching the markets closely in order to buy food for the services when supplies are abundant, demand low, and prices down. As an example, at harvest time in 1951, U.S. Grade 1 apples (Yorks, Winesaps, etc. which keep well in storage) could be bought for $2.00 per bushel. These same apples sold six months later out of storage for $4.00.

Parallel with this program of stockpiling should be continued research on the best methods of storage, lengths of time of storage, etc. Factual material to be used as a basis for intelligent procurement by the Armed Forces should include the ten-year average production of a particular food together with the current year's official production. LCDR Maxton also discussed the problem of furnishing adequate nutrition and selecting the foods which have the most nutrient value. He believes that rations were greatly improved during World War 2 and the postwar period and that an active interest should be maintained.

Reservist Travels 98 Miles to Meetings

Recently received by CDR F. L. Edmondson, VNRRU Director, was a letter from LT G.W. Pomeroy which should be an inspiration to other reservists who have hardships to overcome in attending their unit meetings. LT Pomeroy is in the process of transferring from VNRRU 6-3 (Oak Ridge, Tennessee) to VNRRU 4-9 (Dayton, Ohio). He says: "...I am enjoying the meetings in Dayton, but I find that the 98-mile round trip to the meetings is quite difficult to make alone"—an understatement, to say the least! Mr. Pomeroy has tried to recruit others, from General Electric's Lockland Plant where he works, to attend these meetings and share the driving with him. Although these men have shown interest, not being such hardy souls as Mr. Pomeroy, they feel the distance is too far. CDR Edmondson is interested in hearing from other reservists who attend meetings in the face of difficulties. Address letters to: CDR F.L. Edmondson, Code 233, Office of Naval Research, Navy Department, Washington 25, D.C.

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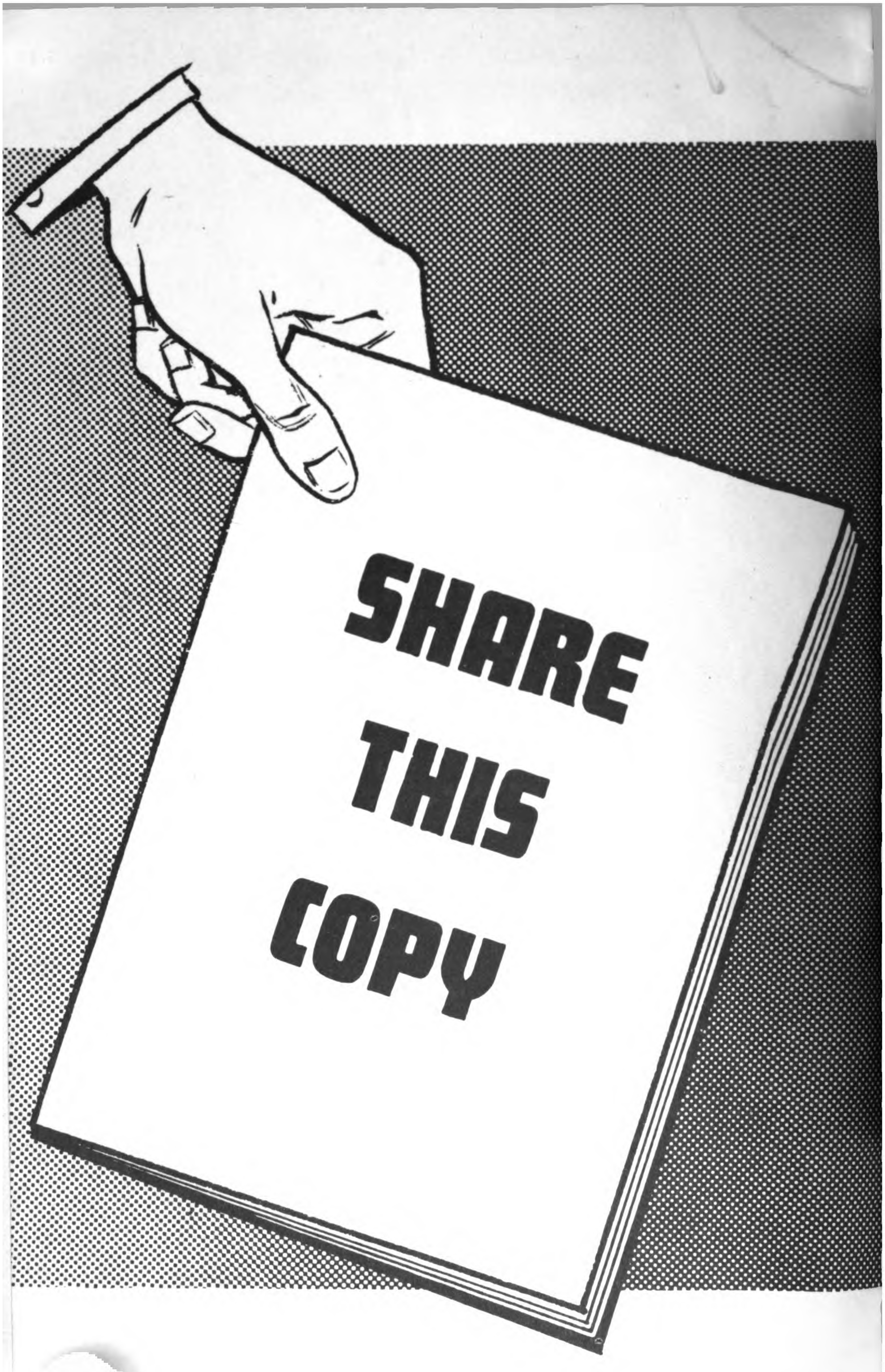
Plotting Combat Data

(See Page 20)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