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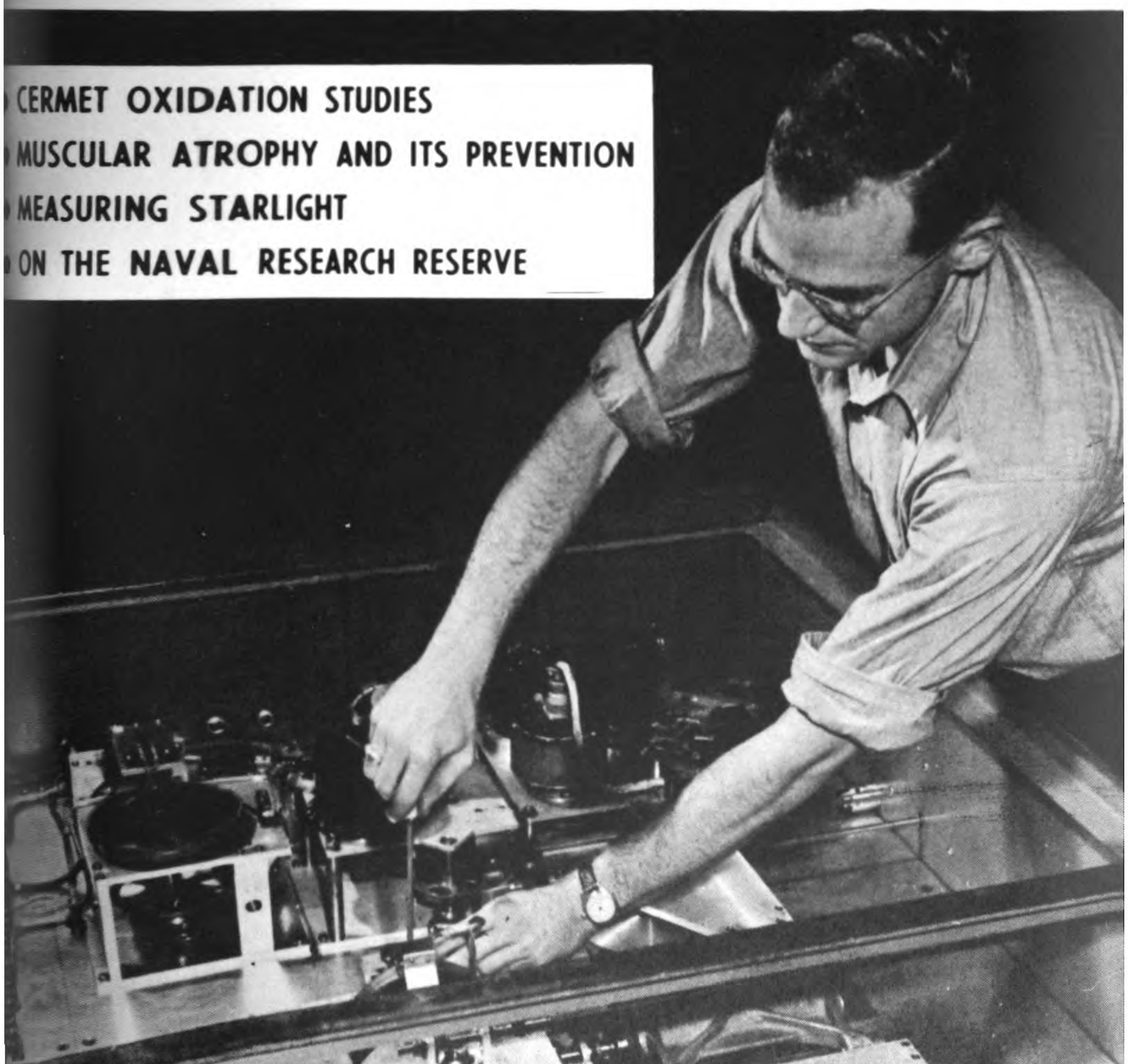
# RESEARCH REVIEWS

- CERMET OXIDATION STUDIES
- MUSCULAR ATROPHY AND ITS PREVENTION
- MEASURING STARLIGHT
- ON THE NAVAL RESEARCH RESERVE



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

NAVEXOS P-510

COVER PHOTO: An engineer in one of the Naval Research Laboratory's Radio Divisions is shown working on an electro-mechanical analogue computer used to simulate the flight of a guided missile to a moving aircraft target. The Laboratory's research in electronics is part of an extensive ONR program in this vital field. Some of the aims and accomplishments of the work to date are discussed in Editorial Notes, p. ii.



Approved by Bureau of the Budget, 13 April 1948.

RESEARCH REVIEWS

Informs the Fleet of ONR-sponsored Research

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# Editorial Notes

One of the notable accomplishments of naval research has been the part it has played in providing the United States with superiority in the field of electronic equipment. The pioneer work of the Naval Research Laboratory, before and during World War II, together with the work of other scientists throughout the world, resulted in radar devices that threw confusion into many of the enemy's schemes for victory.

Although the recollection of these accomplishments is gratifying, they are important today mainly in an historical sense. Past attainments are of interest to the scientist only as they point the way to further progress. It is essentially this philosophy that animates the planning of the Office of Naval Research. It is felt by the scientists in charge of the Electronics Branch that new frontiers must be constantly sought, as former goals are attained. Limitations that have hindered the improvement of equipment in the past must not be considered permanent shackles on future progress. Moreover, mere modifications and improvements of old techniques will not suffice. Research must be extended into new areas; fresh ideas and novel lines of thought must be pursued, even when their direct application is not immediately envisioned.

Any complete summary of the program of the Electronics Branch is, of course, impossible in an unclassified publication. Yet a few examples may serve to illustrate some of its aims and accomplishments.

One of the promising new fields of electronics research has been that of millimeter wave generation. Such work is supported not only by ONR but also by the Signal Corps and Air Force; their efforts will result in the construction of generators for shorter and shorter wavelengths to provide the Navy with new bands for which various uses may be found. In this connection it may be recalled that during World War II, the United States started off with radar which operated in the meter wavelength range, but when the Germans put receivers on their U-boats which were able to detect such wave emissions, other American equipment was put to use employing waves in the centimeter range. This was a source of confusion to the Germans, who, as a consequence, lost large numbers of their submarine fleet. It is possible that some equally important use may be found for the new equipment, which generates even shorter waves.

One of the fields of endeavor that is of utmost interest to military electronics experts is the possibility of improving radar. Research pursued under ONR contract has resulted in two methods which offer promise in this direction. Klystrons have been developed that are much more powerful than any microwave tubes used in World War II, and it is believed that their use will produce substantial increases in the range of radar. Moreover, advances in radar sensitivity are now anticipated as a result of the construction of microwave amplifier tubes such as the electron wave tube and the traveling wave tube.

This sampling of the research being conducted under ONR's electronics program illustrates some of the significant progress that is being made. Research continues on these and many other problems, whose solution will contribute not only to the safety and efficiency of our Navy, but will also add to our basic scientific knowledge.

# Cermet Oxidation Studies

by
William B. Crandall
Alfred University

Engineers are constantly searching for materials which will withstand high temperatures and stresses, since such substances are needed for use in aircraft and in atomic power plants. As a result of this need, mixtures called cermets have been developed, which are composed of metal-ceramic combinations. The purpose of the combination of these substances is to ally the strength and thermal shock resistance of the metal with the refractoriness of the ceramic, thus producing a material with even better service properties than either of them would have separately.

Unfortunately, the desirable properties of the metal are nullified if it oxidizes; consequently, the extent to which a cermet resists oxygen attack is a measure of its usefulness at high temperatures. But all the factors that influence the oxidation behavior of cermets are not well understood. Furthermore, there is not even a standard method for measuring this property. Naturally this situation produces many discrepancies in the literature on the oxidation resistance of cermets.

Many investigators have determined the extent of oxidation by measuring the weight a test specimen gains per unit of area during heating. Although this is one of the best methods presently available for reporting results on tests of oxidation resistance, it was demonstrated in this laboratory that such measurements have meaning only for a particular test specimen having certain physical properties. Under different conditions, even with a specimen of similar composition, the method is inapplicable.

In this laboratory, studies were made on the oxidation resistance of cermets by two methods. One way was to measure the percent of weight gain as a function of time, while the other was to measure the thickness of the oxidized layer as a function of time.

Originally the weight change studies were made by intermittent weighings, i.e., the specimen was subjected to a heating condition for a given period of time, then removed from the furnace, cooled and weighed, and returned for another heating period. This operation was continued until the desired heating period was attained. But it was soon determined that this method of evaluating weight change was not entirely

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William B. Crandall, now director of the Navy Research Project at Alfred University, received his B.S. in Ceramic Engineering from that University in 1942. He was then employed for a short time at the Niagara Falls plant of Titanium Alloy Manufacturing Company, but in 1944 he returned to Alfred and completed work on his M.S. in Ceramic Engineering. Following this he served in the U.S. Navy until 1946 as a Lieutenant (j.g.). Upon separation from the service, Mr. Crandall was employed by the Navy Research Project at Alfred University and became its director on April 1, 1950.

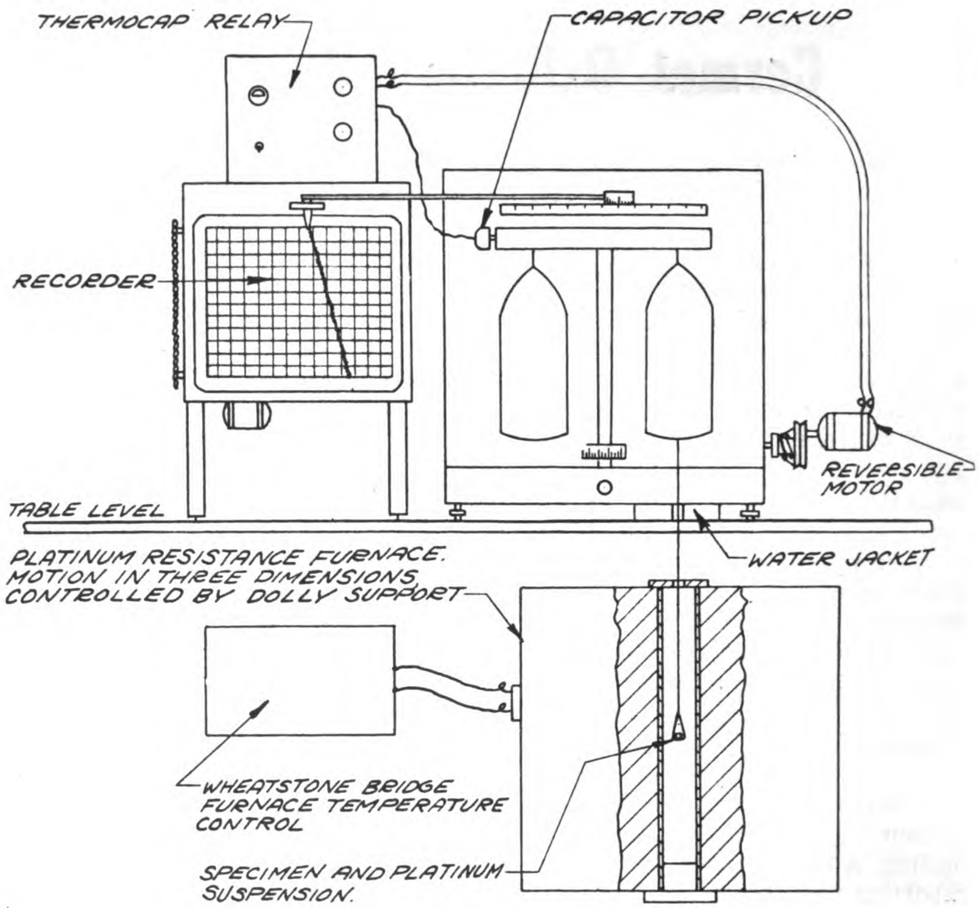


Figure 1. Schematic drawing of automatic recording balance with furnace

desirable because it was nearly impossible to account for the full theoretical percentage increase in weight which should accompany the oxidation. Preliminary studies conducted using a spring-type Jolly balance as a means of continuously weighing a specimen during heating, indicated that there was an appreciable difference between the results obtained with this type of weighing and the intermittent type. As a consequence of this investigation, an automatic balance was constructed which would make it possible to determine the weight change more accurately and at the same time, make a record of the change. Figure 1 is a sketch of this apparatus. The platinum suspension device carrying the specimen is attached to the pan of a standard analytical balance. The automatic balancing is obtained by the capacitor pickup device which is used in conjunction with a Thermocap relay and reversible motor drive employed to position the Chainomatic device on the balance. Direct connection between the vernier scale on the balance and the recorder provides a continuous record of the weight change. The furnace temperature is accurately controlled by a Wheatstone bridge type regulator.

Oxide layer studies were conducted on specimens identical to those used in the weight change investigations. The specimens were cut in half along the cylinder axis and the oxide layer penetration was noted after varying periods of exposure to air at elevated temperatures.

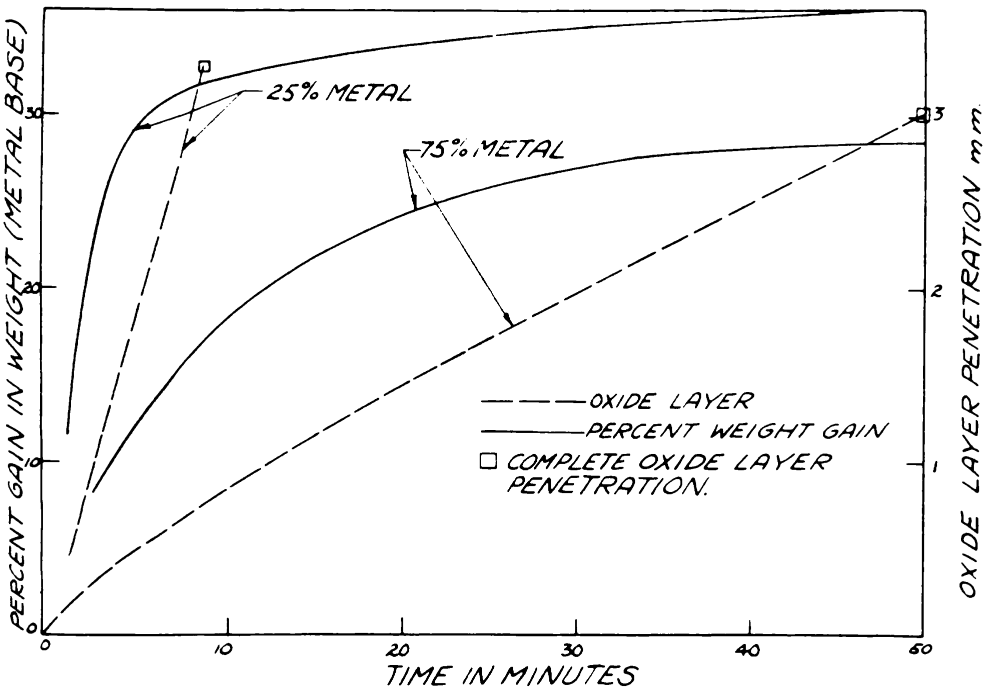


Figure 2. Correlation of weight gain and oxide layer penetration behavior for cermet mixtures

A number of interesting results were obtained from these studies. They showed (as the curves of Figure 2 demonstrate) that there is initially a rapid gain in specimen weight; then the increase proceeds much more slowly. Indications were that the period of rapid gain corresponds to the time during which the oxide layer is penetrating the specimen. The actual rate of oxidation or oxide penetration appears to be greatly influenced by the concentration of the metal; apparently the greater the concentration of metal, the slower is the oxidation. Another factor in the rate of oxidation is the porosity of the cermet - i. e., the more porous bodies oxidize more quickly. Shape also plays a large part

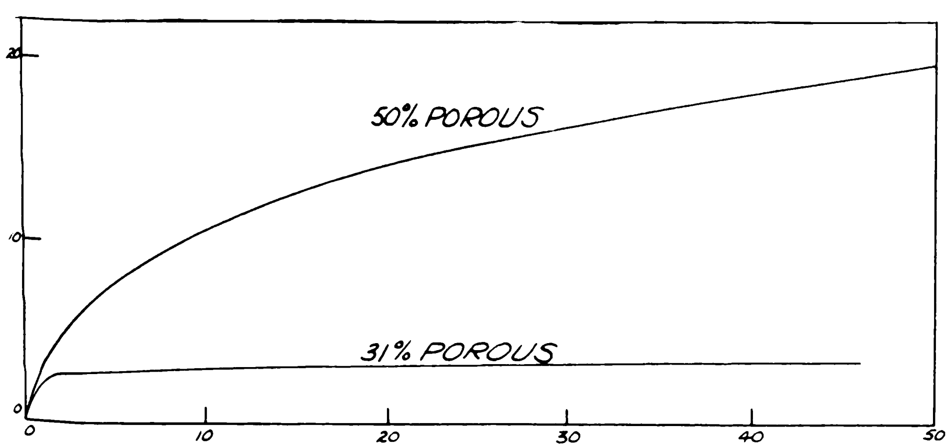


Figure 3. Effect of porosity on the weight gain of a cermet mixture

in the oxidation characteristics, as penetration studies on plane and cylindrical surfaces demonstrated.

In addition to these factors, it was found that temperature, oxidation rate of the metal component, particle size and partial pressure of oxygen also contribute to the oxidation characteristics of the cermet.

The behavior that was observed can all be adequately explained by a general mechanism which depends on an intimate balance between the factors which tend to change the oxygen concentration at any point within the pore structure of the body. This mechanism can be resolved into the factors which affect the rate of oxygen diffusion into the body, such as porosity, temperature, shape, etc.; and the factors which affect the rate at which oxygen is removed from the pores of the body, such as rate of metallic oxidation, number of metal grains, size of metal grains, pore volume, and temperature.

This general concept, or mechanism for cermet oxidation, can be extended to include not only the variables studied above but also other factors, such as grain boundary diffusion for denser bodies and other systems.

A satisfactory method for adequately characterizing the oxidation resistance of a body cannot as yet be proposed here. But it is felt that an understanding of the oxidation mechanism and factors which influence the oxidation behavior will help in attaining this goal. The studies described here should eventually help us to evolve ceramic-metal combinations that will prove highly effective in the engineering applications in which they are needed.

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# Muscular Atrophy and Its Prevention

by
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In medicine "atrophy" primarily implies "wasting of an organ". The term refers to the fact that an atrophying muscle becomes continuously smaller in volume than the corresponding muscle of the opposite, non-affected side of the patient or experimental animal (Figures 1 and 2). But this is not, by any means, the whole story. Although the word "atrophy" does not imply that the cellular composition, cellular chemistry, and the function of the organ are altered, such changes

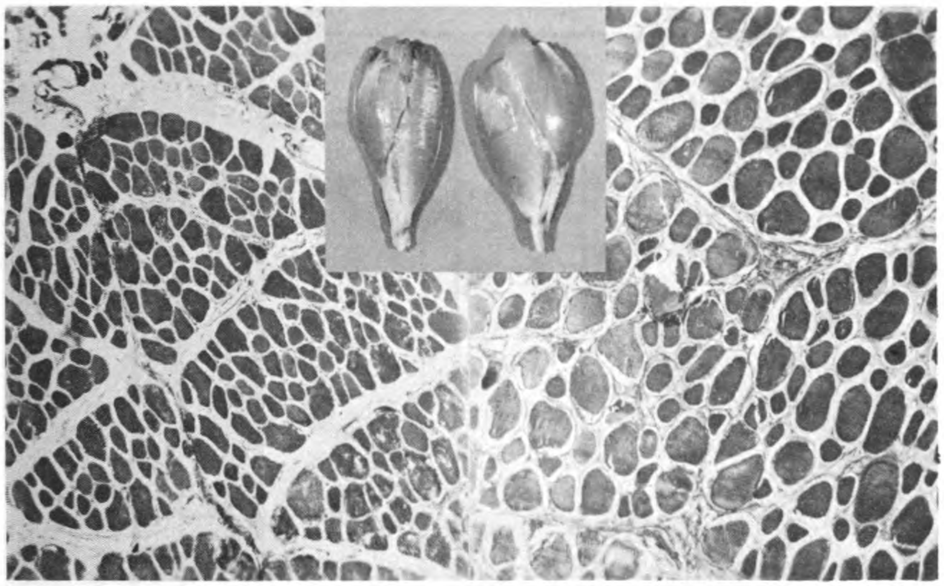

Figure 1. Inset shows calf muscle (gastrocnemius) of rabbit denervated for 23 days (left) and its normal control (right). The microphotographs of the cross-sections (magnification about 100x) show the decrease in fiber diameter and the relative increase in interstitial tissue.

actually do occur in most cases of atrophy. These alterations always tend to deteriorate the specific function of the organ - a process called degeneration. This degeneration is such that an atrophied muscle not only develops less power because of its reduced size but it is often considerably weaker, per unit of muscle substance, than the normal muscle (Figure 3).

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Ernst Fischer, research professor of physiology, Medical College of Virginia, received his M.D. in 1924 and his Dr. habil. physiol. in 1928 from the University of Frankfurt, Germany. He was visiting associate in physiology, Medical School of the University of Rochester, New York, in 1929-30 and in 1934-35, and has been associated with the Medical College of Virginia since 1935. His research work has dealt mainly with the physiology of the nervous and muscular systems. Currently he is directing studies of the biochemistry of muscular atrophy under ONR contract.

The causes of muscular atrophy are many. Curtailment of contraction (caused, perhaps, by a plaster cast immobilizing the joints of a limb) results in "disuse atrophy". The shortening of a muscle which occurs after cutting the tendon, causes "tenotomy atrophy". Maintained weak, abnormal activity without powerful contraction (as in painful arthritis, local contracture due to tetanus toxin, and many other conditions) produces "contracture atrophy". The type of atrophy studied most in experimental work, however, is "denervation atrophy" caused by severance of the nerve connection between the spinal cord and a muscle.

Investigations at various laboratories have demonstrated that under comparable experimental conditions the rate of wasting or volume loss is

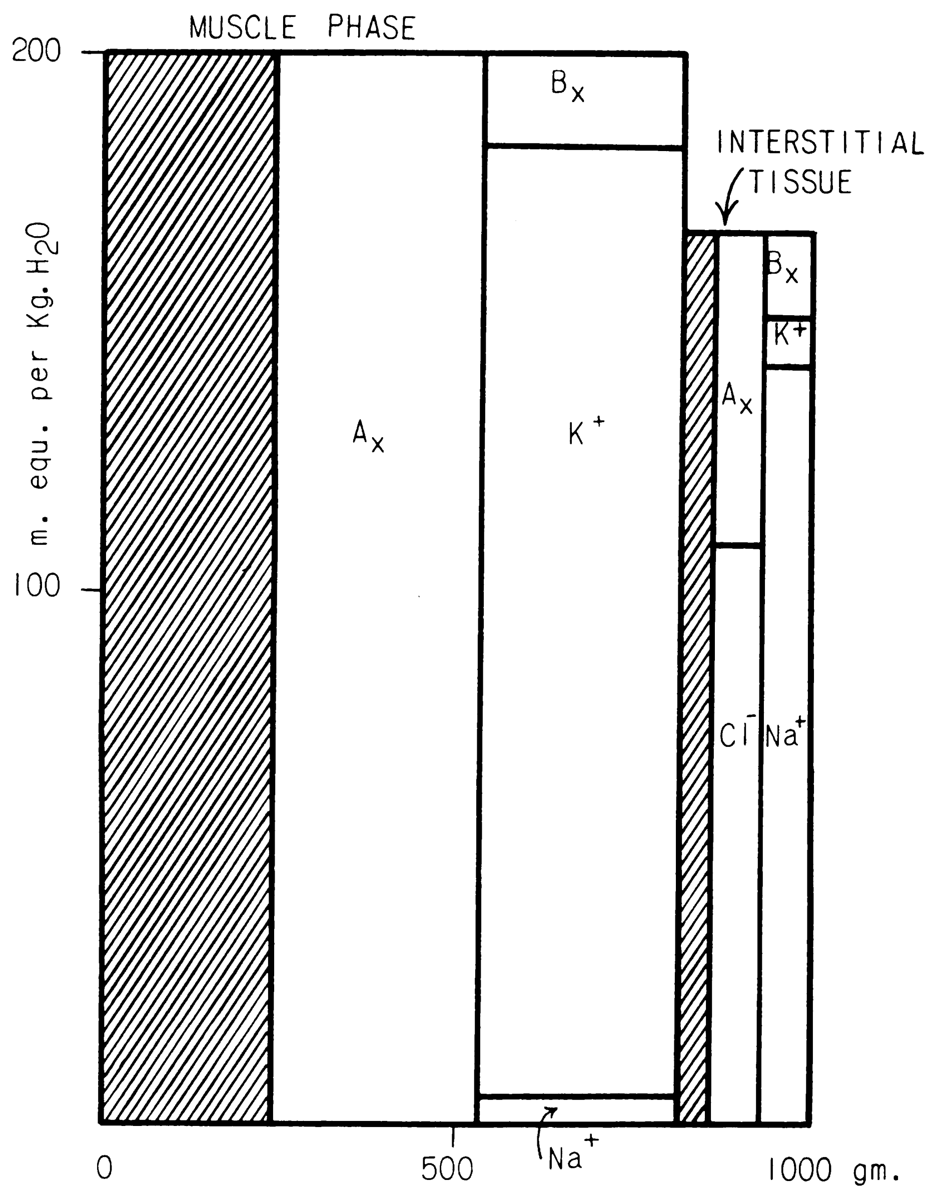


Figure 2A. This illustration represents the scheme of distribution of muscle phase and extracellular (interstitial) phase per kgm muscle for normal calf muscle.

uniform in all types of atrophy, at least for a considerable time. This fact was surprising, since it is well known that the degree to which muscle tissue degenerates and muscular activity is impaired varies greatly for different types of atrophy. Degeneration and deterioration of function per gram of muscle substance are minimal during the whole course of disuse atrophy while in denervation atrophy, after an initial delay, degeneration and deterioration progress continuously. Both tenotomy and contracture atrophy are characterized by very early and severe degeneration and deterioration. The theoretical importance of these findings is that there is no direct relation between the visible wasting process and the actual degeneration of the muscle. The practical implication is that an observed high rate of wasting in a patient with a doubtful peripheral nerve lesion cannot be used as an argument in favor of the diagnosis.

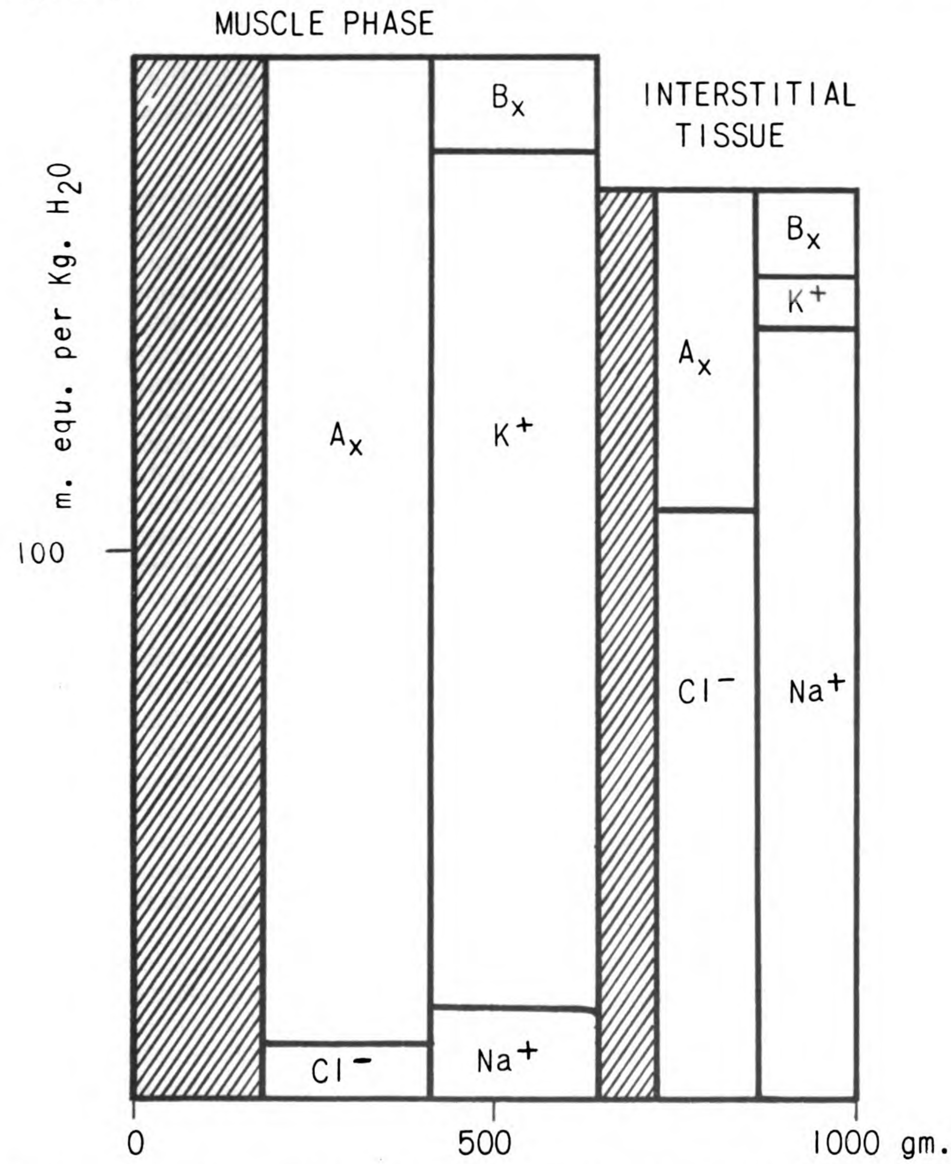


**Figure 2B. Scheme of distribution of muscle phase and extracellular (interstitial) phase per kgm muscle for denervated muscle which has lost 50 percent of its volume.**

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The rate of wasting, then, as long as the whole muscle is affected by the underlying cause, is independent of the cause of atrophy, but can be very much influenced by secondary factors such as circulatory conditions and general nutritional state. For example, it has been well established, at least in the case of denervation atrophy, that the rate of wasting is higher for younger animals than for older ones.

Experimental work on atrophy and degeneration is handicapped by the fact that in man these processes are much slower than in most of our experimental animals, and that, for the latter, considerable difference exists between species. A denervated muscle loses half of its original weight in 13 days for adult mice, in 15 days for rats, in 22 days for guinea pigs, in 30 days for rabbits, and in 100 days for dogs. Knowlton and Hines[1] pointed out that these differences in rates of wasting are not related to differences in the rates of muscle metabolism (as has been suspected for theoretical reasons), but are related to the longevity of the various species: the longer the life span the slower the atrophy. They proposed a useful mathematical equation for comparison of muscular atrophy in various species.

If one studies the rates of denervation atrophy of two different muscles of the same animal, for example the large hip muscle (gluteus maximus) and the calf muscle (gastrocnemius) it is found that the former loses its weight more quickly than the latter. This is because the cellular composition of different anatomical muscles varies. A muscle consists not only of muscle fibers, but between these contains varying amounts of interstitial tissues--connective tissue fibers, blood and lymph vessels, and fat cells (Figure 2). The gluteus of the rabbit is approximately 86 percent muscle fiber (by weight), the gastrocnemius about 82 percent, and the rectus abdominis (the straight abdominal muscle) only about 75 percent. It is well established that the weight loss of a muscle is due only to the diminution in size of its individual muscle fibers; the elements of the interstitial tissue are not distinctly affected. Thus, it is obvious that if the muscle fibers of different muscles waste at identical rates, the over-all weight loss must be highest for the muscle containing the least relative amount of interstitial tissue. The fact that a muscle contains various types of cells, of which only the muscle fibers proper are losing in volume, is also responsible for the difference in the microscopic picture of a normal muscle and a muscle atrophied without any degenerative changes. In the latter there is always a relative increase of the interstitial tissue. In a normal rabbit gastrocnemius, 18 percent of the muscle is interstitial tissue; in a gastrocnemius with a weight loss of 50 percent, interstitial tissue represents 36 percent of the muscle volume, a relative increase of 100 percent. In the atrophied muscle the intracellular or muscle phase would be only 64 percent, a decline of importance from the 82 percent for a normal gastrocnemius (Figure 2). If one compares chemical constituents of normal or atrophied muscles, or the forces they can develop, it is relatively meaningless to express the values as per gram muscle. Instead they should be expressed in terms of grams of the muscle fiber. (Figures 2A and 2B illustrate the changes that occur in the atrophying muscle. The hatched areas represent the solids in

[1] Knowlton, G. C., and H. M. Hines, Kinetics of muscle atrophy in different species. Proc. Soc. Exp. Biol. & Med. 35: 394, 1936.

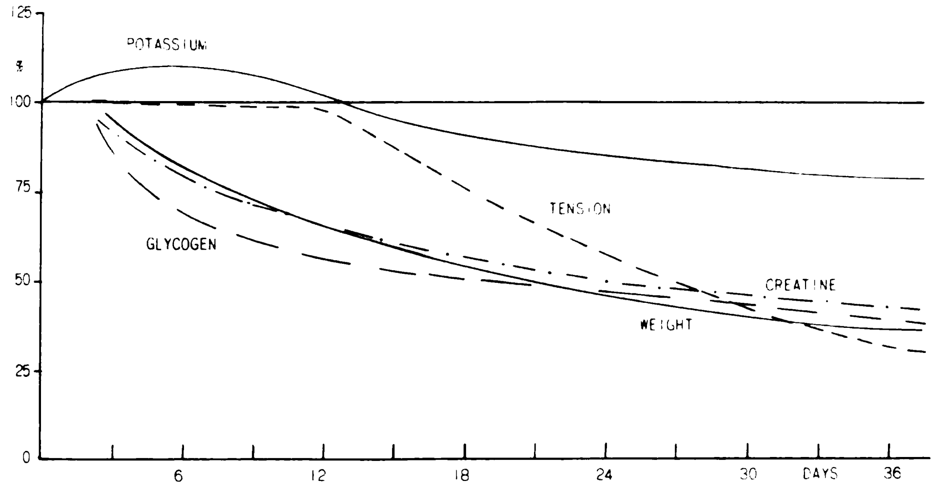


Figure 3. Changes during denervation atrophy are expressed in percent of corresponding values for normal muscle. All values besides weight were calculated per gm muscle phase.

muscle and extracellular phase respectively. Non-hatched areas show intramuscular and extracellular water. K, Na and Cl are the potassium, sodium, and chloride concentrations of the different phases. $A_X$ represents anions other than Cl while $B_X$ stands for cations other than K and Na.)

A normal muscle fiber responds with a contraction not only to an arriving nerve impulse but also to an electrical stimulation. The current strength needed to elicit a contraction depends mainly on the rate with which the current strength reaches its maximum and on the duration of the current flow. The theory of this "direct electrical excitability" of muscle is very well worked out, and proposed equations demonstrate that the relation between needed strength and duration of short electrical stimuli depends on a "time constant".

Most changes in excitability can be expressed and measured as changes of the "time constant". Of all the various types of muscular atrophy, only "denervation atrophy" shows early, distinct, and rather progressive changes for the value of the time constant. In consequence, careful evaluation of the excitability of an atrophying muscle is the best means of recognizing denervation atrophy. It should be noted in this connection that change in the time constant does not mean, as often assumed, that the denervated muscle becomes less and less excitable. It only means that the type of current optimal for stimulation has changed. For example: of sinusoidal alternating currents of various frequencies, the least voltage for maximal stimulation of a normal muscle is needed with a frequency of about 200/sec. At a certain stage of denervation atrophy, a current with the frequency of 2/sec requires the smallest voltage for stimulation. To stimulate a normal muscle with a current of 2/sec would require a current strength which would damage the muscle. The same is true if we try to stimulate the denervated muscle with a frequency of 200/sec.

If we take these changes in excitability into account, we are easily able to produce contractile activity in a denervated muscle. Naturally the forces developed by an atrophying muscle are necessarily smaller even when calculated per gram muscle, since muscle fiber has decreased. If we express the contractile forces per gram muscle fiber, however, we find that in denervation atrophy during an initial period (10 days in a rabbit, Figure 3) the forces are unaltered, despite the fact that the weight loss reaches about 25 percent. This is a further indication that weight loss and deterioration of the muscle substance itself are two independent processes. Only after a time lapse does the tension developed per gram muscle fibre decline considerably in denervation atrophy. In atrophy of disuse, on the other hand, the forces per gram muscle phase remain more or less constant if no secondary complication exists, while in "tenotomy atrophy" a rather early and severe decline in tension production is apparent.

For some of the various types of atrophy, the changes in tension/gm muscle phase correspond well with the histologically observed degenerative changes of the muscle cells, especially with the changes observed with the "polarization microscope".

Muscle fibrils have a regular but anisotropic arrangement of the long chain molecules of the proteins which form the fibrils and therefore exhibit optical properties similar to that of certain crystals, e. g. Iceland spar. The refractive indices for light passing in perpendicular planes are different. This phenomenon is called "double refraction" or "birefringence" and can be quantitatively measured with the polarization microscope. The birefringence and with it the orderly arrangement of the protein molecules of the fibrils declines at the same rate as the tension in denervation and in other types of atrophy.

Szent-Gyorgyi and coworkers[2] have demonstrated that, of all the various proteins of the muscle, "myosin" and "actin" are, in their combination as "actomyosin", an integral part of the contractile mechanism. Myosin and actin can be extracted from the muscle by salt solutions of specific concentrations and can be isolated in pure form from the crude extract. The amount of protein extractable per gram muscle phase diminishes very little in disuse atrophy, moderately after an initial delay in denervation atrophy (Figure 4), and immediately at a high rate in tenotomy atrophy. Although the decrease in the amount of extractable protein is smaller than the decrease in tension/gm muscle phase, the amount of myosin which can be isolated from the crude extracts corresponds fairly well to the decrease in tension (Figures 3, 4). Apparently, during atrophy, some of the myosin has deteriorated to other proteins which can still be extracted by the salt solution, but which no longer have the specific solubility and precipitation characteristics of true myosin. Moreover, the myosin isolated, especially in advanced denervation atrophy, does not correspond in all respects to normal myosin. Myosin is characterized by its enzymatic ability to split adenosinetriphosphate into adenosine diphosphate and phosphoric acid. This so-called ATPase activity, which is intimately related to the contractile process, is distinctly diminished in myosin isolated from early stages of tenotomy atrophy or from later stages of denervation atrophy.

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[2] Szent-Gyorgyi, A., Chemistry of muscular contraction. New York, Academic Press, 1947.

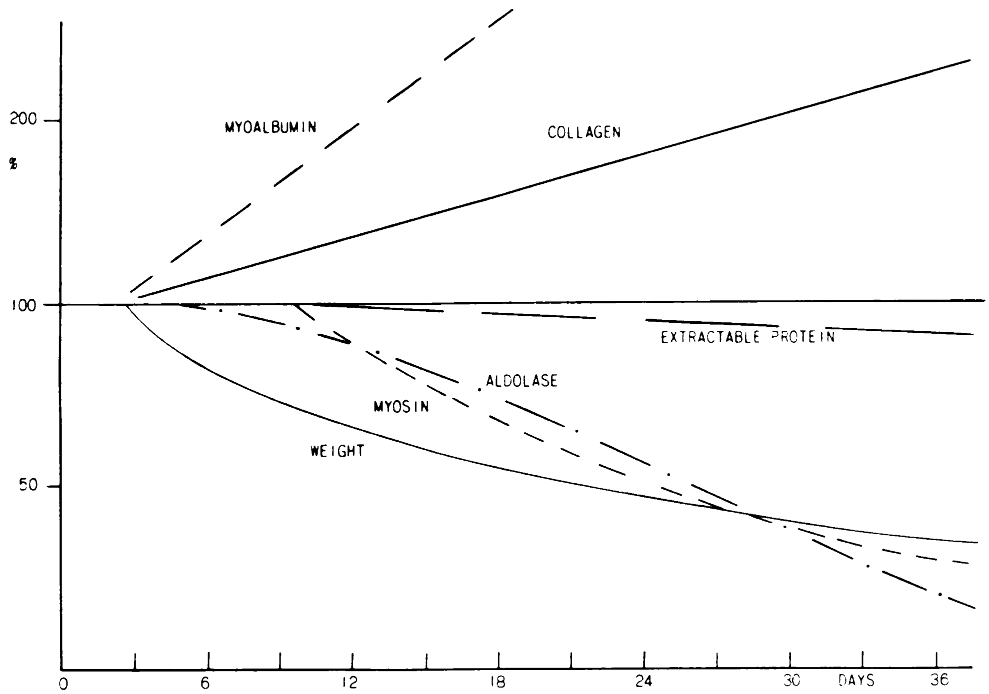


Figure 4. Here the changes which occur during denervation atrophy are expressed in percent of the corresponding values for normal muscle. The collagen content has been calculated per gm muscle, while extractable protein, myosin, aldolase, and myoalbumin were calculated per gm muscle phase.

Another specific muscle protein is myogen, which can be extracted from muscle mash by water, but not by salt solutions. Although this protein is not present in a high concentration in normal muscle, it is a rather important constituent since it has the enzymatic activity of an aldolase and thus plays an important part in making the energy of glucose metabolism available for muscular work. The protein content of a crude watery extract of atrophying muscle, if calculated per gram muscle phase, is nearly the same as in a similar extract of normal muscle. However, with little delay, the aldolase activity of the extract diminishes progressively in denervation atrophy. Fractionation of the water-soluble proteins has demonstrated that the diminished protein content of the extracts of atrophied muscles is due to the fact that the appreciable loss in myogen is nearly completely balanced by an increase in myoalbumin (Figure 4). This latter protein is present in normal muscle in very small amounts; its molecular weight is much smaller than that of myogen; its molecular structure is apparently much simpler; no specific function can be assigned to it; and rather similar proteins are found in other tissues. Apparently during denervation atrophy and also in other types of atrophy, the highly specific and specialized myogen degenerates to the much less specific myoalbumin.

The early decrease in aldolase content, which precedes the decrease in tension production, is one of the many indications that glucose metabolism is not the primary source of energy for muscular activity, but recharges the primary energy-liberating systems which are directly linked with the contractile mechanism. The unimportance of the glucose metabolism for the strength of contraction is attested further by the fact that in denervation atrophy the glycogen content of the muscle has dropped at least 25 percent before any considerable decline in the strength can be detected (Figure 3). Theoretical considerations suggest that impairment of the glucose metabolism should affect the endurance of the muscle. In nearly all types of atrophy, the fatigability of the muscle increases considerably, long before the strength of a limited number of test contractions declines.

Although in various types of atrophy the changes of some of the muscle constituents can be linked to specific physiologic alterations, such definite interpretation cannot be given for all substances investigated, e. g., creatine and potassium (Figure 3).

All attempts to prevent atrophies, or at least to delay them, by administration of drugs, especially of vitamins, have failed completely. The only way to stop atrophy, regardless of the type, is by removing its cause. The earlier this is done the quicker is the return to normal muscle condition. In disuse atrophy due to immobilization, the atrophying process stops immediately after removal of the immobilization, and the speed of recovery parallels the amount of conscious activity performed during recovery by the involved muscles. In consequence, any limb immobilization for medical reasons should be as brief as possible, and active exercise should be started as soon as it is feasible. In tenotomy atrophy, tendon suture removes the cause of atrophy, but the beneficial effect of the suture is delayed by the necessary temporary immobilization of the limb.

In denervation atrophy, an immediate removal of the cause of atrophy is impossible, since suture of a divided nerve does not restore functional continuity between the cut nerve fibers. A nerve fiber severed from its connection with the spinal cord is a part of a cell separated from its nucleus and condemned to death and degeneration. Nevertheless, nerve suture will ultimately establish reinnervation of the muscle by a complicated and time-consuming process. The nerve fibers in the stump of the nerve, which is still connected with the spinal cord, will, after some delay, sprout at the cut surface, and start "outgrowing". If no nerve suture has been made, the chances that the outgrowing fibers will ever reach the denervated muscle through all the intervening tissue is remote, in fact for all practical purposes nil. If, however, a perfect suture is established between the proximal and peripheral nerve stumps, the outgrowing fibers have only to penetrate the very small scar to reach the peripheral stump. The nerve fibers in the latter are by now completely degenerated, but the connective tissue cells of the peripheral stump are still vital and, in consequence, the rough structure of the nerve is preserved with more or less empty tubes where originally the old nerve fibers ran. The outgrowing nerve fibers from the proximal stump are guided through these tubes of the peripheral stump to their destination--the denervated muscle. But the rate of outgrowth of the nerve fibers is slow; at best it is only about two inches per month. Furthermore, when the nerve fibers have reached the muscle, a certain delay occurs before functional contact is made between nerve fibers and muscle fibers. As soon as the contact is established, the cause of denervation atrophy is removed and the muscle begins to return to normal condition. The speed of recovery depends on the amount of volitional activity performed by the reinnervated muscle and on the stage of atrophy at which functional reinnervation

Figure 5. A patient with atrophy of the left arm is treated with electrotherapy at the Branch Center of Physical Medicine. This method of treatment had been thought to be of little value until it was found that the type of current used was of utmost importance. To be effective in retarding denervation atrophy, the current must be well adapted in shape and frequency to the excitability of the muscle.

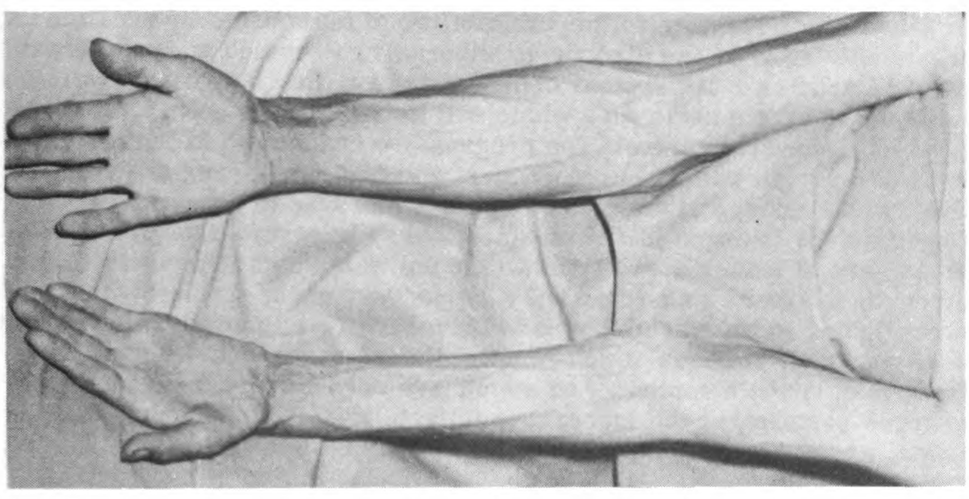

**Figure 6. Note the difference in the size of the patient's arms, indicating the wasting of the muscle.**

occurred. It is obvious that if the site of nerve injury is far from the muscle involved, considerable time elapses before reinnervation is established despite immediate nerve suture. All attempts to speed the rate of outgrowth of the proximal nerve fibers by administration of drugs or vitamins have been complete failures.

Reid reported in 1841 that daily electrical stimulation retards considerably denervation atrophy of frog muscles. From that time on electrical treatment has been used clinically, since it appeared obvious that recovery after reinnervation must be much better if the outgrowing nerve fibers make functional contact with a better preserved muscle. However, the clinical results were disappointing and until World War II, electrotherapy of denervated muscles was praised by a few physicians but regarded as useless by the majority. The last group was supported in their attitude by the experimental work of some physiologists during the first World War. Foremost was the well known English physiologist Langley, who demonstrated beyond doubt that the type of current used by Reid and by most of the clinicians does not retard denervation atrophy of mammalian muscle. At the beginning of the last World War, however, the anticipated large number of nerve injuries revived the interest in electrotherapy of atrophy. The advances in muscle physiology in the intervening years have led to the following reasoning. The currents used by Reid and the clinicians can produce vigorous contraction in normal frog and mammalian muscle, and in denervated frog muscle which shows little alteration of excitability. The same type of currents, on account of the duration of the single shocks and the high frequency of repetition, can produce, at best, rather weak contraction of denervated mammalian muscle with its rapid progressive change in excitability. Furthermore, experience with electrical training of normal mammalian muscle had revealed that only vigorous activity in which maximal forces are developed increases the volume of the muscle and its power.

Independent experimental work in the United States, in England, and in Canada revealed that such reasoning was sound. The experimental work of the last ten years demonstrated clearly that stimulation of denervated mammalian muscle, with electrical currents well adapted in shape and frequency to the excitability of the muscle at the time of treatment, retards the atrophy considerably. Provided adequate treatment is started at the time of nerve injury, the weight loss will be minimal and the muscle as a whole will be much stronger than the untreated denervated control. The progressive changes in excitability are considerably slowed down. Moreover, the muscle fibers have more or less normal size, and there is no relative increase in connective tissue. Degenerative changes in the muscle fibers, however, though still obvious, are of lesser degree than in the untreated control muscle. Total strength is increased mainly on account of the greater size; the strength per gram muscle phase is only slightly improved. The various denervation alterations which parallel the strength loss, such as birefringence, myosin content, and so on, are only slightly delayed. Those changes paralleling the increasing fatigability are much more diminished, and the treated muscles are distinctly less fatigable.

Adequate daily electrical treatment means about 150 vigorous contractions against resistance, applied in three to six sessions, with sufficient intervals between the contractions in each session to avoid fatigue. Since this is a time-consuming procedure requiring highly trained personnel, it is rather expensive. Furthermore, it was only recently that an apparatus appeared on the market which could produce the various currents needed, without requiring a physicist to operate it. In consequence, the clinical application has been limited, but the results are encouraging. To date there exists only one clinical paper on a large number of patients with adequate controls. Jackson[3] demonstrated that, for lesions of the ulnar and median nerves affecting the small hand muscles, the method can produce in the human results similar to those obtained in animals. The currents used by the English clinicians in 1945 are no longer regarded as the optimal ones, and this might explain the less impressive results they observed when treating larger muscles. Only with optimally adapted stimuli does there exist a chance that, with a surface electrode, the deeper muscle fibers are reached by a current with a strength sufficient to stimulate them, but not to cause injury to the more superficial fibers or to produce intolerable discomfort to the skin of the patient.

The number of nerve injuries in peacetime is so small that a considerable time will elapse before sufficient data have accumulated for careful evaluation. Since the rate of atrophy is influenced greatly by age, nutrition, and other conditions, a few favorable reports on a limited number of patients does not help very much in scientific evaluation of the new clinical method. The clinician is in a less favorable position to study the problem than the physiologist, who can use any number of animals, each with its own control. Yet it is hoped eventually to gather enough information from clinical and laboratory work to evolve effective techniques in this field of muscle therapy.

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[3] Jackson, S., The role of galvanism in the treatment of denervated voluntary muscle. Brain 68: 300, 1945.

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# Measuring Starlight

by
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In the most powerful telescope, even the largest stars appear as mere points of light. Although their actual diameters are measured in hundreds of thousands or even hundreds of millions of miles, their distances from us are so tremendous that it is impossible to study them by many of the methods used in investigating the moon and the planets.

Nevertheless, the astronomer is curious about these "points of light." What are their sizes, their masses, their densities? How far are they from us and from one another, and how are they distributed through space? Of what sort of material are they constructed, and what are their temperatures? The only means of answering these and many other questions is by careful study of the tiny amounts of light reaching us from these celestial bodies. The light we receive from a sixth-magnitude star--the faintest one visible to the unaided eye--is of the order of $10^{-8}$ meter candles. To put it more simply, this is roughly equivalent to the brightness of an ordinary candle at a distance of 6-1/2 miles! Even so, there are comparatively few stars of this brightness; many of those with which the modern astronomer is concerned have only from 1/100 to 1/1, 000, 000 of this radiance. Thus, the fundamental problem of the astronomer is the collection and analysis of tiny quantities of light, and much of his time is spent in the design and construction of special instruments for this purpose.

The Steward Observatory program of photoelectric photometry makes use of two such instruments, the construction of which was advanced by financial aid from various sources, including an ONR contract. The purpose of an astronomical photometer is to measure with all possible precision the amount of light reaching it from any given star. In our program, the work is concentrated on variable stars (i.e., those whose brightness does not remain constant) and especially on one type of such stars--those known as eclipsing binaries.

An eclipsing binary consists of two stars so close together that they appear as a single point of light. Both are in motion, each moving in a circular or elliptical orbit around the center of mass of the system, just as the earth and moon revolve around their common center of mass. The plane in which the stars revolve is nearly the same as that containing the line of sight from the system to the earth, so that once each revolution, the cooler star comes between us and the hotter, thereby cutting off part or all of the light from that star. At such times, the brightness of the system is noticeably diminished. Half a revolution later, the hotter component cuts off part or all of the light of the cooler, and the system again appears dimmed, although the loss is somewhat less than before. Precise measurement of the manner in which the light

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Figure 1. One of the photometers used at the Steward Observatory

of such a system varies enables us to determine many of the properties of the stars involved. This is because the shape of the light curve depends on the relative sizes and shapes of the stars and of their orbits. The theoretical problem is to find out what the characteristics of the stars must be in order to give the observed light curve.

Even more information is available if the changes in radial velocity (speed with which the system is approaching or receding from us) have been determined by use of the spectrograph. In favorable cases, a combination of spectrographic and photometric results enables us to compute the sizes, shapes, masses, and densities of the stars comprising the system and the sizes and shapes of the orbits in which they move. In addition, such studies provide information of great importance to the student of stellar atmospheres. It is even possible in some cases to obtain information about the manner in which the star's density is concentrated toward its center.

Like most astronomical photometers now being built, those at Steward Observatory are designed to take advantage of the recently developed photomultiplier tubes. In these, a photosensitive surface emits electrons when light falls upon it; the number of electrons emitted varies directly with the intensity of the light. These emitted electrons are drawn to a similar surface by applying a potential difference between the two; here, their impact liberates more electrons. These electrons are drawn to another similar surface and the process is repeated--nine times in all. Thus, the original current is amplified tremendously within the tube itself. The actual amount of amplification varies considerably from tube to tube, but is of the order of at least 1,000,000. But even this amplification is not sufficient for any but the brightest stars; for the others, the current must again be amplified after leaving the photomultiplier tube.

Steward Observatory photometer B[1], which is intended chiefly for observation of the brighter stars, uses a d-c amplifier and an 840-volt battery for supplying potential to the cell. It is attached to the 12½-inch reflecting telescope mounted on the U. S. Magnetic Observatory grounds in the desert about 10 miles from the light, smoke, and other disturbing influences of the city. Photometer C[1], of great power and versatility, uses a-c amplification. This photometer (shown in Figure 1) is intended primarily for use with the 36-inch telescope for observation of very faint objects, for example, the white dwarf stars. These mysterious stars, little larger than the earth, have densities so great that one cubic inch of their material, transported to the earth, would weigh half a ton. If our survey finds an eclipsing system among such stars, much information concerning the behavior of matter under such conditions can be obtained which will be of tremendous interest to both the astronomer and the physicist.

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[1]The construction of these photometers is the product of generous collaboration. The mechanical and optical parts of photometer B were designed by the author; the amplifier was constructed by Dr. R. E. Corby of the University of Arizona Physics Department, who followed a design of Dr. G. E. Kron of the Lick Observatory. The mechanical and optical parts of photometer C were designed by Dr. E. F. Carpenter of the Steward Observatory; the amplifier and power supplies were constructed by Dr. C. W. Gartlein of Cornell. The mechanical construction was carried out in the University of Arizona shop by Mr. J. L. Hartwein.

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# On the Naval Research Reserve

## CAPT Shilling Speaks at VNRRU W-5 Meeting

CAPT C. W. Shilling, ONR's Deputy for Biological Sciences

CAPT C. W. Shilling, ONR's Deputy for the Biological Sciences, spoke on various aspects of submarine medicine at a meeting of Bethesda Research Reserve Unit W-5, held at the Naval Medical Center on September 29. CAPT Shilling reviewed the history of submarine medicine in World War II, and discussed the problems of habitability encountered. He explained methods of medical and surgical treatment of casualties aboard submarines and went on to tell of new developments in such craft and their implications in regard to medical and personnel problems.

CAPT Shilling has been one of the most active participants in the Research Reserve program since its inception. He has been a speaker at numerous meetings and has officiated at the activation of a large number of units. His efforts have done much to arouse interest in the program and to further its aims.

## Course in Atomic Defense in Progress

Under the direction of Volunteer Research Reserve Unit 9-6, commanded by LCDR Joseph A. Wise, USNR, a course of instruction in atomic civil defense began at the University of Minnesota on 31 August. One hundred and fifty selected Minnesotans are participating, by invitation of the State Director of Disaster Relief and Civil Defense. Eight experts are presenting discussions of such atomic age problems as mob psychology and physiological effects of atomic explosions.

## Procedure Governing Transfers

It is the function of the Commandant of the Naval District to issue and terminate orders to Volunteer Reserve Units. Therefore, transfers between units within the same Naval District can be effected by the Commandant of that Naval District.

However, transfers cannot be effected between units of different Naval Districts since the orders must be written by different Commandants. The procedure for such is as follows:

1) Request termination of orders from old unit.

2) Submit "change of address" in accordance with Article H-1802, BuPers Manual. Upon receipt of this request, the Commandant of the old Naval District will transfer records to the Commandant of the new Naval District.

3) Upon taking up new residence, submit request for orders to new unit to the Commandant of the new Naval District, via the Commanding Officer of the new unit, via the appropriate Reserve Program Officer at the ONR Branch Offices.

## Change in Rules on Instructors for VNRR

The Chief of Naval Research has authorized volunteer research reserve units that maintain an average attendance of at least 15 members to have one or more paid instructors. Formerly it was necessary to have a minimum membership of 25, but now the attendance, not the total number of members, will be the determining factor. If more than one subject is being taught the unit, additional paid instructors may be employed, but their number is limited to one for every 25 members of the unit, and no unit may have more than five. Authorization for instructors will be based upon the previous quarter's attendance. Two weeks' training duty will be available to these teachers, subject to the quota limitations on instructors.

## Reserve Unit Now Active in Las Cruces

A new unit has been established since July 6, 1950 at Las Cruces New Mexico, with LT Calvin Ira Ricketts, USNR, as commanding officer. Fourteen members make up the unit to date, and meetings have been held to discuss naval organization, the structure of the Office of Naval Research, and plans for the type of project to be carried out by the unit.

# Special Devices Association Meets

CDR Cook, USNR, director of Research Reserves, addresses the Special Devices Association. On the stand (from left to right) are: CDR C. V. Gordon, USN; RADM Luis de Florez, USNR; Mr. Igor Sikorsky; Mr. Emil F. duPont; CAPT J. R. Ruhsenberger, USN; Mr. C. A. Carey; CAPT J. P. W. Vest, USN; Mr. C. P. Andrade and Mr. Viktor Schreckengost.

For the sixth time in as many years, former military and civilian employees of the Special Devices Center met in mid-September for the annual assembly of the Special Devices Association.

More than 200 persons, some of them still employed at the Sands Point base, came from as far as Texas to attend the three-day sessions which were highlighted by the presentation of the Association's Annual Distinguished Service Award to the E. I. duPont de Nemours & Company for its "outstanding accomplishment in its scientific programs involving rapid learning techniques and mass training." The award was presented by RADM Luis de Florez, USNR, founder of the Navy's Special Devices Division.

In addition to the award, members of the association saw the presentation of many new training devices; witnessed the first in a new series of television training programs; and heard the latest word on mobilization billets and on Army participation in the work of the Center. Mr. H. D. Rose, Training Officer of VNRRU 3-8 was elected President of the Association, succeeding Mr. C. P. Andrade.

The 200 who came to Sands Point were the representatives of more than 600 who now belong to the Association. Membership is open to anyone who has been trained in, or worked at Special Devices, or who is engaged in similar commercial and industrial work.

Formed in late 1945 "to maintain and advance interest in the development and use of scientific devices for naval and aeronautical training; to maintain and advance interest in the development of new and improved naval and aeronautical equipment; and to advance the art and science of the development of such devices and equipment," the Special Devices Association is actually a forerunner of the Research Reserve.

During World War II, the Armed Services and industry were required to train an unprecedented, number of men quickly and effectively

--the greatest job of its kind ever undertaken. As a result many facts about new training techniques were learned, which, it was realized, would be useful to industry and to the nation's Armed Forces during the years ahead. For that reason, the war-time staff of the Special Devices Division formed an independent group, the Special Devices Association Inc., which is dedicated to the further development of rapid training techniques as a measure of national preparedness.

The first agitation for a Research Reserve came from a group of officers in Los Angeles who were members of the Special Devices Association, which had been conceived by Admiral de Florez as a Reserve for Special Devices. Their many and frequent petitions to the then Office of Research and Inventions were acknowledged when the Research Reserve was formed and Unit 11-1 became the first VNRR Unit. The Association has aided the Research Reserve immeasurably and has offered its services to Admiral Solberg for any assistance he might require.

## Increase in On-the-Job Training Billets

The original budget for fiscal 1951 provided for 600 VNRR personnel to receive training duty, including both seminar and "on-the-job" training, and the establishment of an Organized Research Reserve of 300 billets. Since such a small percentage of billets was allotted to the Research Reserve for Organized Reserve status, it was deemed advisable to use the money provided for this purpose for 300 additional training duty billets for Volunteer Research Reservists. The Commandants have been given these additional billets for "on-the-job" training. These, together with the "on-the-job" billets made available from cancellation of seminars, authorize the Commandants to assign training Duty to Research Reservists by Districts as follows:

| District | Quota | District | Quota | |
|---|---|---|---|---|
| 1 | 60 | 9 | 130 | |
| 3 | 76 | 11 | 60 | TOTAL---637 |
| 4 | 60 | 12 | 50 | Proposed Seminar Billets---263 |
| 5 | 26 | 13 | 36 | |
| 6 | 32 | PRNC | 53 | 900 |
| 8 | 54 | | | |

## VNRRU 6-9 to be Activated Soon in Athens, Ga.

Plans have been made to activate a research reserve unit, to be designated 6-9, at Athens, Ga. on October 25. LCDR Aubie Rivers Robertson, USNR, will be issued orders as commanding officer.

CDR William Corbett, volunteer reserve program officer for the Sixth Naval District, will officiate at the activation and the Office of Naval Research will be represented by LCDR L. I. Estep, research reserve program officer for the southeastern area.



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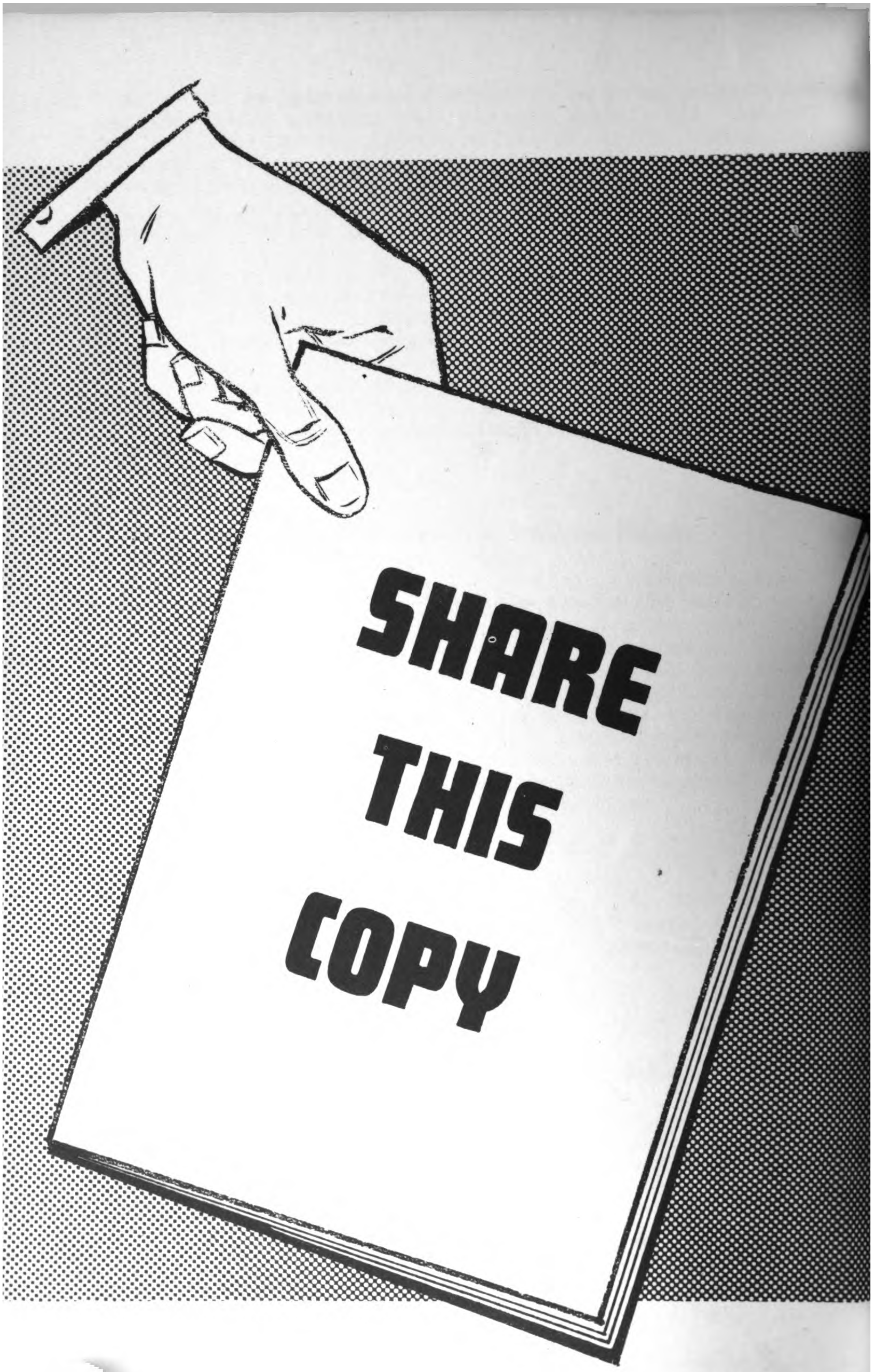
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